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Revised Proceedings of
The Department of Energy's Solar Update

Four Regional Conferences Highlighting the Objectives, Plans and Experience of the National Commercial Solar Heating and Cooling Demonstration Program and the National Solar Data Program

July 1978
Atlanta, San Francisco, Chicago, Boston

Funded by
U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Applications
Solar Heating and Cooling Demonstration Branch

Under Contract No. EC-78-C-01-4131

November 1978

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Coordinated by
Planning Research Corporation
With
Trinity University and
University of Alabama in Huntsville

Funded by
U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Applications
Solar Heating and Cooling Demonstration Branch
Washington, D.C. 20545

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PREFACE

The growth and future of the United States of America is directly linked to the availability of clean, safe and abundant new energy sources. Solar energy offers one such source that is now gaining new attention and finding support for more widespread development and application. The subject of The Department of Energy's Solar Update Regional Conferences was the use of solar energy as an alternative to fossil fuels. These conferences provided four opportunities to learn from experience - the operating experience of some 221 solar heating and cooling projects in 47 states, the Virgin Islands, and Puerto Rico, under government contracts since 1974. The following information was emphasized:

(1) The Department of Energy's role, objectives, plans and priorities in accelerating the use of solar energy as an alternative to nonrenewable sources

(2) The technical and other lessons learned from the experiences of solar energy contractors

(3) The status of the National Solar Data Network

These proceedings represent the overview and project papers made available to all the participants at each of the regional conferences. Additional materials, which were not available for distribution at the conferences, have been incorporated into these Revised Proceedings.

An expression of sincere appreciation is extended to all participants of each of the four regional conferences, for it is through their support and the close working relationships they have demonstrated, that our efforts have been successful.

David L. Christensen
Editor

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INTRODUCTION

The Oil Embargo of 1974 brought to light a problem that had been emerging, but not widely acknowledged, for some time. That is, the world's non-renewable, fossil fuel reserves, particularly petroleum and natural gas, are being used at astounding rates, becoming increasingly expensive and will be depleted within a matter of years.

Though not entirely dependent on foreign, and therefore insecure, sources of energy, the United States was hampered by the embargo and consequently forced to examine alternative forms of energy in order to diminish the effects of any future embargoes and to prepare for such time as when the reserves are used up.

To this end, the Congress passed The Solar Heating and Cooling Demonstration Act of 1974 which helped establish a vigorous program of research, development and demonstration of solar energy as an alternative energy source, in order to conserve fuel and reduce the nation's dependency on non-renewable sources.

The Department of Energy's (DOE) Office of the Assistant Secretary for Conservation and Solar Applications is charged with these tasks and is being assisted by the Department of Housing and Urban Development (HUD), the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), the National Bureau of Standards (NBS) and other Federal agencies.

Demonstration of the viability of solar energy systems for domestic hot water, heating and cooling is divided into two programs. The Commercial Demonstration Program, for non-residential uses, is managed by DOE while the residential program is directed by HUD.

Both programs are designed to accelerate the conversion process, from fossil to solar energy, by providing Federal assistance to selected individuals or groups wishing to incorporate a solar energy system into a new or existing building. This assistance not only stimulates the fledgling solar industry but also gives higher visibility to solar energy as an alternative fuel source.

The Commercial Demonstration Program has issued a series of solicitations, known as Program Opportunity Notices (PON), for proposals for domestic hot water, heating, cooling or combination systems, powered by solar energy.

Solar Update, a series of conferences held in July, 1978 in Atlanta, San Francisco, Chicago and Boston, was designed to acquaint those interested citizens with the status of the Commercial Demonstration Program, the National Solar Data Program and solar technology in general.

In excess of 220,000 invitations were mailed, of which nearly 1,850 people responded; 397 in Atlanta, 565 in San Francisco, 452 in Chicago and 434 in Boston.

The respondents were drawn from numerous professions with a potential interest in solar energy; designers, builders, financiers, craftsmen, utility,

governmental and consumer representatives, and included enthusiasts who wish to put such a system on their residence.

The first day of each conference saw a number of papers presented by DOE officials, DOE contractors and representatives of demonstration projects from that particular region.

Two workshops were held simultaneously the second morning. One was on the Commercial Demonstration Program and the other on the National Solar Data Program. Conference participants could choose to attend either workshop or move between the two. Far-ranging questions, comments and suggestions were entertained in both series of workshops. Summaries of each workshop were presented to the entire group of attendees in the afternoon.

Conference participants were asked to complete and return a questionnaire evaluating the conference and the Commerical Demonstration Program. Among the comments were requests for more demonstration projects involving passive solar techniques, streamlined governmental procedures, more public relations and public education on the viability of solar and more easily comprehensible data about demonstration projects.

This volume contains the entire proceedings of Solar Update. All papers presented by DOE officials, DOE contractors and demonstration site representatives are contained herein, as well as summaries of all workshops, comments from questionnaires, and a listing of all participants.

Solar Demonstration Program Overview

Carl Conner

INTRODUCTION

In 1974, the United States initiated an aggressive program of research, development and demonstration of solar heating and cooling technology for residential and commercial applications. The primary goal of the program (Fig. 1) is to work with industry in the development and early introduction of economically competitive and environmentally acceptable solar energy systems to help meet national and international energy requirements. The thrust of the program is to demonstrate the economic viability of solar energy for the heating and cooling of buildings within the five-year federally sponsored program.

The importance of this solar heating and cooling of buildings program is reflected in the extent of available funding. In fiscal year 1975, the funding level was $10.9 million. It is expected to reach about $130 million in the current fiscal year, a 12-fold increase.

The Department of Energy (DOE) has responsibility for the solar energy program; however, other government agencies are significantly involved. (Fig. 2). Those agencies include the Department of Housing and Urban Development, and National Aeronautics and Space Administration, the Department of Defense, the National Bureau of Standards, and the Department of Health, Education and Welfare. State and local government, portions of the private sector and other groups within DOE are also active participants.

The three major elements of the solar heating and cooling program are research, development and demonstration (RD&D). Research is aimed at advancing the state of solar energy technology to reduce costs, improve performance and reliability and enhance retrofit capability. Development is directed toward accelerating the applicability of solar energy components and systems for use in demonstration and commercial structures. Through demonstration of these systems, the government seeks to establish a data base which will facilitate the broad commercial application of solar energy systems for residential and commercial (non-residential) buildings.

OBJECTIVES OF THE SOLAR ENERGY PROGRAM

As summarized in Fig. 3 the following objectives of the federal solar energy program have been formulated:

- conduct a research and technology development program directed at substantially reducing solar heating and cooling system costs and improving their performance;
- operate an information system for collecting, storing, evaluating, reporting and disseminating technical, environmental and socio-economic data;
- demonstrate the use of solar heating technology in new and existing residential and commercial buildings by 1977;

- demonstrate the feasibility of solar heating and cooling in new and existing residential and commercial buildings by the end of 1979, with special emphasis on the development of low cost systems for retrofit installations;

- develop solar heating and cooling systems performance standards and criteria for the production and installation of solar energy systems, subsystems and components with appropriate provisions for consumer protection;

- identify the necessary legislation, codes and incentives to mitigate or eliminate existing legal or institutional restrictions which may discourage the development of solar energy;

- support the development of a solar hot water industry and market, through a concentrated demonstration activity;

- support solar heating and cooling applications in federal buildings to promote the utilization of solar energy by all government agencies;

- develop analytical methods for rigorous economic and technical assessment of solar energy systems;

- develop guidelines for the design of solar heating and cooling systems, subsystems and components;

- assure early availability of accredited private sector testing facilities; and

- assist in the development of site and structural design criteria of high utilitarian and aesthetic value.

MEETING THE OBJECTIVES

During the past three years, the program has moved from the conceptual stage to the applied demonstration stage. The Demonstration program is based on a series of cycles using a variety of systems, building types, applications, and climatic regions. Succeeding cycles incorporate upgraded state of the art technology as available from product development activities. Cycle 4A of the HUD grants will de-emphasize solar domestic hot water systems for single family homes, the focus of the previous cycles. Rather, it will encourage more advanced combined heating and cooling designs. The government also has sponsored a special initiative in the commercial area to develop solar energy systems for high volume users of domestic hot water, providing 50% funding for solar water heating project for hotel/motel demonstrations. To date, through PON II and the hot water initiative, the US government has funded 181 non-federal solar heating and cooling demonstration projects for commercial structures in the private sector. An additional 40 projects for the commercial demonstration program have been funded for

federal buildings. These demonstrations are in various stages of construction in every climatic region of the country (except Alaska) with a variety of collector types, building types and solar energy applications. (Fig. 4.)

Because of the initiative directed toward hotels and motels, nearly one-third of the total number of demonstrations (49) fall into this building category (Fig. 5). Another third is evenly divided between schools and low-rise office buildings. The remaining third includes libraries, clinics, restaurants, municipal facilities and light industrial plants. 42% of the total projects are new while 58% are retrofit.

Again because of the hotel/motel initiative, 70 of the projects are designed for water heating only, as shown in Fig. 6. Sixty-four demonstrations integrate both space and water heating applications; 36 are heating only; 35 projects provide heating, cooling and hot water. Approximately one quarter of the projects include space cooling, either alone or in combination with other applications. No solar system in the demonstration program provides 100% of the space heating, cooling and hot water needs of the building in which it operates, though many fulfill the total energy requirements for one of these applications and a few do so for both space and water heating.

Over three-quarters of the collectors are flat plate, most of which use a liquid transfer medium. There are 28 tubular collectors among the demonstration projects; the remainder are concentrating or passive (Fig. 7). Only 10% of the collectors overall use air as the transfer medium. The average collector area is 4350 square feet, but this ranges from a small office building with 244 square feet to a light industrial plant with 25,000 square feet of collectors.

The commercial demonstration projects are described in DOE Publication C/S-0009 "Solar Heating and Cooling Projects Summaries" book, available at this conference. The information for each project includes its owner, builder, contractor, location, building type, solar energy system description, project description, photograph and schematic.

The Solar Heating and Cooling Contractors Review in New Orleans, December 1977, provided a forum for the review of progress and problems associated with the commercial building demonstration program. In general, it was observed that serious problems can develop if too little attention is given to design and specification of the elements of the solar energy system and its interface with the basic structure and conventional heating and cooling systems. A corollary concern is coordination between solar, architectural and mechanical engineers and contractors. Adequate subsystem failure analysis is needed to avert serious operational problems and often costly modifications. The following address will present data on experience with commercial demonstration projects from the New Orleans Review and additional information that has become available recently.

DATA COLLECTION, EVALUATION AND DISSEMINATION

The collection and evaluation of data from the demonstration projects and their dissemination to a wide range of potential users are key objectives of the solar heating and cooling demonstration program. Three categories of information have been identified; instrumented technical; non-instrumented technical data and non-technical data. The knowledge generated by this data can be applied in deciding upon the selection and application of solar energy systems. Special emphasis is therefore being placed on the determination of users needs, standardization of data to allow system comparison and close interagency coordination to minimize duplication of activities. The Solar Data Program which has been established to gather, analyze and document this data is the subject of this afternoon's agenda.

SOLAR IN FEDERAL BUILDINGS PROGRAM (FIG. 8)

In addition to the 40 federal commercial projects, the solar in Federal Buildings Program has many of the same objectives of the commercial demonstration program. In fact, the only real difference is that it is aimed at demonstrating solar systems in government buildings. As stated in the National Energy Act legislation, DOE has responsibility for soliciting and evaluating proposals from agencies applying for solar heating and cooling installations on any existing or proposed Federal building; publishing criteria by which the proposal will be evaluated; providing funds for total costs of the project and monitoring the project as it becomes operational. DOE funding for solar in federal buildings includes design, acquisition, construction and installation costs of the solar equipment. Future DOE awards for federal commercial solar buildings projects will depend upon the National Energy Act legislation. The Act includes a 3-year, $100 million maximum effort to install solar equipment in Federally owned buildings.

STANDARDS DEVELOPMENT

The implementation of a complete solar collector testing and certification program is of equal urgency to both the consumer and solar industry. A complete certification program is being implemented to help consumers select solar components and systems since recognized standards will lend confidence to the product. Three major areas of standards development are shown in Fig. 9 along with a reference to warranties. Federal agencies, especially the National Bureau of Standards (NBS), are cooperating with other organizations in the development of consensus standards, a system used extensively by government and industries in the United States. Interim performance criteria developed for both residential and commercial solar energy systems have been issued and will be updated as necessary to incorporate experience from the Demonstration Program. Definitive criteria will be provided. DOE is participating in a voluntary industry program to certify solar equipment for compliance with standards to ensure consumer protection. (Fig. 10.) DOE has entered into a contract with the Solar Energy Research and Education Foundation (SEREF) an affiliate of the Solar Energy Industries Association (SEIA), to develop the procedures for certifying and labeling solar collectors. Fig. 10 outlines the basic obligations of

the contract. It is anticipated that test results and certification procedures will be available in the fall of 1978. Based upon the results of these tests, standards will be developed which will facilitate the consumer's purchase decision, provide a basis for consumer protection and promote competition in the marketplace without being too restrictive or costly. Also, meaningful warranties are being provided.

MARKET DEVELOPMENT

The thrust behind the market development program is to accelerate the product development/commercialization process for solar and thus stimulate the development of a viable solar industry. Fig. 11 lists the major components of DOE's technology transfer program for solar. Technology Transfer is the important link between the solar RD&D Program and the utilization of its proven technology by a solar industry. Due to the scope and complexity of solar data and requirements, the solar Technology Transfer Program, STTP was implemented in early FY 1977, to adequately meet the information needs. The program disseminates user-information, identifies target opportunities for technologies, develops and implements education programs and a consumer representation plan, and develops an international technology transfer capability for solar.

Initial STTP efforts are directed at "early impact" technologies; those in which industry can significantly participate by 1980. To provide dissemination of this early impact technology information, STTP has developed a model for technology transfer. The model includes a Solar Technology Delivery System, a system for disseminating user information which is coordinated primarily by the DOE National Laboratories; and SOLCOST, a digital computer design aid which cost-optimizes solar energy systems. SOLCOST provides some standardization for the technology and is available to both large and small firms.

Under provision of the Solar Energy Research and Development Act (Fig. 12) of 1974 there was a proposal calling for the establishment of a solar energy research institute. In 1977, ERDA solicited proposals and selected the Mid West Research Institute to manage and operate a national SERI to be located in Golden, Colorado. ERDA then announced its intent to establish regional solar energy centers and provided planning grants to organizations representing four United States regions--Northeast, North Central, West and South. These regional centers are in various stages of implementation. The Northeast, North Central and Southern regions, located in Cambridge, Maysachusetts and Eagan, Minnesota and Atlanta, Georgia respectively, are now operating. The western regional center with headquarters planned for Portland, Oregon is in the pre-implementation phase.

In March, 1978, Secretary Schlesinger established missions for the national SERI and the regional centers. National SERI was mandated as DOE's leading institution with respect to solar research, development and demonstration activities. It is managed by the office of the Assistant

Secretary for Energy Technology. The regional solar energy centers have a primary mission of commercialization of solar technologies and conservation activities integral to solar application. The centers work with the region's demonstration project managers, state and local governments, the private sector and consumers in order to promote commercialization. The Assistant Secretary for Conservation and Solar Applications has responsibility for the regional centers.

There are a number of economic and non-economic barriers and (Fig. 13) constraints to solar commercialization. One of the more obvious non-economic concerns is the protection of an individual's right to solar access. A few solar access cases have been before the courts and precedents are being established through the invocation of various existing laws on the Federal, state and local levels. There is a lengthy discussion of this issue and others in the Environmental Law Institute's study entitled "Legal Barriers to SHAC of Buildings," HCP/M2528-01.

From an economic perspective, the tax incentives for solar installation are included in the National Energy Plan. Further, the House recently passed Bill #11713, Solar Energy Loan Program, providing $45 million in guaranteed loans and 30 million in direct and immediate participation loans for solar small businesses. The loan program will be directed by the Small Business Administration and provides a good incentive for potential solar small businesses to get involved.

(Fig. 14) To provide a basis for selecting appropriate land use controls to assure solar access in new developments, HUD has commissioned the American Society of Planning Officials (ASPO) to develop operating handbooks for site planner builders, and local officials. These books will provide information on how existing forms of land use control, such as zoning, private covenants and easements, can be used to further the development of solar by providing full solar access.

The widespread use of solar energy for heating and cooling may have a serious impact upon electric and gas utility companies. Attention must be given to the design and application of solar systems to minimize incompatabilities with existing utilities. If solar energy systems enter the market on a wide scale and electricity is used as the auxiliary energy source, there will be times when no electricity is used and short periods when full capacity is required. If provisions are not made to ameliorate this situation, electric utilities would have to establish rates that might penalize solar users in order to support a large, seldom used, reserve capacity. But proper design can produce a solar system with increased storage capability and thus reduce the peak utility load. DOE is working with utilities to develop strategies to achieve this. Alternatively, further design plans call for gas as a more compatible backup for solar systems than electricity. Obviously, the design depends on natural gas cost and availability.

Planned studies for 1978 as regards the solar/utility interface include integrating an existing utility grid with an optimal solar system design, as well as the design of the potential of solar systems for utility load

mitigation. Further, more economic analyses will be done regarding the solar/utility interface from the public and private perspectives.

ENVIRONMENT AND RESOURCE ASSESSMENT (FIG. 15)

The environmental and resource assessment program will continue to collect a wide range of geophysical data for criteria and performance evaluation essential to the solar energy program's demonstration projects. The Environmental Resource Assessment, utilizing the capabilities of NOAA, NASA, NSF, USDA and DOD, collects, analyzes, archives and disseminates information on relevant data measurements and environmental analyses. The program not only identifies potential environmental effects of the new solar technology, but also its potential social effects in order to minimize those impacts considered undesirable. Also, these impact forecasts are necessary so that we do not pursue technologies which will prove impractical for commercialization.

NOAA has led the effort in collecting, analyzing, recording and disseminating solar radiation, wind, cloud and other meteorological information. These data are available in the Solar Data Bank.

PROGRAM REPORTS AND ACCOMPLISHMENTS

An important aspect of the data dissemination process is the publication of reports, manuals and handbooks. Figure 16 lists some of the typical reports which have resulted from the solar energy program. These various documents provide detailed information on the design, installation, operation and cost of the solar energy systems used in the demonstration projects. Handbooks and guides directed at specific audiences also further our goal of promoting the commercialization of solar energy for the heating and cooling of buildings. They are readily available from the Department of Energy.

Figure 17 shows the major accomplishments of the federal solar energy program as we move toward our objectives. We have implemented a comprehensive program of research and development, established a data collection system and funded over 200 demonstration projects. Continued expansion of the demonstration effort will result in the extensive data base needed to assess the wide scale use of solar energy systems. This data will enable improvements in system design, the development of appropriate standards and criteria and ultimately, the widespread use of economically competitive and environmentally acceptable solar energy systems.

CONCLUSION

We believe the United States is well on its way to witnessing an eventual large scale commercialization of solar energy technology. At the Department of Energy, we are continuing in our efforts to meet the solar program's established objectives. We are also aware of the need to constantly redefine these objectives in accordance with the dynamics of the technology and current breakthroughs. Perhaps the most positive indication

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for solar's future is the enthusiasm and acceptance it is receiving from the public to learn about solar energy. The romantic and adventuresome spirit surrounding the technology is so inviting that we are witnessing a dream becoming a reality.

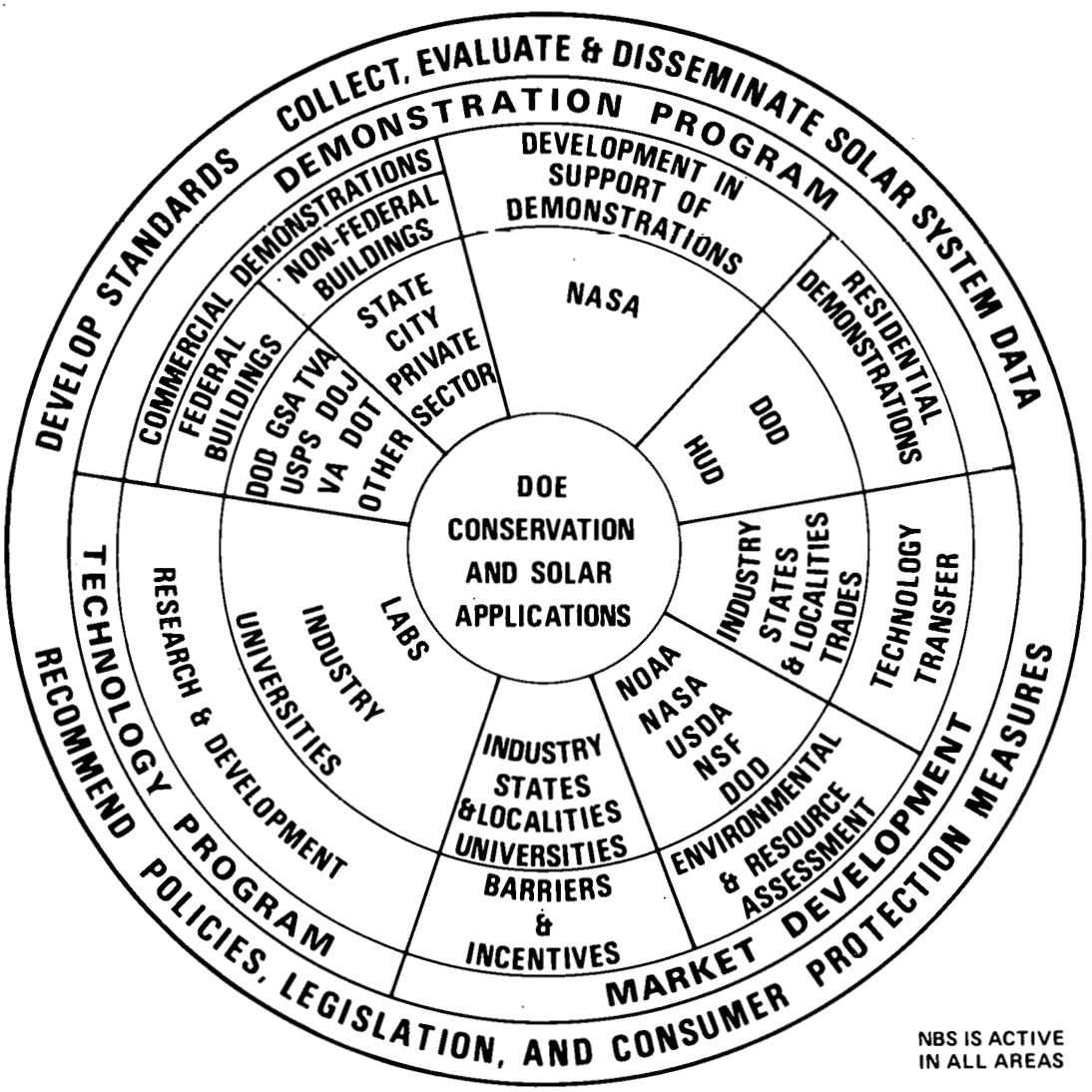
Figure 1

SOLAR HEATING AND COOLING PROGRAM

- **GOAL**
  "... TO ASSIST IN THE EARLY ESTABLISHMENT OF A VIABLE SOLAR INDUSTRY FOR THE DESIGN, MANUFACTURE, DISTRIBUTION, SALES, INSTALLATION AND MAINTENANCE OF SOLAR WATER HEATING, SPACE HEATING AND COOLING SYSTEMS ..."

- **BASIS**
  PUBLIC LAW 93-409, SOLAR HEATING AND COOLING DEMONSTRATION ACT OF 1974.

Figure 2



NBS IS ACTIVE IN ALL AREAS

Figure 3

MAJOR OBJECTIVES

- REDUCE COST AND IMPROVE PERFORMANCE
- COLLECT, EVALUATE AND DISSEMINATE DATA
- DEMONSTRATE SOLAR HEATING BY 1977
- DEMONSTRATE SOLAR HEATING AND COOLING BY 1979
- DEVELOP SOLAR STANDARDS AND PERFORMANCE CRITERIA

COMMERCIAL DEMONSTRATION PROGRAM

NON-FEDERAL BUILDINGS

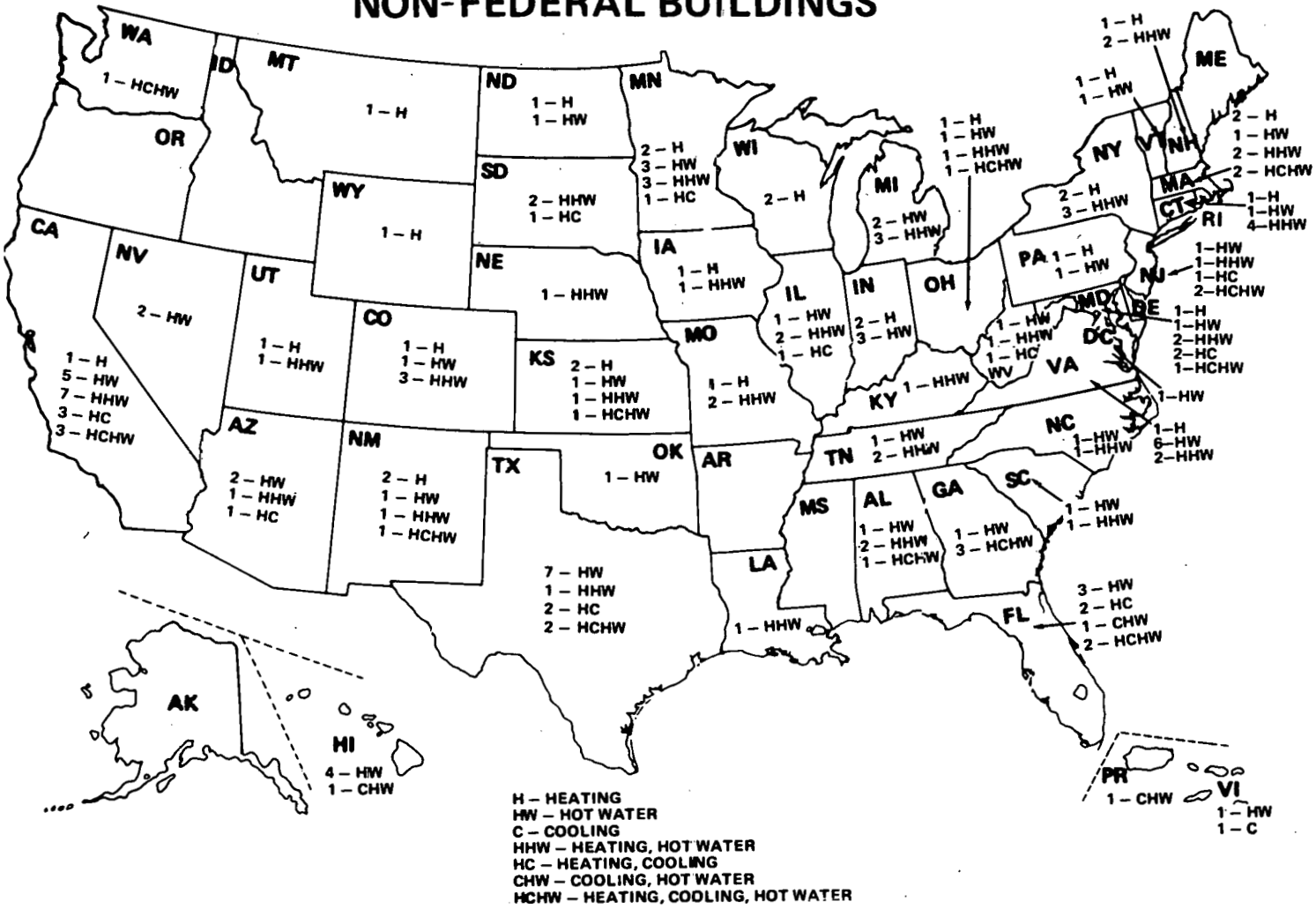


Figure 4

PERCENT TOTAL DEMONSTRATIONS PER SOLAR ENERGY APPLICATION

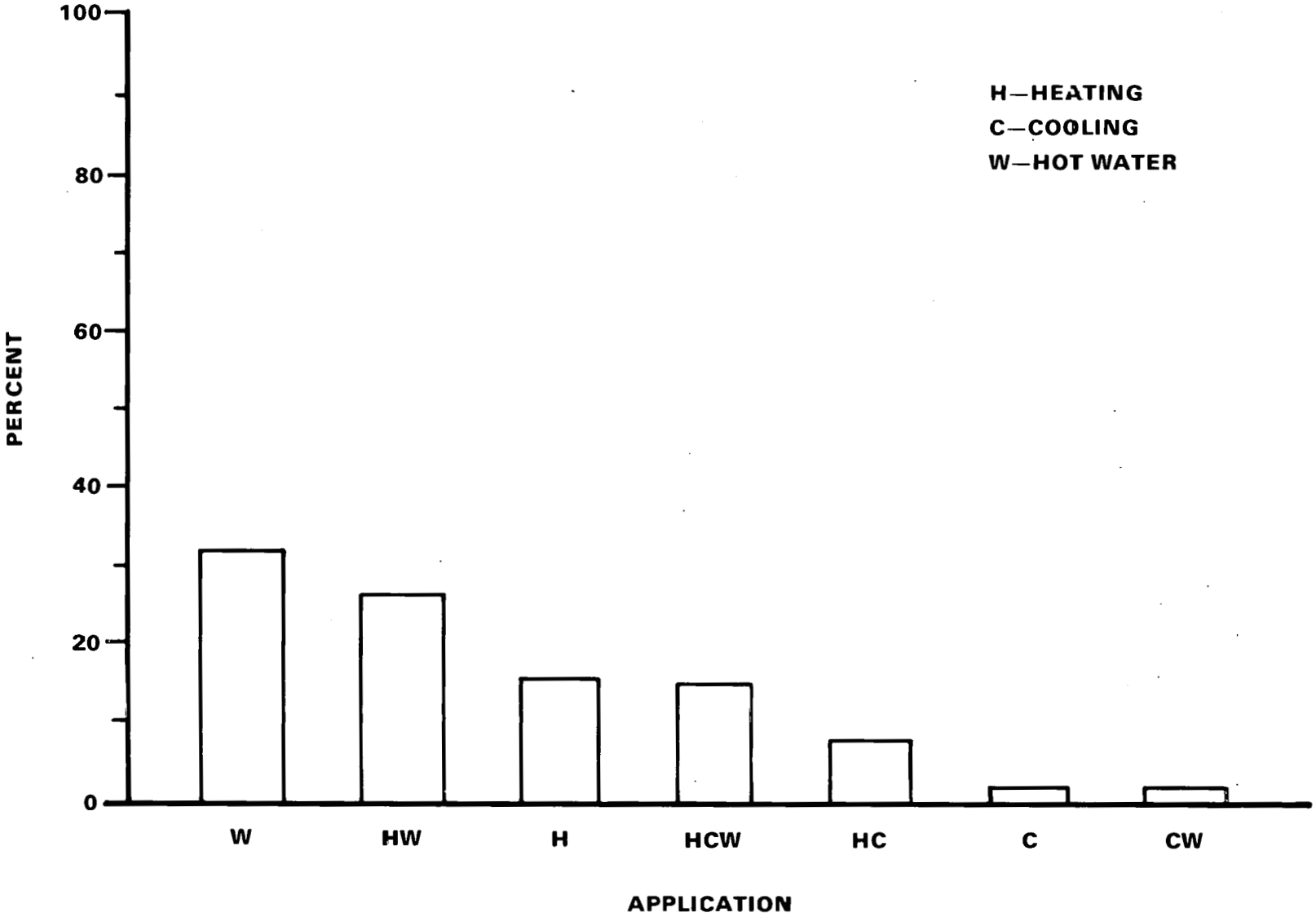


Figure 5

PERCENT TOTAL DEMONSTRATIONS PER BUILDING TYPE

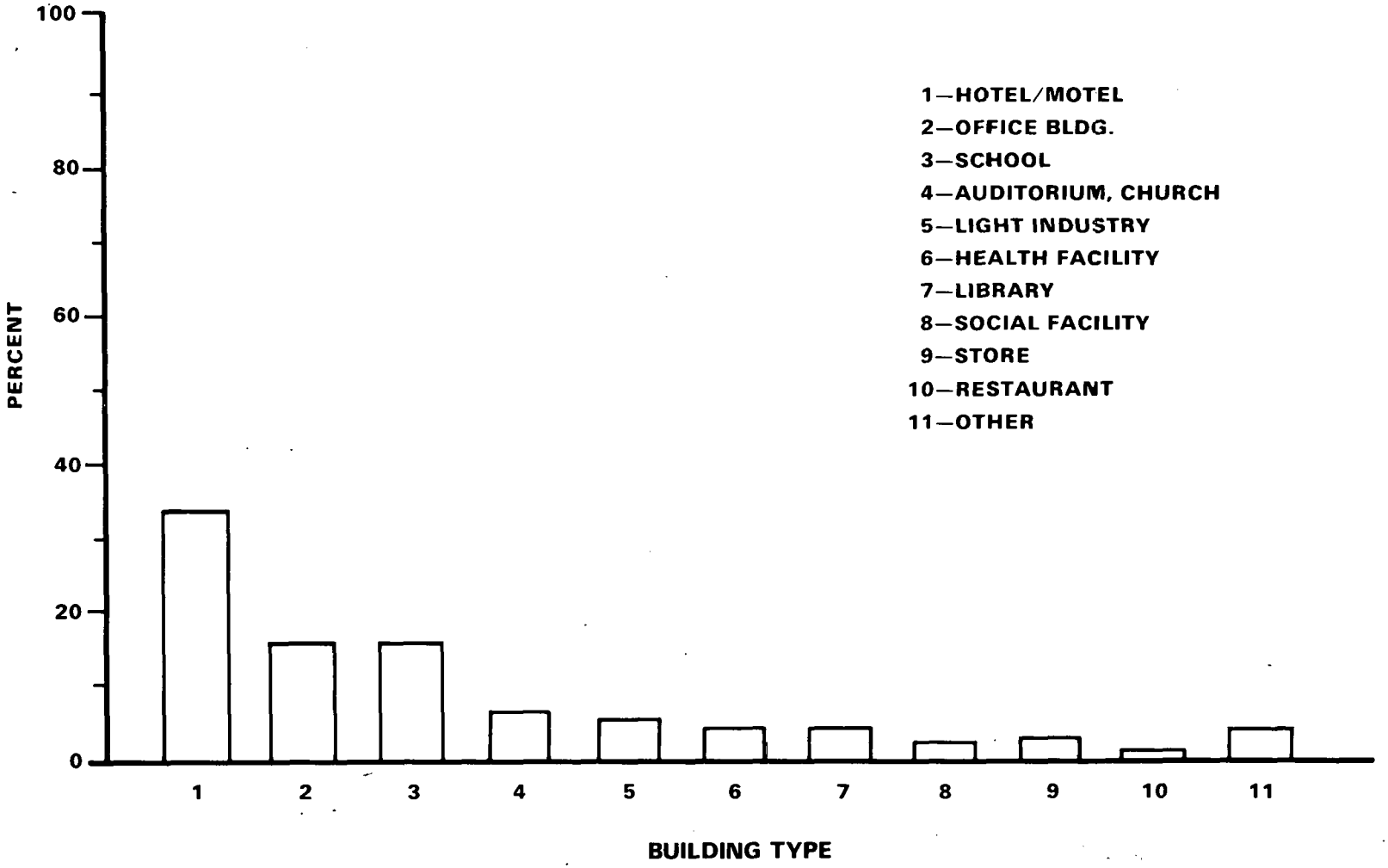


Figure 6

FIGURE 7: PER CENT TOTAL DEMONSTRATIONS PER COLLECTOR TYPE

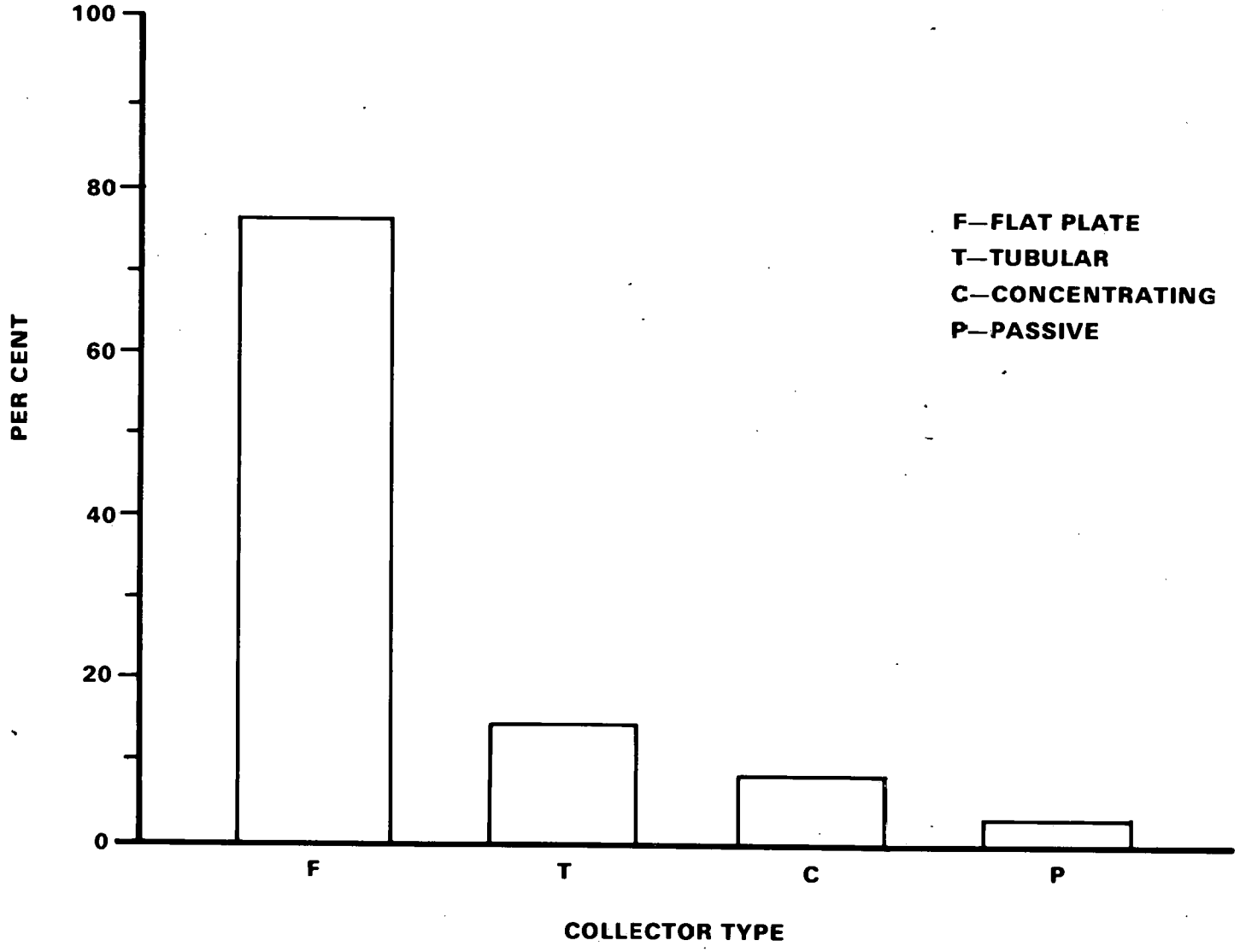


Figure 8

SOLAR IN FEDERAL BUILDINGS PROGRAM

THE FEDERAL ENERGY INITIATIVE LEGISLATION STATES:

"IT IS THE POLICY OF THE U.S. THAT THE FEDERAL GOVERNMENT HAS THE OPPORTUNITY AND RESPONSIBILITY WITH THE PARTICIPATION OF INDUSTRY, TO FURTHER DEVELOP, DEMONSTRATE AND PROMOTE THE USE OF ENERGY CONSERVATION, SOLAR HEATING AND COOLING AND OTHER RENEWABLE SOURCES IN FEDERAL BUILDINGS. . ."

Figure 9

STANDARDS DEVELOPMENT

- **STANDARDS AND PERFORMANCE CRITERIA DEVELOPMENT**
- **LABORATORY ACCREDITATION**
- **HARDWARE TESTING, CERTIFICATION, AND LABELING**
- **WARRANTIES**

Figure 10

SOLAR ENERGY RESEARCH AND EDUCATION FOUNDATION (SEREF) CONTRACT OBLIGATIONS

1). RELIABILITY, DURABILITY AND SAFETY TEST PROGRAMS

2). DESIGN OF LAB SELECTION, ACCREDITATION AND VALIDATION PROCEDURES

3). DESIGN OF RATINGS FOR COLLECTORS

4). DESIGN OF LAB FORMAT

Figure 11

MARKET DEVELOPMENT TECHNOLOGY TRANSFER

—SOLAR TECHNOLOGY TRANSFER PROGRAM (STTP)

—SOLAR TECHNOLOGY DELIVERY SYSTEM (STDS)

—SOLCOST

Figure 12

LOCATIONS OF SOLAR ENERGY RESEARCH INSTITUTE AND SOLAR ENERGY REGIONAL CENTERS

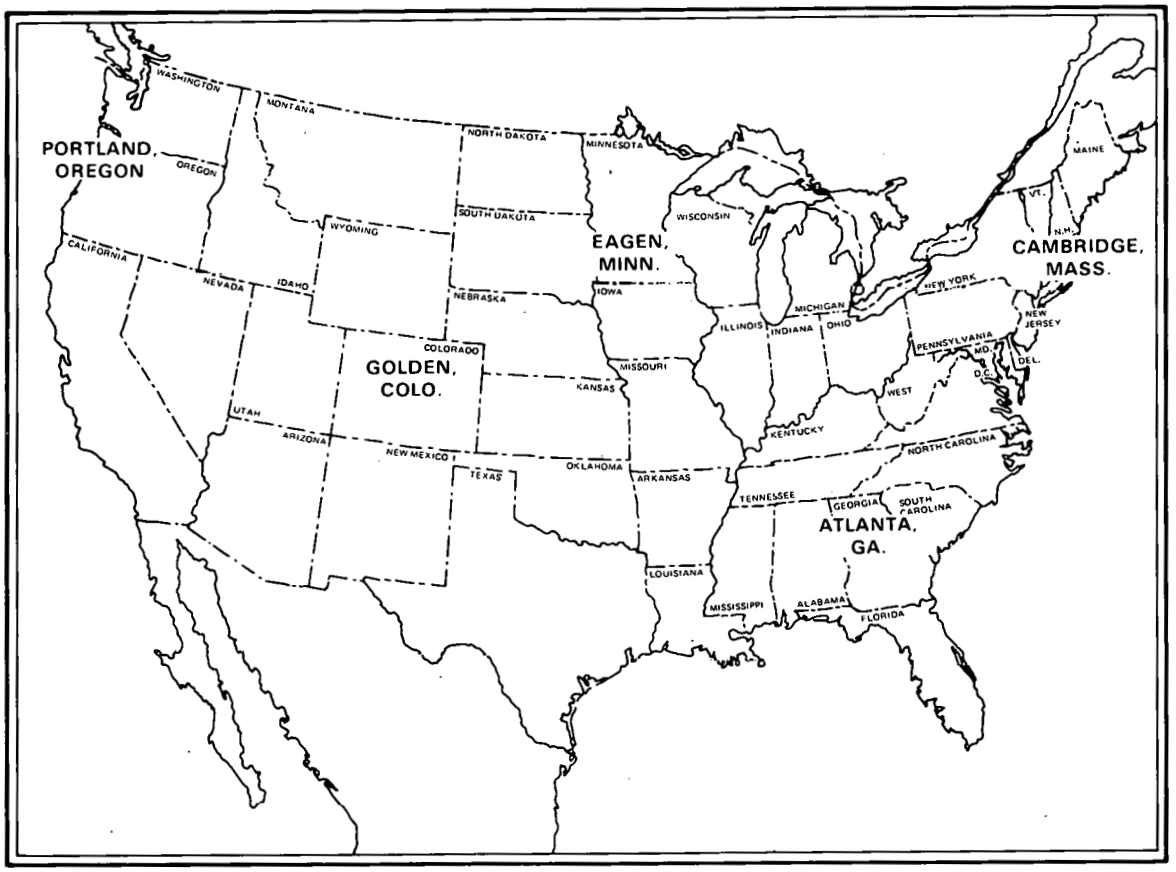


Figure 13

MARKET DEVELOPMENT

BARRIERS AND INCENTIVES

- **NONECONOMIC**
  —LEGAL
- **ECONOMIC**
  —SOLAR ENERGY LOAN PROGRAM

Figure 14

MARKET DEVELOPMENT

SITE AND LAND USE PLANNING
—AMERICAN SOCIETY OF PLANNING OFFICIALS (ASPO)

SOLAR UTILITY INTERFACE
—ELECTRIC; GAS

Figure 15

MARKET DEVELOPMENT

ENVIRONMENT AND RESOURCE ASSESSMENT

—COLLECTION,

—ANALYSIS,

—DISSEMINATION OF RELEVANT ENVIRONMENTAL AND GEOPHYSICAL DATA

Figure 16

TYPICAL REPORTS FROM THE DEMONSTRATION PROGRAM

- **SOLAR SYSTEM PERFORMANCE REPORTS**—Presents monthly and seasonal data on solar climatic data and actual thermal performance of solar system and sub-systems.
- **COMPARATIVE SITE EVALUATION REPORTS**—Presents data on relative merits of various solar system types for specific applications and climatic regions.
- **SYSTEM DESCRIPTION DOCUMENT**—Presents complete description of the solar demonstration sites including the four features of the solar systems components.
- **PROJECT SUMMARIES**—Including cost and technical summaries of operational projects (more detailed than ERDA 76-127) published periodically.
- **DESIGN AND CONSTRUCTION PROGRESS SUMMARY**—Summarizes the problems experienced by the demonstration projects in designing and installing solar systems.
- **COST/BENEFIT REPORT** — Presents cost/benefit analyses of operational demonstration projects.
- **COMMERCIAL SOLAR DESIGN HANDBOOK**—Handbook for A&E and HVAC contractors providing a methodological approach to solar system design.
- **IMPLEMENTATION GUIDE FOR COMMERCIAL SOLAR PROJECTS**—Guide for building owners and managers who are contemplating implementing solar heating and cooling.
- **COMMERCIAL SOLAR HANDBOOK FOR INSURANCE COMPANIES**—Presents information on economics and safety of solar systems to aid in developing actuarial evaluations.
- **COMMERCIAL SOLAR HANDBOOK FOR FINANCIAL INSTITUTIONS**—Presents information on economics and performance of solar systems to aid in establishing lending policies.

Figure 17

MAJOR ACCOMPLISHMENTS TO DATE

- COMPREHENSIVE R&D PROGRAM IMPLEMENTED
- DEMONSTRATION PROGRAM ON TARGET
- HOT-WATER INITIATIVE INSTITUTED
- DATA COLLECTION SYSTEM OPERATIONAL
- NATIONAL HEATING AND COOLING INFORMATION CENTER OPERATIONAL
- CERTIFICATION PROGRAM INITIATED
- COMPLETED INITIAL PROGRAM DESIGN FOR FEDERAL SOLAR BUILDINGS PROGRAM
- CONSTRUCTION INITIATED ON SEVEN IPH EXPERIMENTAL PROJECTS
- ESTABLISHED AN "ON-THE-FARM" SOLAR APPLICATIONS PROGRAM

Heating and Cooling Projects Program Review
Prepared by PRC Energy Analysis Company
Presented by Myron L. Myers, Richard E. Davis, Ted. L. Kurkowski

1.0 INTRODUCTION

1.1 Purpose

The purpose of this presentation is to describe the design, construction, installation, and testing experiences associated with the 222 government supported Commercial Solar Heating and Cooling Demonstration Projects. Advantageous concepts and practices are identified, and problem areas are described. By sharing experiences gained throughout the industry, known problem areas can be avoided in the future, and designers can take advantage of the design features that have proven successful.

The experiences related to the system aspects of the commercial demonstration program are highlighted through a discussion of the:

- design approach
- applicable design aids
- solar system cost history
- experiences from the 222 demonstration projects
- experiences from 56 operational sites

The data were obtained from DOE government representatives who are directly involved in the management of the projects and from government support contractors who have been intimately involved with the demonstration program. Also considered were the data presented at the December 1977 Solar Heating and Cooling Demonstration Program Contractors' Review in New Orleans, where key individuals representing seventy-two of the projects reported on their experiences.

Although many projects have had typical construction problems, this discussion concentrates on the problems which impacted the solar energy systems of the demonstration projects. There were numerous "one-of-a-kind" problems experienced. However, the general conclusion is that there are no technical problems which preclude the implementation of commercial solar heating and cooling systems.

1.2 Background

The general plan for the commercial building demonstration program is shown in Figure 1 with the shaded bar segments indicating progress to date. The basic program outline was developed in a series of published studies and identified as Phase 0 and Phase 1. Phase 0 studies, sponsored by the National Science Foundation (NSF), were completed in 1974. They addressed general technical problems and issues of commercial application and assessed the feasibility of program development. Phase 1 studies were initiated by NSF and continued by ERDA and DOE. They provided an initial matrix of recommended project types and locations based on the range of variables

COMMERCIAL DEMONSTRATION PROGRAM PLAN

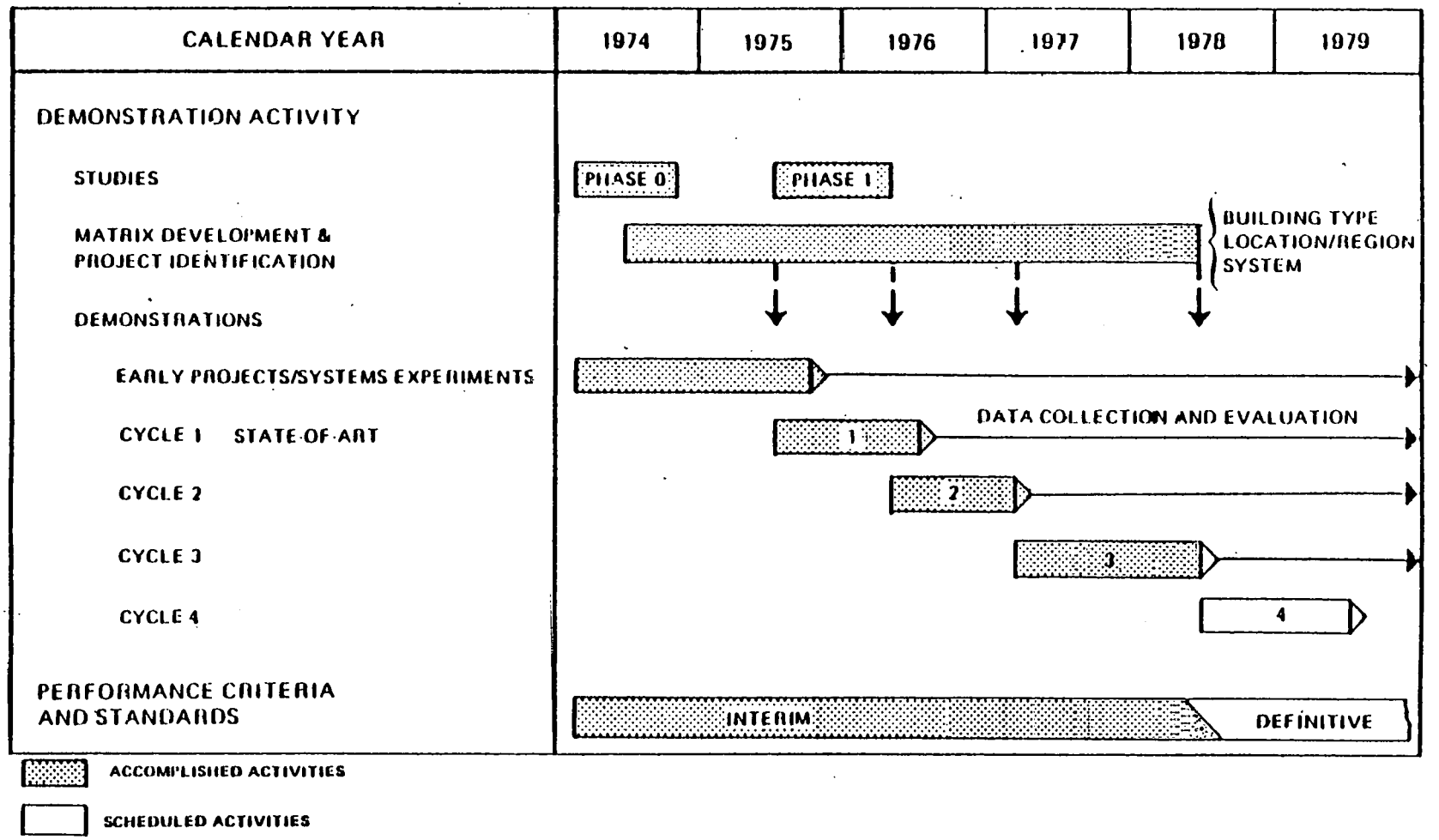


FIGURE 1

required to establish costs, system confidence levels, and the extent of business/public exposure necessary to stimulate the market. This approach was used in identifying the early projects and also served as the basis for continuing efforts in the selection process wherein various combinations of building types, climatic regions, and solar design types are considered in determining a program with adequate balance.

The two major elements of the demonstration program are non-Federal buildings and Federal buildings, both of which are managed by DOE. The non-Federal project cycles contain the elements identified in Figure 2. The cycles are implemented using Program Opportunity Notices (PON's) which identify bid opportunities for the private sector.

Three cycles have been initiated along with a special Hot-Water Initiative. Each succeeding cycle incorporates more highly developed solar energy systems. The third cycle of demonstrations was initiated with PON-3, issued in November 1977.

The solar heating and cooling demonstration program was designed to provide a wide range of experiences with solar systems including variations in building types, equipment types, and solar system applications. The various building types used in the demonstration are shown in Table I.

TABLE I

BUILDING TYPES

1. Apartment, high rise
2. Apartment, low rise
3. Auditorium, concert hall, convention center, theater
4. Bank
5. Bar, night club
6. Cafeteria
7. Church
8. Dormitory
9. Education facility (class rooms, lecture halls, etc.)
10. Fire station
11. Gymnasium, sports arena
12. Health facility, clinic
13. Health facility, hospital
14. Hotel/motel
15. Industrial building, heavy
16. Industrial building, light
17. Laboratory
18. Library
19. Shopping mall
20. High rise office building (>3 story)
21. Low rise office building (1-3 story)
22. Post office
23. Police station
24. Restaurant
25. Store
26. Warehouse

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SOLAR HEATING AND COOLING OF BUILDINGS
COMMERCIAL DEMONSTRATION PROGRAM
REPRESENTATIVE CYCLE

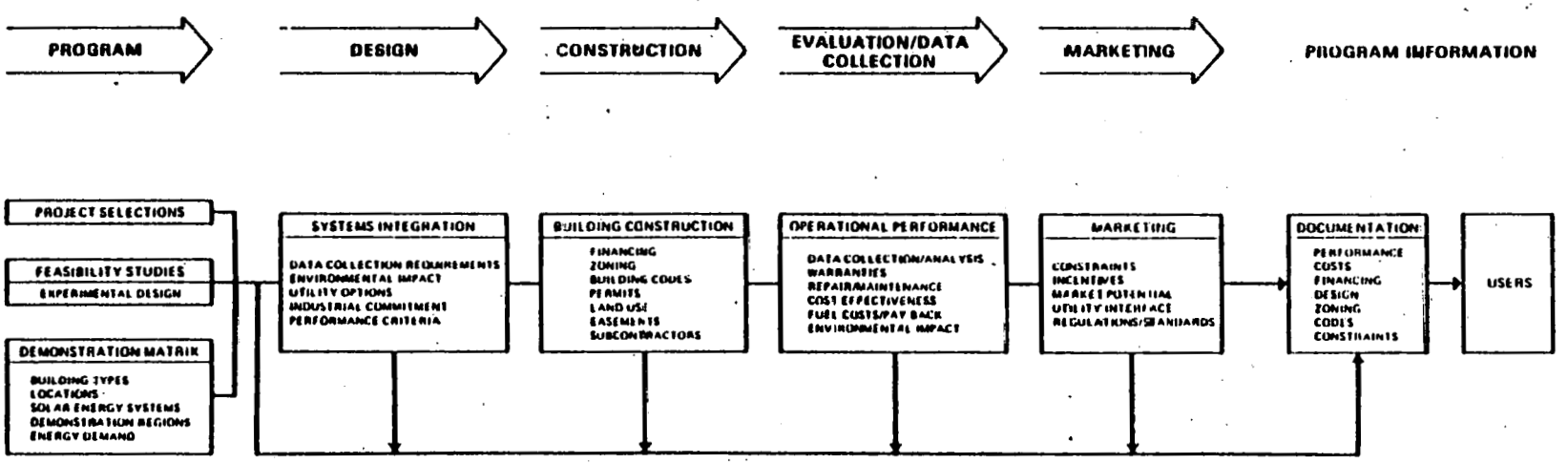


FIGURE 2

An example of the variations in equipment is shown in Table II which summarizes the collector types utilized on demonstration projects.

TABLE II

SUMMARY OF COLLECTOR TYPES

Type of Collector	Area (Square Feet)
Flat Plate	673,800
(Liquid)	(595,800)
(Air)	(78,000)
Concentrating	98,700
Evacuated Tube	102,600
Passive	8,400
Hybrid *	13,000

*Systems using a combination of several types of collectors

Tables IIIA and IIIB show the number of square feet of each collector type utilized for heating and cooling applications in the demonstration projects. Table IIIC provides summary data on total collector applications.

TABLE IIIA

COLLECTOR APPLICATIONS - HEATING AND HOT WATER
(Area in Square Feet, and Number of Sites)

	Heating	Hot Water	Heating & Hot Water	Totals
Flat Plate	93,000	141,200	254,000	488,200
(# sites)	(26)	(49)	(56)	(131)
Concentrating	700			700
(# sites)	(1)			(1)
Evacuated Tube	10,900	7,000	8,700	26,500
(# sites)	(5)	(3)	(5)	(13)
Passive	8,400			8,400
(# sites)	(3)			(3)
Concentrating with Flat Plate		1,100	2,000	3,100
(# sites)		(1)	(1)	(2)
Flat Plate with Passive			7,000	7,000
(# sites)			(1)	(1)
Concentrating with Passive			6,000	6,000
(# sites)			(1)	(1)
Collector to be determined (in design phase)		5,400		5,400
(# sites)		(3)		(3)
Square Footage Totals	112,900	154,700	278,700	545,300
(Total # sites)	(35)	(56)	(64)	(155)

TABLE IIIB

COLLECTOR APPLICATIONS - COOLING

(Area in Square Feet, and Number of Sites)

	Heating, Cooling & Hot Water	Cooling & Hot Water	Cooling	Heating & Cooling	Totals
Flat Plate	126,500	18,600		40,500	185,600
(# sites)	(21)	(1)		(5)	(27)
Concentrating	56,000	13,600		10,200	79,800
(# sites)	(7)	(1)		(4)	(12)
Evacuated Tube	32,000		7,000	28,500	67,500
(# sites)	(4)		(1)	(7)	(12)
Concentrating with Flat Plate	7,000			11,300	18,300
(# sites)	(1)			(2)	(3)
Collector to be determined (system in design phase)	10,000				10,000
(# sites)	(1)				(1)
Square Footage Totals	231,500	32,200	7,000	90,500	361,200
(Total # sites)	(34)	(2)	(1)	(18)	(55)

TABLE IIIC

COLLECTOR TOTALS

(Area in Square Feet, and Number of Sites)

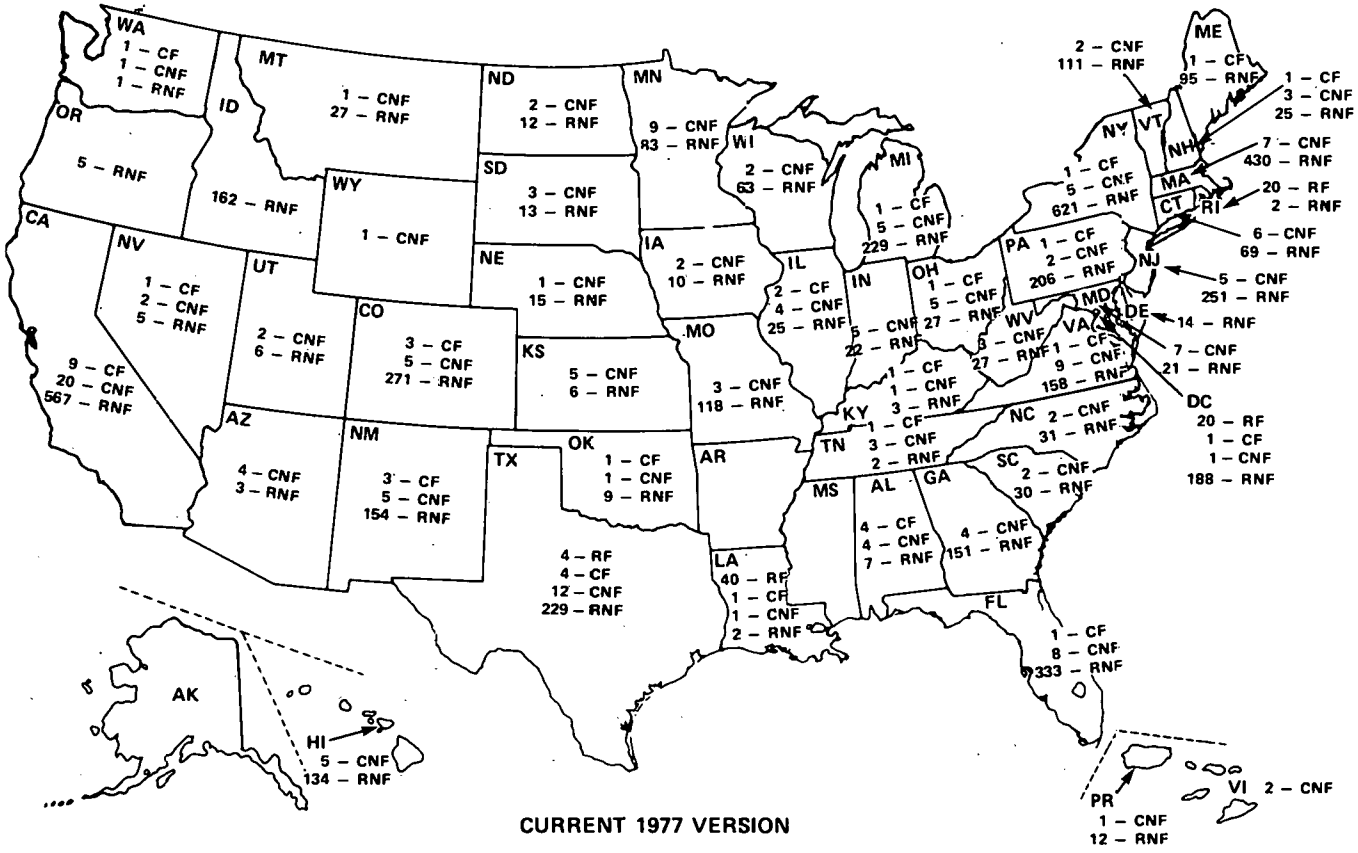
Flat Plate	673,800*
(# sites)	(158)
Concentrating	80,500
(# sites)	(13)
Evacuated Tube	94,000
(# sites)	(25)
Passive	8,400
(# sites)	(3)
Concentrating with Flat Plate	21,400
(# sites)	(5)
Flat Plate with Passive	7,000
(# sites)	(1)
Concentrating with Passive	6,000
(# sites)	(1)
Collector to be Determined (System in design phase)	15,400
(# sites)	(4)
Square Footage Totals	906,500
(Total # sites)	(210)**

* Liquid: 595,800 square feet (136 sites)
Air: 78,000 square feet (22 sites)

** 12 sites are not included in the above totals since they have undetermined square footage at this time.

In addition, to gather data on different climates and solar regions, demonstration projects are distributed throughout the United States as shown on the following map.

DISTRIBUTION OF SOLAR HEATING & COOLING DEMONSTRATION PROJECTS COMMERCIAL AND RESIDENTIAL



CURRENT 1977 VERSION

RF – RESIDENTIAL FEDERAL PROJECT UNITS
CF – COMMERCIAL FEDERAL PROJECTS
CNF – COMMERCIAL NON-FEDERAL PROJECTS
RNF – RESIDENTIAL NON-FEDERAL PROJECT UNITS

2.0 DESIGN CONSIDERATIONS

Design considerations involved in the system selection process included the following:

- Energy Conservation
- Solar System and Components
- System Performance/Cost
- Commercial Standards

Most of the commercial demonstration projects utilized a team approach to design selection. It was evident that a member experienced in solar design should be included on the team. This expertise was obtained from various sources; for example, the Santa Clara Community Center solar project involved industry, universities, equipment manufacturers, and an advisory committee composed of eminent solar experts.

The following sections discuss experiences associated with the design activities.

2.1 Energy Conservation

National policy now requires that buildings be planned and designed to minimize energy consumption. ASHRAE 90-75 Energy Conservation in New Building Design provides standards for energy conservation. From the beginning of the demonstration program, energy conservation has been addressed in order to increase the capability of the solar energy system. The early projects were primarily retrofits and thus were not able to incorporate optimum energy conservation techniques. However, Shenandoah, which was one of the first demonstration projects to incorporate comprehensive energy conserving features into the new building itself as well as through the use of solar energy, received the Energy Conservation Award for 1975 (Commercial Category) from the Owens-Corning Fiberglass Corporation and the American Institute of Architects Honors Award for 1977. The energy conserving features included earth berming, air economizers, and judicious placement of a minimum number of windows.

2.2 Solar System and Components

In the early stages of the program there were few examples and little experience upon which designers could rely. Now, even though there are more examples, it is still necessary to customize the solar system for large commercial applications. The system and component experience gained on the projects can be utilized during the "customizing" process. The experiences are summarized in this section with special emphasis given to those sites which are operational. Systems are discussed along with their collector, storage, distribution and control subsystems.

The fifty-six operational sites are discussed in Appendix A which describes the periods of site operation, the performance (in quantitative terms) and experiences with the various solar system components.

Some general experiences for all of the 222 projects are summarized in the following paragraphs. Details are included in Appendix B identifying specific problems and corrective actions. A detailed analysis of the technical experiences of all of the commercial demonstration projects is being prepared by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).

A key area of interest in solar system development is, of course, collectors. They have been constructed from many different materials and in a wide variety of designs including the three most common types--flat plate, concentrator, and evacuated tube. Typical problems experienced with collectors include: deterioration of the paint on the absorbing surface, glazing breakage due to thermal expansion, deposits of dust and moisture, freezing, etc. Extreme temperatures, weather conditions and the sun's ultraviolet radiation have in some instances damaged the collectors and adversely affected their performance. Other collector problems have been caused by the human element: damage from handling during shipping and installation, improper installation and failure to observe maintenance procedures. Other examples of collector damage are corrosion and clogging which have resulted from the chemical reactions of the transfer fluid with the hardware.

Storage has been another area of prime concern in solar systems. Tanks or rock beds were used either above or below ground and either inside or outside of buildings. Above-ground storage has been found to require protection from the elements and insulation to prevent heat loss. Below-ground storage had problems associated with water table levels, external and seismic loads, and accessibility. Provision had to be made to protect the storage facility from both internal and external corrosion. Mildew in rock bed storage was felt to be a possible source of health problems. Leakage and corrosion in concrete and steel tanks were problems that were countered by using linings of flexible copper or by special coatings.

Distribution subsystems and controls are complex. Common problems with the distribution subsystem included inadequate pipe slope to accomplish complete drain-down, air entrapment due to inadequate air bleeding capability, leaky expansion joints, and deformed hoses and expansion joints which trapped fluid. Control malfunctions have resulted in problems at numerous points in solar systems. For example, in one case a temperature measuring sensor on a collector was influenced by a heated pipe connected to the collector, resulting in a temperature reading far above the outside ambient temperature. This situation, if it had not been detected, could have resulted in freezing of the collectors and other components. In more subtle cases, inaccurate sensing of collector and storage tank temperature differentials caused pumps to cycle or to operate when the collector was cooler than the storage medium. Another type of control problem occurred with tracking collectors which tended to focus on bright objects rather than focusing on the sun when the sun is obscured. This tendency to track the brightest object in the sky has led to efforts to redesign the tracking control so that the collector will always face the sun, even when obscured.

2.3 Solar System Integration

Solar system integration chiefly covers two areas: 1) physical integration of solar system components with the building and 2) integration of the solar energy system with the conventional energy system used as backup.

One example of a physical integration problem pertains primarily to retrofits. The plans and drawings of the existent building did not correspond to what was actually found when construction began. Specifically, beams indicated in the drawings to which solar collectors were to be attached did not exist. The design and construction alterations required in order to mount the collectors increased costs and caused delay.

Integration of the solar and the conventional backup can result in a system which does not reduce the total fossil Btu requirement, even if the solar system is supplying the specified amount of energy. For example, it is common practice to use an absorption chiller for solar cooling. When the same absorption chiller is also used in the backup configuration, excess fossil fuel is required because of the absorption chiller's low COP (approximately .6). When this combination of solar and gas was used for cooling, more fossil energy was required than would have been used if the total cooling system consisted of a heat pump only. Alternatively, a heat pump backup could be considered.

As can be seen from the above example, integration problems are an area requiring continued research. There are cost tradeoffs involved in the choice of components having varying COP's. The more fossil energy conserving designs may be more expensive initially. Furthermore, in retrofit designs, the cost of replacing existing inefficient auxiliary components may be prohibitive. Designers should consider these factors in selecting and integrating auxiliary systems.

2.4 Solar Systems Performance and Cost

During the early stages of the demonstration program few substantial data on solar performance and cost were available. It was necessary that equipment performance characteristics supplied by the manufacturers be used in selecting components. Also, only very fundamental analytical aids had been developed. Very limited data on weather and insolation were available so that the information had to be extrapolated for local application. However, as the program progressed from the early National Science Foundation (NSF) projects through the first and second Program Opportunity Notices (PON I and PON II) and the Hot Water Initiative projects, special analytical aids were designed and utilized in examining alternatives. Additionally, a base of information on local weather patterns and insolation was developed by NOAA and the National Weather Service. Component performance data began to be available to use with these models and analytical aids as a result of DOE's initiating programs with the National Bureau of Standards (NBS) and the Solar Energy Research and Education Foundation (SEREF) for establishing standards and accredited test facilities to provide approved collector performance values. Some of the analytical aids developed and used are SOLCOST, FCHART, E-CUBE, and TRNSYS. See Appendix C for references on analytical aids, weather information, etc.

The effective use of analytical aids was demonstrated at the Santa Clara Community Center in California during the cooling season of 1977. Santa Clara developed a simulation, a modified form of SIMSHAC/TRNSYS, which was used to predict the performance of the solar system. The results generally agreed with the measured performance data, which served as a check on the model. It also identified that certain components were not performing as well within the system as they did in individual tests.

In some instances it was necessary to resort to conservative designs in order to build a system within a limited budget. Experience has shown that this has limited solar system performance. However, owners have been pleased with their solar systems in spite of these limitations and are seriously considering spending the additional monies required to upgrade the systems to get the optimum benefit from solar. An example is New Mexico State University where the problem of an undersized cooling tower is being studied.

The general conclusion was that solar worked well, but care must be taken in selecting and integrating the components and backup system to achieve maximum benefit from the solar system.

The cost for a solar system is often expressed in terms of $\$/ft^2$ of collector as well as total project cost. The average cost per square foot for the 182 non-Federal commercial projects is:

Application	NSF	PONI	PONII	HWI
Domestic Hot Water	$ 58	$ 46	$--	$37
Space Heating	114	61	41	--
Space Heating and Domestic Hot Water	122	48	46	--
Space Heating and Cooling	216	105	69	--
Space Heating, Cooling and Hot Water	127	114	79	--

Figure 3 shows that there has been a consistent decrease in the cost per square foot of the demonstration projects from an average of $89 per square foot on the early NSF demonstration projects to an average of $37 per square foot on the latest projects.

Figure 4 shows a breakdown of the decrease in cost per square foot of domestic hot water heating systems, space heating systems, heating, cooling and hot water systems, heating and cooling systems, and heating and hot water systems between 1974 and 1978.

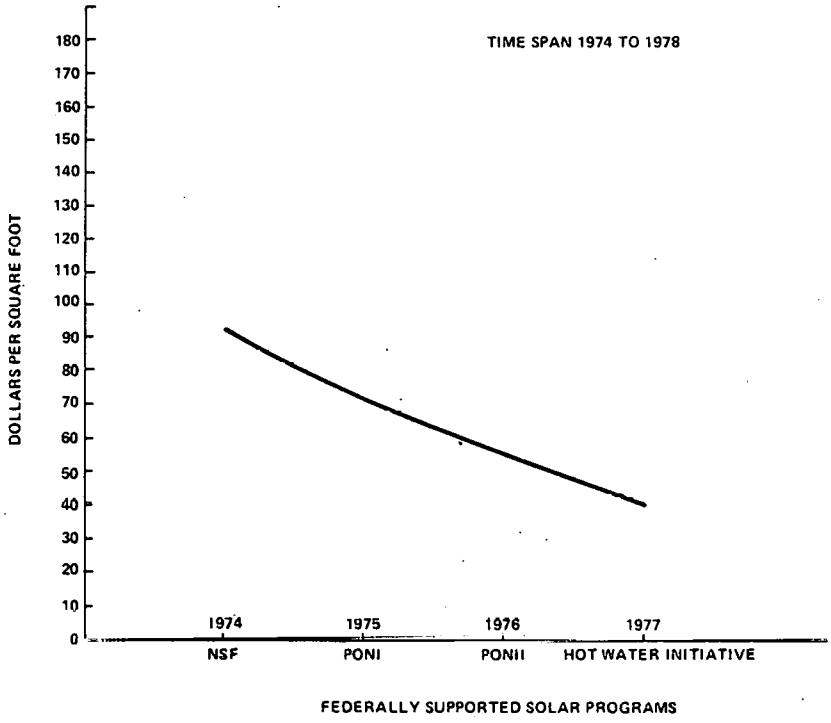


FIGURE 3
AVERAGE OVERALL COSTS ON COMMERCIAL SOLAR
HEATING AND COOLING DEMONSTRATION PROJECTS

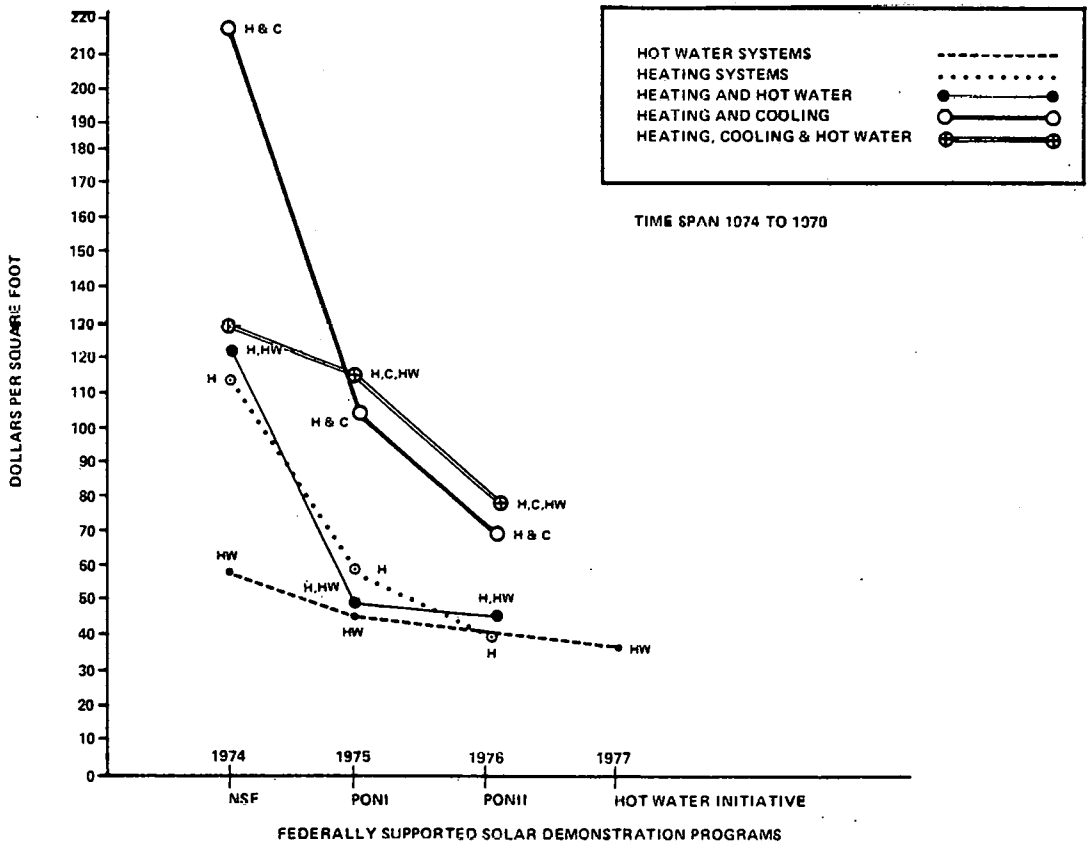


FIGURE 4
AVERAGE COSTS PER SQUARE FOOT ON VARIOUS APPLICATIONS OF
COMMERCIAL SOLAR HEATING AND COOLING DEMONSTRATION PROJECTS

These costs include the cost of design and bid package preparation, solar related components, construction, installation and testing. In addition to the direct construction costs there are additional taxes, insurance and other costs. Legislation in the form of tax rebates or tax incentives are envisioned to foster the growth of the solar industry on a national level. State and local laws will have a positive impact. For example, the 10,550 square foot solar installation on the Telex Communication Manufacturing Plant in Blue Earth, Minnesota, was considered a standard building improvement and an assessment tax was going to be imposed on the owners. This tax increase would have offset any energy cost savings provided by the solar energy system. However, a special solar tax exemption was enacted and the project became operational in February 1978. Other states are enacting solar legislation.

A serious concern has been the number of projects which have experienced overruns. It appears that initial cost estimates were in error because:

- Key cost elements were omitted
- The cost of integrating the solar with the structure and backup were underestimated
- Unforeseen changes were required to either make the solar system operate properly or meet unanticipated code/zoning requirements
- Delays occurred in delivery of equipment
- Labor jurisdictional delays occurred

Incorrect assumptions influenced total cost in some cases. Some designers assumed, for example, that the solar array was the most cost intensive item. Demonstration projects have shown that this is often not the case. It has been found that such design characteristics as long piping runs, massive collector support structures, special energy storage configurations and complex control systems can cost as much as the solar array. Generally, simpler designs which do not attempt to collect and utilize the maximum possible amount of solar energy appear to be the most cost effective.

2.5 Commercial Standards

It has been necessary to develop standards which insure the quality and performance of the solar energy components and systems. Test standards were generated by the National Bureau of Standards (NBS) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) to measure the thermal performance of collectors and storage devices.

- Method of Testing Solar Collectors Based on Thermal Performance (ASHRAE Standard 93-77)
- Method of Testing Storage Devices Based on Thermal Performance (ASHRAE Standard 94-77)

Other test standards are being developed to deal specifically with domestic hot water heaters and swimming pools. In addition, material standards developed by the American Society for Testing and Materials (ASTM) subcommittee on Solar Heating and Cooling Applications are being prepared.

- Recommended Practices for Determination of Reliability of Solar Collectors Exposed to a Natural Environment
- Recommended Practices for Sizing and Rating Solar Space Heating Systems
- Evaluation of the Performance of Containment Materials in Components Testing for Service in Solar Heating and Cooling Systems
- Test Standards for Non-Metallic Flexible Couplings for Solar Energy Systems

The Sheet Metal and Air Conditioning National Contractors Association (SMACNA) has developed installation standards for solar energy systems.

- Heating and Air Conditioning Systems Installation Standards for One and Two Family Dwellings and Multifamily Housing Including Solar, Third Edition, February 1977.

Performance criteria developed by NBS and NASA were used for the design, development, technical evaluation and procurement of the commercial projects.

- Interim Performance Criteria for Solar Heating and Cooling Systems in Commercial Buildings (NBSIR 76-1187)

From the Interim Performance Criteria it is intended that a definitive set of criteria will be established.

2.6 Model Solar Building Codes

To assist the Department of Energy in studying the feasibility of a model solar building code, eight contracts were awarded. The recipients were:

- National Institute of Building Sciences (NIBS)
- The Council of American Building Officials (CABO)
- The Southern Building Code Congress Internation, Inc. (SBCCI)
- The Building Officials and Code Administration, Inc. (BOCA)
- The National Conference of States on Building Codes and Standards (NCSBCS)
- The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
- The American Institute of Architects Research Conference (AIR/RC)
- International Conference of Building Officials (ICBO)

3.0 GENERAL EXPERIENCES

Experiences gained during the bidding, construction and test activities are discussed in this section. The labor, codes, zoning and institutional factors which are closely related are also included in the discussion.

A frequent occurrence in the initial phases of the demonstration projects was that the bids were higher than expected or higher than the budget could accommodate. There were several reasons for high bids and several solutions have been suggested or utilized.

One area where high bids occurred was in solar system installation. It was deemed important to break up the installation work into a number of separate bid packages since very few subcontractors specialize in all of the subareas of structural welding, plumbing, carpentry, and roofing. Usually subcontractors are specialized in one of these areas and will overprice their bids for work outside their specialty.

Some bids came in too high because the subcontractors were unfamiliar with solar systems and they wished to protect themselves from losses. This "fear factor" can be much alleviated by holding a pre-bid conference to describe the solar system design rationale and to familiarize the bidders with solar in general.

When bids are too high in general, one solution has been to redesign the solar installation to bring the costs down. As mentioned earlier, it is important to carefully consider system integration when "redesigning to cost." Cutting costs in certain areas, such as using combinations of components having high COP differentials, can seriously impair the optimum performance of the solar and auxiliary systems.

Another solution used to alleviate high costs was to work with the general contractor to reduce building costs. This may be possible in some cases where the general contractor is selected early in the design process. However, it is important to be aware of state laws regarding the selection of subcontractors because some, such as the State of Illinois, specifically require competitive bidding. Since the competitive bid process takes time, being aware of state laws will ensure compliance and avoid costly delays.

A major concern of the construction phase is the excessive damage which has occurred during the transporting of collectors and some damage from handling by site personnel. DOE is working with industry to improve packaging procedures and handling techniques.

There have also been problems during installation where collectors have been damaged or improperly installed due, in some cases, to incomplete installation instructions and, in others, to a lack of adherence to recommended procedures. Working relationships between contractors and manufacturers are leading to solutions for these problems.

Collectors have been damaged when not designed to withstand the high temperatures encountered during periods of stagnation. Thermal stress has deformed collector cases resulting in air and moisture leaks and glass breakage. Insulation has deformed and displaced collector plates, and coating on collector plates has peeled or deteriorated. These problems were prevalent in early projects but there are now collector models available which appear to have overcome these problems. However, the long term effects of stagnation must still be determined.

Construction delays have been a major problem in the demonstration projects. The most common delays have resulted from:

- late delivery
- damage
- weather
- zoning and building codes.

Most delivery delays involved solar equipment. They were directly related to the nature of a limited production capability and the need for special equipment such as controls and large storage devices. For example, a large tank was damaged during transport because it did not fit beneath an overpass and thus the project was delayed

To reduce cost and on-site installation efforts, collectors were preassembled in groups of seven for one project and delivered to the roof of the building by helicopter. This preassembly method reduced the number of on-site pipe connections from 1,176 to 126 and accelerated the installation process.

Several labor problems have occurred in the demonstration program ranging from trade jurisdictional disputes to subcontractor contract definition. In another case a new trade union contract increased costs considerably. Most of the problems associated with labor were recognized and resolved without conflict. For example, on one project it was decided that various trade personnel were not needed to install the solar collector but, as the project began, a jurisdictional dispute arose. The resolution made was to use ironworkers for frame and support work and plumbers for collector installation.

Zoning and local building codes have had some impact on the installation of commercial solar heating and cooling systems. Problems were encountered mainly because of the lack of precedence set for solar installations. Examples of delays include: local planning board objections to aesthetics of collectors (6 months), local zoning changes to allow roof-mounted collectors (6 months), and approval of a building code variance which was needed to eliminate solar collectors from boiler ratings.

Insurance companies have gained much needed experience in the solar field as a result of the demonstration program. Problems such as boiler classification of the solar collectors and pressurized storage tanks have been

answered. Questions of rate structures and the method of classifying solar energy systems by the underwriters are still being addressed.

During acceptance testing balancing has proved to be a problem. In addition to normal air and hydronic balancing problems, the proper balancing of flow rates in the collector array is vital for optimum performance. The demonstration projects showed that balancing is difficult on large solar systems because of the number of collector panels and the piping runs. If some collectors receive significantly less flow than others, degraded and unstable performance can result. Proper design utilizing balancing valves (even on reverse return systems) has eliminated this problem.

Other testing experience has shown that the solar components placed in water lines or ducts of existing systems sometimes cause pressure drops which impair the performance of the conventional system. This problem has been overcome by the use of larger pumps and fans.

Throughout the program, controls have been identified as a major problem area. See Appendix B for a more detailed outline of control problems and corrective actions taken on demonstration projects. In several cases, sensors were misplaced and thus caused the system to operate inefficiently. In one specific project where the sensor was placed too close to the thermal storage tank, the air-conditioner was operating to cool the building, the solar collectors were operating to dissipate heat from the thermal storage, and, at the same time, the backup boiler system came on to moderate the effects of the air-conditioning. A simple relocation of the sensor eliminated the problem.

DOE recognizes that complete system checkout and verification are involved and costly. New acceptance testing procedures have recently been established and improved instruments such as infrared scanners have been devised to seek out heat leaks in the systems.

The final evaluation considers the operational performance, final costs and overall impact of solar projects. DOE has installed and monitored detailed data collection systems on selected demonstration sites in order to provide long-term performance data which can be compared with original design specifications. The results of the National Solar Data Program's efforts will be discussed during this conference.

4.0 SUMMARY

The National Program for Solar Heating and Cooling of Buildings is directed toward stimulating industry to develop solar water heating, space heating, and space cooling systems for residential and commercial use. The overall goal of the demonstration program is to assist in the establishment of a viable solar industry for the design, manufacture, distribution, sales, installation and maintenance of solar heating and cooling systems. Objectives of the Commercial Solar Heating and Cooling Demonstration Program include:

- Demonstration of the feasibility of solar heating and cooling technology in new and existing commercial buildings
- Acceleration of the development of a solar energy industry and market, through a concentrated demonstration activity
- Development of solar energy system performance standards and criteria for the production and installation of solar energy systems, subsystems, and components
- Development of design guidelines for solar heating and cooling systems, subsystems, and components

Results of the commercial solar demonstration program to date are:

- 222 solar projects have been designed and are in various stages of implementation
- 56 sites are operational and are providing qualitative performance data
- Teams of trained professionals have been developed
- Analytical aids and models have been developed to aid in cost/performance and design calculations
- Equipment is being refined based on experience
- Standards and codes are being developed and interim standards are in use
- Design guidelines have been compiled
- The market is being stimulated

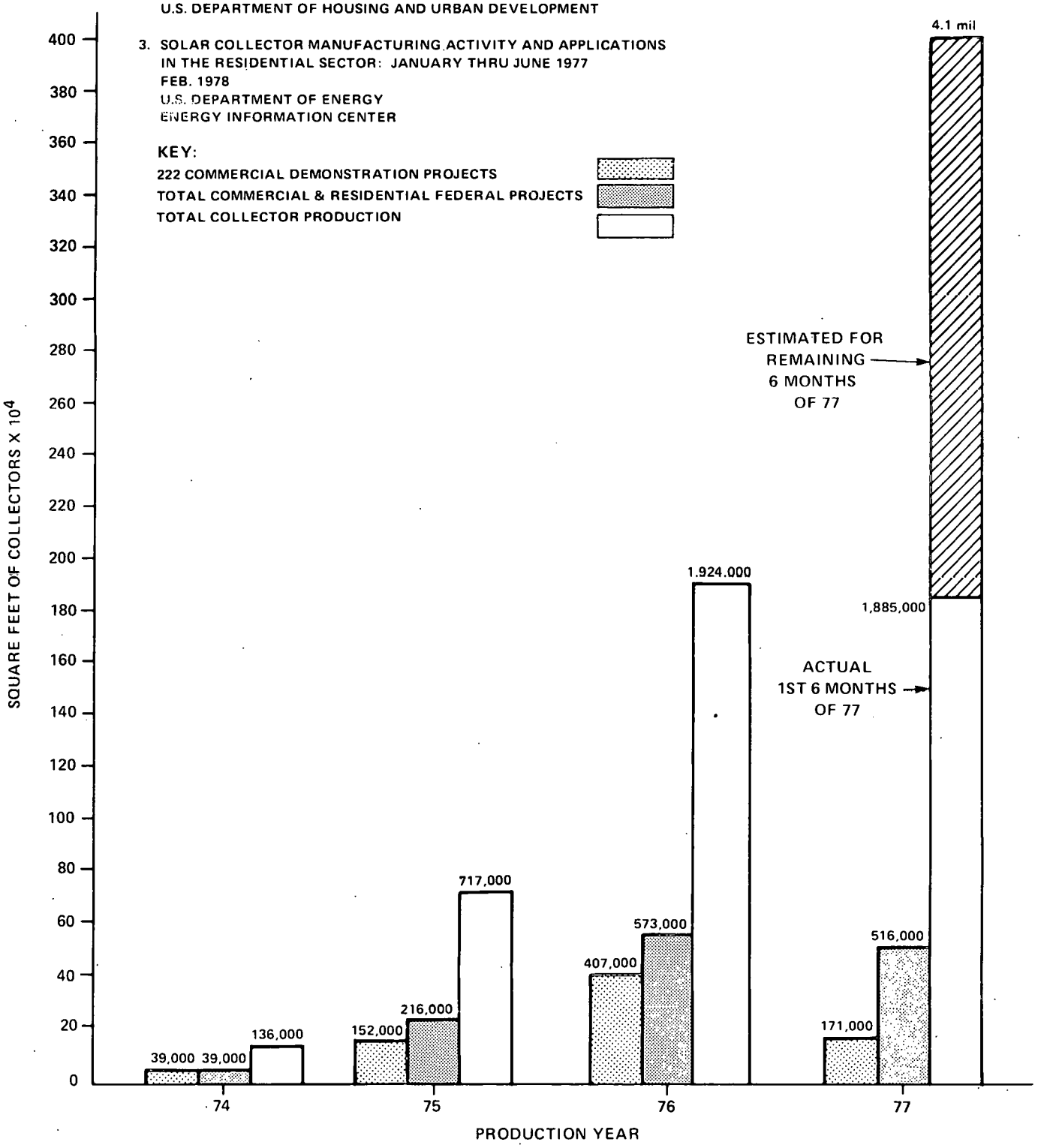
The growth of the market is indicated in Figure 5 which shows the relationships between commercial solar demonstration projects, total Federally funded solar projects, and industry's total production from 1974 to 1977.

REFERENCES:

1. SOLAR HEATING AND COOLING DEMONSTRATIONS
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3. SOLAR COLLECTOR MANUFACTURING ACTIVITY AND APPLICATIONS
   IN THE RESIDENTIAL SECTOR: JANUARY THRU JUNE 1977
   FEB. 1978
   U.S. DEPARTMENT OF ENERGY
   ENERGY INFORMATION CENTER



FEDERALLY FUNDED AND MANUFACTURERS PRODUCTION
OF SOLAR COLLECTORS IN SQUARE FEET

FIGURE 5

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APPENDIX 1

SUMMARY OF OPERATIONAL SITES

IN THE

SOLAR HEATING AND COOLING COMMERCIAL

DEMONSTRATION PROGRAM

SUMMARY OF OPERATIONAL SITES IN THE SOLAR
HEATING AND COOLING COMMERCIAL DEMONSTRATION PROGRAM

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas					REMARKS X = Related experiences /X/ = Continuing concern
				System	Collector	Plumbing	Storage	Controls	
Alabama Power Company Montevallo, Alabama	4 months 3-17-78 to present	Double-glazed flat-plate with	Heating 57% Cooling 18%	X					System instrumented to provide performance data.
					X				Collectors tested for 30-day stagnation. No reduction in performance noted.
Reynolds Metal Company Listerhill, Alabama	7 months 1-78 to present	Flat-plate	Heating 79% Hot water 59%	X					System performed as expected.
						X			Leaking connectors caused two-week system-down time. Leaks fixed.
						/X/			Faulty valve results in dry guard pump protection activity. New valve did not resolve problem.
							X		Poor sensor connection caused collector pump to cycle on and off. Tightened sensor: resolved problem.
							X		High and low temperature limits set-point caused unnecessary cycling from storage to load. Resetting of limits resolved problem.
Tempe Union High School Tempe, Arizona	4 months 3-18-78 to present	Flat-plate	Heating 78% Hot water 89%	X					System instrumented to produce performance data.
				X					Largest PON I system.
					X				Length of collector module (19.5 feet) resulted in reduction in installation time.
Fredricks Development Corporation Apartments El Toro, California	3 years 8-75 to present	Flat-plate	Hot water 70%	X					System sized to provide forty gallons of hot water per day to each unit. Thirty gallons per day would have been sufficient. Tenants pleased. Manager has found solar a strong selling point.
				X					System instrumented to provide performance data.
					X		X		Freeze protection not initially provided. Simple circulation control was added to heat collectors when required.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
Aratex Services Inc. Fresno, California	11 months 9-77 to present	Double-glazed flat-plate	Hot water 56%	X					System design integrated waste-water heat recovery and solar.
				X					System instrumented. Data available. Low solar insolation has prevented high performance Solar has provided 18% of load designed to provide 56%.
					X				During installation collectors were left in hot summer sun. Selective coating peeled, insulation outgassed. Damaged collector was replaced.
							X		Thermal short-circuiting of fluid in the storage occurred. Diffuser installed at inlet.
Iris Images Inc. Mill Valley, California	2 years 7-76 to present	Flat-plate	Hot water 59%	X					System instrumented. Data available. Performance greater than expected.
				/X/					Building now vacant. To be sold or leased.
					X				Collector froze during power failure because design of freeze protection required circulation of fluid. Drain-down now included.
							X		Leak developed at tank manifold inlet. Cause is unknown, suspect o poor installation quality o low-temperature solder o damage caused by misuse of manifold as scaffolding.
						X	X	X	Tank sensors placed in wrong location during repairs causing pump cycling. Repositioned properly.
								X	Flow meters overdesigned; had to be replaced.
						X			Flow-meter failure caused system down time. No provisions for by-pass. No spares on hand.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas					REMARKS
				System	Collector	Plumbing	Storage	Controls	X = Related experiences /X/ = Continuing concern
Santa Clara Community Center Santa Clara, California	1 year, 4 months 4-77 to present	Double-glazed flat-plate	Heating 85% Cooling 65%	X					System instrumented. Data available. Solar system has been delivering an average of 67% of the thermal energy requirements and has delivered an average of 3.3×10^6 Btu per day to the building load. Performance predicted with TRNSYS solar system model.
					X				Construction delay during summer caused insulation to outgas. Collectors were covered. Manufacturer redesigned insulation.
					X				Moisture condensation on inner glazing degraded performance. Purged space between glazing with nitrogen. Added more desiccant and more sealing compound.
						X			Corrosion in pump seal caused failure. Replaced seal. Added chemical treatment to water.
				X					Absorption chiller did not perform as specified. Manufacturer recommended cleaning of condenser tubes. Performance increased from 32 tons to 42 tons.
							X		Location of inlet and outlet of storage tanks caused thermal short circuit. Relocated inlet.
								X	Instrumentation allowing energy balance to be maintained in ten zones results in good performance.
Lake Valley Fire District Lake Tahoe, California	3 months 4-78 to present	Flat-plate	Heating 50% Hot water 50%	/X/					System is a retrofit which uses the existing baseboard hot water heating system. Solar was providing only 140° water when 165° was required. Small storage tank may resolve problem.
							X		Concrete storage tank oversized and poorly designed. Has been replaced with smaller fiberglass tank.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas					REMARKS
				System	Collector	Plumbing	Storage	Controls	X = Related experiences /X/ = Continuing concern
Fredricks Development Corporation Upland, California	2 years, 3 months	Flat-plate	Hot water 70%	X					System was designed and installed based on previous experience by the owner/builder (see El Toro). As a result the system is more cost-effective and labor costs were 10% less. Performance of the system good.
Adams-Arapahoe School District Aurora, Colorado	5 months	Flat-plate	Heating 42% Hot water 35%	X					System to be instrumented.
								/X/	Controls for the system are very complex. Installation errors caused pump to circulate fluid at night. Readjustment resolved this problem but other minor control problems are annoying.
				X	X				Building owner is pleased with system collector performance. Three additional solar buildings are now under construction. Less complex controls experience gained has resulted in reduced cost.
City Hall Littleton, Colorado	5 months 2-78 to present	Flat-plate	Heating 89% Hot water 80%	X					Solar-assisted heat pump operating with no problems as predicted.
Hogates Restaurant Washington, D.C.	6 months 1-78 to present	Flat-plate	Hot water 55%	X					Existing drawings of building were not compatible with actual structure. Retrofit bracing cost $5,000 above bid price.
					/X/				Several collectors damaged during installation. Care must be exercised to prevent handling damage.
					X				Several collectors developed leaks. Replaced by manufacturer. Collector glazing seal allowed moisture to enter collector and cloud glazing. Added more solvent.
					/X/				Corrosion of header resulted from acid flux. Problem being investigated.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas						REMARKS X = Related experiences /X/ = Continuing concern
				System	Collector	Plumbing	Storage	Controls		
Hogates Restaurant (Continued)						X				Copper expansion connectors leaked excessively and were replaced with stainless steel versions at main pipe run and with silicone hose at collector connections.
						X				Pipe leak test performed after insulation installed. Insulation was not properly sealed. Water has penetrated insulation decreasing R factor.
								X		Undersized flow meters initially installed. Replaced with proper size. Pipe length had to be increased for larger flow meters. Cost increase resulted. Delay in installation.
Disney World's Central Energy Plant Lake Buena Vista, Florida	5 months 3-78 to present	Concentrator	Heating 100% Cooling 80% Hot water 100%	X						System instrumented to provide performance data. Early performance indicates the system performance is better than expected. Collecting 200% of energy requirements.
					X					Early collector cost estimates were low resulting in cost overrun. Manufacturer developing production method.
								X		Tracking sensors were affected by moisture. Design changed to hermetically sealed photodiodes.
								X		Cooling system performance was low. Manufacturer reviewed problem and changed chilled water temperature range from 44-55 to 40-60. Cooling system now working to full capacity.
Towns Elementary School Atlanta, Georgia	2 years, 10 months 9-75 to present	Double-glazed Flat-plate with reflector	Heating 50% Cooling 60% Hot water 80%		X					Several collectors were damaged during shipment. New packing methods are being used.
					X					Several collectors were damaged during installation. Care in handling of collectors must be stressed.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas						REMARKS X = Related experiences /X/= Continuing concern
				System	Collector	Plumbing	Storage	Controls		
Towns Elementary School (Continued)					X					Early in the project thermal stresses caused the inner glazing to break. Manufacturer investigated and upgraded strength of inner glazing in their product.
					X					Pinhole leaks occurred in collector. Manufacturer found problem in production process and corrected.
					X					Selective coating has faded and peeled. This coating has been discontinued.
					X					Mylar reflectors provide better than expected performance increase. Low cost indicates a good economic trade-off was made. Mylar will have to be replaced as expected.
					X					Wood trusses used for collector mounting were inexpensive, easy to install and have a life expectancy of 20 years. Wood was good quality and treated.
						X				Valve network is costly and causes simple problems. Designer should make network less complex.
						X				Poppet valve leaked and allowed fluid to seep back into collector array and caused freeze problem. Valves were replaced with bubble-tight butterfly valve.
							X			Thermal storage and cooling storage tanks located too close to each other, resulting in decrease of system efficiency.
Padonia Elementary School Cockeysville, Maryland	2 months 5-78 to present	Concentrator	Heating 75% Cooling 75%	X						System performance to be monitored and compared with Timonium Elementary School with flat-plates.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas						REMARKS X = Related experiences /X/ = Continuing concern
				System	Collector	Plumbing	Storage	Controls		
Shenandoah Recreational Center Shenandoah, Georgia	1 year, 4 months 4-77 to present	Double-glazed flat-plate with reflector	Heating 90% Cooling 60% Hot water 90%	X						System instrumented. Data available. Performance is as predicted providing 67% of total load designed for 60%. Collector fluid temperatures have reached 240°F.
				X				/X/		System was inoperable during winter because of freeze. Power failure during freeze; conditions resulted in freeze damage. Backup manual drain-down not adequate. New designs being considered.
					X					Collectors were preassembled and placed on roof in modular packages. This reduced labor cost.
					/X/					Reflector material, anodized aluminum, was expensive and has begun to deteriorate.
						X				Pressure loss due to fluid contraction resulted in pump failure in the chilled water loop. Addition of open tie to borderline to provide makeup feed resolved problem.
Scattergood School West Branch, Iowa	1 year, 2 months 5-77 to present	Flat-plate	Heating 85% Hot water 75%	X						System instrumented. Data available. Data show solar providing 88% of space heating and 33% of hot water.
						X				Hot water is heated by a coil in an air duct. A loose damper allowed outside air to freeze coil. Tightening of damper seals will prevent future freeze.
								X		Fuses undersized causing periodic system down time. Replace with larger fuses.
Louisiana State University Baton Rouge, Louisiana	2 months 5-78 to present	Flat-plate	Heating 28% Hot water 25%	X						System instrumented to provide data.
								X		Sensor locations were found to be wrong causing poor performance.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
Montgomery Community College Germantown, Maryland	7 months 12-77 to present	Double-glazed flat-plate	Heating 60% Hot water 88%						
Timonium Elementary School Timonium, Maryland	4 years, 3 months 4-77 to present	Double-glazed flat-plate with reflector	Heating 60% Cooling 90%	X					System performs as expected. First school to have solar.
					X				Thermal shock caused inner glazing to shatter. This resulted from large flow introduced into hot collectors on cold winter days. Industry-wide collector design was modified to use stronger glass and allow for freedom to adjust with expansion.
							X		Storage tank insulation cement cracked due to expansion.
Jordan College Cedar Spring, Michigan	7 months 12-77 to present	Double-glazed flat-plate	Heating 52% Hot water 52%	X					Collector system delivers hot water directly to heated boiler water. Solar does not always maintain 180°F. Water should always be pre-heated with solar.
						X		X	Automatic makeup control and pipe leak caused dilution of antifreeze resulting in freeze of collectors.
						X		X	Temperature controls caused short cycling of pump. A time delay was incorporated.
Medical Offices Traverse City, Michigan	6 months 1-78 to present	Flat-plate	Heating 22% Hot water 67%	X					System operating at predicted performance.
William Tao and Associates, Inc St. Louis, Missouri	2 months 5-78 to present	Glass Tube Concentrator	Heating 45% Hot water 50%	X					System operating and is being fine-tuned.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
Telex Blue Earth, Minnesota	5 months 2-78 to present	Flat-plate	Heating 60%	X					System instrumented to provide performance data.
					X				Collector header connections required close tolerance for alignment. Tolerances were not maintained. Installer made field modifications, removing galvanized coating and exposing metal. Corrosion problem existed. Repairs were made.
						X		X	Secondary pump caused pressure limit switch to turn system off. Upper pressure limit reset.
Lincoln Housing Authority Lincoln, Nebraska	3 months 4-78 to present	Flat-plate	Heating 50% Hot water 97%	X					System is two complete solar energy systems; one provides hot water, the other heat.
						/X/			Collector hose connections were clamped using nylon. These clamps were brittle in the winter and began to stretch during summer. Clamps were replaced with stainless steel. Owner worried about flexible hose being knocked off during maintenance.
							X		System integration with the backup reduces overall system effectiveness. Backup boiler has no by-pass of the storage capability.
Kalwall Corporation Manchester, New Hampshire	1 year, 11 months 9-76 to present	Passive	Heating 60%	X					System instrumented for performance data. Insulating collector wall concept. Data on wall "U" valve to be checked. System has been operating with no problems.
Daltyon T. Brown, Inc. Bohemia, New York	3 months 4-78 to present	Flat-plate	Heating 70%	X					System operating with no problems. No data available.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas						REMARKS
				System	Collector	Plumbing	Storage	Controls		X = Related experiences /X/ = Continuing concern
Somerset County Park Commission Basken Ridge, New Jersey	1 year, 10 months 10-76 to present	Flat-plate	Heating 50% Cooling 70% Hot water 100%	X						System is instrumented to provide performance data.
						X				Flow meters became clogged preventing data collection. A filler was installed in solar loop.
						X				Flexible metal connections were used to reduce maintenance requirements.
					X					Corrosion was suspected to be a problem. To prevent any problem, deionized water and Prestone antifreeze were used. Dielectric couplings were used between steel and aluminum connections. System is checked monthly.
					X					During installation each row of collectors was pressure-tested for leaks. Two minor leaks were located and easily corrected. System turn-on resulted in no problems.
							X			Buried storage tank is insulated with urethane foam and coated with vapor barrier. Excellent performance.
								X		Automatic controls with manual intervention has provided good operational control for maintenance, experimentation, and operation. Automatic diagnostic system for failure indication.
				X						Emergency generator for power backup enabled solar energy input during power outage. Building was used as a refuge during this period.
Animal Control Center Albuquerque, New Mexico	4 months 3-78 to present	Tracking concentrator and passive	Heating 64% Hot water 95%	X						System project team considered many problems at beginning of project and avoided all conflicts and delays.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas					REMARKS X = Related experiences /X/= Continuing concern
				System	Collector	Plumbing	Storage	Controls	
Animal Control Center (Continued)						X			Pump overdesigned and operated at excessive flow rate. Throttling of flow rate enabled pump to operate properly.
Coachlight Inn Las Cruces, New Mexico	3 months 4-78 to present	Evacuated flat-plate	Hot water 75%	X					Three individual systems. Performance level above expected. Allows for venting of the pool, which was not in the original design.
					X				Two collectors replaced because of loss of vacuum. Manufacturer testing collectors for stagnation.
New Mexico State University Las Cruces, New Mexico	2 years, 11 months 9-75 to present	Flat-plate and concentrator	Heating 100% Cooling 50% Hot water 100%	X					System instrumented to provide performance data. System designed for cooling load.
				X					System has provided 100% of heating for three winters.
				/X/					Cooling tower underdesigned, reducing chiller performance. Adequate solar input does not result in adequate system performance.
					X				Low-temperature solder was used at connections, which melted and caused leaks.
					X				Tracking device (cable and pulleys) are prone to slippage and result in defocussing of collectors. Manufacturer is changing to linkage device.
New York Botanical Gardens Millbrook, New York	3 months 4-78 to present	Flat-plate and concentrated evacuated tube	Heating 85% Hot water 60%		X				Twenty-six evacuated tube collectors were damaged during shipping. Inspection of all equipment is necessary. Shipping procedure is being investigated. Delay in project resulted.
				X	X				During system check-out collectors were manually operated. After a short period of stagnation fluid was introduced into hot collectors. Thermal shock resulted in damage to many evacuated tube collectors.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
New York Botanical Gardens (Continued)					X				Collector glazing was not allowed any degree of freedom. Thermal expansion and contraction has worked loose bolts and frame. Manufacturer is redesigning glazing.
					X				Wooden structural supports have deformed due to moisture and weather attack. Wood untreated. Was replaced with steel beams. Delay and cost increase resulted.
					X				Silicone hose connections show signs of wear. Inspection found that the collector inlet/outlet tubing had not been deburred.
							X		Storage tank insulation was not designed to be moisture-proof. It was redesigned before installation.
Charlotte Memorial Hospital Charlotte, North Carolina	1 month 6-1 to present	Flat-plate	Heating 40% Hot water 79%	X					System to be instrumented.
					X				System is a retrofit and shading will reduce effectiveness of solar input.
Troy-Miami Public Library Troy, Ohio	3 months 3-78 to present	Evacuated tube	Heation 67%		X				Shortly after system turn-on five collector tubes broke. Low flow resulted in thermal stress. Flow rate was changed. Tube inlet diameter was decreased. The system is operating again.
Day's Inn Anderson, South Carolina	9 months 11-77 to present	Flat-plate	Hot water 45%	X					System is operating as expected.
Loudoun County School Board	4 months 3-78 to present	Flat-plate	Hot water 26%	X					System is instrumented to provide performance data. System is performing as expected.
					X				Collectors were damaged during shipping. Better packing is to be used.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
Bell Telephone Company of Pennsylvania West Goshen, Pennsylvania	10 months 10-77 to present	Flat-plate	Heating 62%	X		X			System has a drain-down freeze protection. Restrictions of flow resulted from a ball valve and 90° elbow, allowing an ice block to form. Fluid-filled collectors froze.
							X		The sensor controlling drain-down was located on the collector. Freeze occurred at a remote location first.
Blakedale Professional Center Greenwood, South Carolina	1 year 8-77 to present	Double-glazed flat-plate with reflectors	Heating 85% Hot water 100%		X				Collector reflector adds little to useable solar energy because of poor positioning.
					X				Collector inner glazing broke. Black paint began to peel from aluminum absorber plates. Manufacturer replaced all collectors.
						X			Manual gate valve of air vent used for drain-down was blocked. Drain-down did not occur and system froze.
							X	X	Malfunctioning sensor on collector resulted in night cycling of pump, causing 5-10% reduction in stored energy. Sensor had corroded and was not operating properly.
							X		Storage tank location is below water line. Heat losses were occurring. Drainage provided in storage area.
Basin Electrical Headquarters Building Bismarck, North Dakota	5 months 2-78 to present	Double-glazed flat-plate	Heating 34%	X					Solar retrofit tied into existing heat pump system. Building designed to conserve energy.
					X				No summer load-collectors are shaded to protect from stagnation.
					/X/				Glazing has slipped from collector frame. Investigation is necessary.
						X			Parallel pump had to be installed to assist original undersized pump.
						X			Long pipe runs results in large heat losses.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
Basin Electrical Headquarters Building (Continued)					X				Collector insulation deteriorated.
					X				Collector degassing can cause breakage. Manufacturer is investigating all of the above.
					/X/				Shipping damage.
Terrell E. Moseley Lynchburg, Virginia	1 year, 8 months 11-76 to present	Flat-plate	Heating 70%	X					System instrumented. Data is available. Solar provides 60% of energy required to heat building.
					X				Collector's internal glazing broke. Manufacturer replaced it and claimed 1-2% failure rate is normal.
Mount Rushmore National Memorial Keystone, South Dakota	8 months 11-77 to present	Double-glazed flat-plate	Heating 45% Cooling 45%	X					System is instrumented. Data is available. System is providing 45% heating and 53% cooling.
					X	X			System installation procedures were not strictly followed. During system fill air leaks occurred.
Radian Corporation Austin, Texas	1 year, 5 months 2-77 to present	Tracking concentrator	Heating 90% Cooling 80%				X		The tracking controls and devices were the only problem encountered with this system. The sensors input high charge to electronic load caused failure. This was resolved by resistors. Tracking drive devices had a mechanical failure and slippage. Manufacturer is developing a heavy duty tracker.
American Motor Inns St. Thomas, Virgin Islands	8 months 11-77 to 5-78	Tracking concentrator	Cooling 25%	X					System design requires no storage by using solar as available. System provided hot water to drive 100-ton absorption chiller. System provides double the expected output.
					/X/				Collector housing is corroding in saltwater atmosphere.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
Fauquier County School Warrenton, Virginia	5 months 2-78 to present	Flat-plate		X					System operated for several years as proof-of-concept demonstration. Experimental collectors have been replaced. System turn-on date was 2-78.
					X				Original collectors' selective coating degraded. Wooden cases were deformed. Glass breakage occurred. New collectors were installed with black chrome coating and tempered glass.
						X			Radiator hose was used for collector connection. Ultraviolet radiation degenerated rubber and leaks resulted. New hoses withstand higher temperatures and are protected from sunlight.
							X		Concrete storage tanks leaked at high temperatures. Tank was sealed.
								X	Original automatic control system had unreliable components and control had to be manual. New controls use plug-in solid state components.
								X	Sensor was positioned at long end of collector resulting in faulty control. Sensors were relocated to middle of collector.
Page Jackson School Charlestown, West Virginia	2 months 5-78 to present	Double-glazed flat-plate with reflector	Heating 85% Cooling 51%	X		X			System design indicated the lack of expansion/contraction provision in piping. Redesign is necessary.
				X					Building's structural components were increased to withstand snow loads.
Olympic Engineering Richland, Washington	4 months 3-78 to present	Flat-plate	Heating 71% Cooling 97% Hot water 90%	X					System is to be instrumented to provide performance data.
					/X/				Collector's selective coating changed color from black to bronze.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas: System	Collector	Plumbing	Storage	Controls	REMARKS (X = Related experiences; /X/ = Continuing concern)
Elementary School Howard Grove, Wisconsin	4 months 3-78 to present	Air flat-plate	Heating 58%	X					System is instrumented to provide performance data.
							X		Air-flow meters were providing faulty data. Air straighteners had to be installed.
						X			Leaks were found at air duct seams and around damper shafts. Sealing of leaks resolved problem and increased performance.
Nambe Indian Pueblo Nambe, New Mexico	8 months 11-77 to present	Air flat-plate and passive	Heating 55%	X					System is operating satisfactorily. No problems to date.
Junior High School Brooklyn Center, Minnesota	3 months 4-78 to present	Flat-plate	Heating 54% Hot water 21%						
El Camino School Irvine, California	3 months 4-78	Evacuated tube	Heating 50% Cooling 50%		X				System was down shortly after turn-on. A number of tubes were broken. Manufacturer found clamp leak allowing fluid depletion resulting in thermal shock.
Trinity University San Antonio, Texas	1 year 8-77 to present	Tracking concentrator	Heating 60% Cooling 5% Hot water 60%	X					System is instrumented. Data is available. System is supplying 100% of hot water. Performance is good in space heating.
							X		Tracking controls cause defocussing of collectors. This results in reduction in collection performance.
				X					System collectors were specified and bids were gathered for quote.
North Georgia Planning Dalton, Georgia	3 months 4-78 to present	Double-glazed flat-plate with reflectors	Heating 93% Hot water 86% Cooling 55%	X					System is working and performing as expected.
Quality Inn Key West, Florida	3 months 4-78 to present	Flat-plate	Hot water 47%	X					System is saving 60% of fuel requirements.

OPERATIONAL SYSTEMS

Site and Location	Operating Time	Collector Type	Application	Operating Experience Areas					REMARKS
				System	Collector	Plumbing	Storage	Controls	X = Related experiences /X/ = Continuing concern
Rademaker Corporation Louisville, Kentucky	1 year 8-77 to present	Liquid and air flat-plate	Heating 50%	X					System is operating as expected. Low insolation reduced solar energy input.
							X		Cycling of fan was resolved with a time delay.
					X				Passive solar glazing seemed cloudy. Manufacturer replaced it with better quality glazing.
						X			Antifreeze was kept at 20% solution. A colder than expected winter resulted in a freeze. 40% solution will be maintained.
Lutz Sotire Stamford, Connecticut	1 month 6-78 to present	Flat-plate with reflectors	Heating 50%	X					Reflectors provide collector cover during summer when no energy is used.
					X				Collectors' header connection had close tolerances and did not align properly. Installer cut clearance hole with shears. Collectors began to corrode. Manufacturer replaced.
						X			Initial design did not have expansion provision. System was redesigned to include expansion joints.

APPENDIX 2

SUMMARY OF THE PROBLEMS ENCOUNTERED

IN THE

SOLAR HEATING AND COOLING COMMERCIAL

DEMONSTRATION PROGRAM

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
COLLECTORS — GENERAL

Problem Area	Problem Description	Corrective Action
Handling damage • bending • scraping	Collectors have been damaged in shipping because of inadequate protective packing.	There is still a problem, and proper packing and shipping procedures should be implemented. DOE has placed high priority on the resolution of this problem.
	Collectors have been damaged because of improper handling.	Shippers and receivers must handle collectors with care. Sturdier collectors must be built.
	Collectors have been damaged during installation.	Installation-handling procedures must be provided by manufacturers and followed by installers.
	Collector seals have broken during installation.	Manufacturers should improve seal and weld techniques. Installers should follow manufacturer's procedures completely.
External corrosion	Hardware supplied by manufacturer not protected from corrosion.	Manufacturers have developed corrosion protection requirements.
	Saltwater environments caused extreme corrosion problems.	Designers, manufacturers, and installers should consider extreme environmental conditions in selling equipment. Corrosion resistant materials are available.
	Improper handling causes voids in corrosion protector coating.	Field touch-up of voids prevented corrosion.
	Field change to collector housing to facilitate installation was performed. As a result corrosion protection was eliminated in change areas.	Field touch-up of voids prevented corrosion.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
COLLECTORS — GENERAL
(Continued)

Problem Area	Problem Description	Corrective Action
Internal corrosion	Dissimilar metals created galvanic effect when in contact with water.	Eliminate the use of dissimilar metals.
	Moisture condensation posed threat of corrosion. Dessicant inadequate to remove moisture.	Dessicant containers redesigned to prevent saturation of dessicant by atmospheric air.
Leaks	Hose clamps used to connect internal header. Leaks hard to discover.	Use mechanical or soldered connections.
	Flexible hose connections were secured with screw type clamps causing shearing of hose.	Use spring type connector to reduce excessive shear.
Outside air infiltration	Outside air leak caused heat losses while collector was on and added cool air to the system while collector was off.	Adequate sealing of collectors and ducts is required.
Air leaks	Pressure drops across the collector due to leaks restrict flow into storage.	Adequate sealing of collector required.
Improper alignment of mounting structure	Design tolerance in collector mounting and interface connection required field modification.	Allow for flexibility in mounting structure.
Material deterioration	Some materials have deteriorated under ultraviolet light.	Select materials that do not deteriorate when exposed to ultraviolet radiation or add protective cover.
Outgassing	Insulation, sealants, and other material with volatile components have emitted gases	Use materials which do not outgass at maximum expected temperature. See

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
COLLECTORS — GENERAL
(Continued)

Problem Area	Problem Description	Corrective Action
Outgassing (Continued)	at high temperatures, which caused clouding of glazing.	standards.
High pressure buildup	Stagnation temperatures caused boiling.	Install a pressure relief valve.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
COLLECTOR — FLAT PLATE

Problem Area	Problem Description	Corrective Action
Glazing damage	High thermal stress concentration at rough edges resulted in cracking.	Smooth edge of glass before manufacturing or installation.
	Plain glass broke under high temperature stress.	Use tempered glass to prevent breakage.
	Glazing was restricted from expanding when heated. This resulted in shattering of glass.	Allow adequate means for thermal expansion at maximum temperatures.
Glazing deterioration	Some plastic (polymers) deteriorated when exposed to sunlight or moderate or high temperatures. Transmissivity was reduced.	An investigation of glazing properties and conditions to determine glazing deformation effects on solar collectors is now being performed.
Glazing abrasion	Wire supports under thin film glazing caused clouding and holes.	Elimination of supports were not necessary. Support surface area was increased to minimize stress.
Glazing clouding and condensation	Clouding and condensation resulted in loss of transmissivity.	Collectors should be assembled when little moisture is present. Use dessicants under glazing. Inspect glazing seals.
Absorper plate buckling	High temperatures caused buckling of absorber plate and cracked glazing.	Adequate expansion and floating of the absorber plate is necessary. Manufacturer redesign.
	Expansion of absorber plate was restricted by collector frame/glazing.	Adequate expansion and floating of the absorber plate is necessary. Manufacturer redesign.
Flow	Inlet and outlet on the same end resulted in flow short circuits.	Inlet and outlet were placed diagonally opposite each other for maximum flow distribution.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
COLLECTOR — FLAT PLATE
(Continued)

Problem Area	Problem Description	Corrective Action
Selective coating peeling	Absorber plate paint peeled and cracked at high temperatures because of the use of low temperature paint and improper application.	Use high temperature paint and specific application procedures (degreasing, washing, primer paint).
Selective coating fading	Outgassing occurred due to high temperatures.	Heat treat and coat plates to withstand high temperatures.
Absorber corrosion	Moisture penetration caused pitting and leaks.	Inspect and maintain collector seals to prevent moisture penetration.
Insulation shrinkage	Material used for insulation shrank under high temperatures.	Insulation should consist of temperature material.
Insulation expansion	Material used for insulation expanded under high temperatures and deformed collector.	Provide expansion slots and utilize stable materials.
Inadequate insulation	High heat losses through back and sides of collector due to inadequate insulation.	Increase insulation.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

Problem Area	Problem Description	Corrective Action
	COLLECTORS — TRACKING	
Tracking system controls	Erratic and malfunctioning tracking systems defocused collectors.	Additional positioning. Control has been incorporated into existing design.
Fresnel lens	Seals of Fresnel lenses allowed slipping which caused defocusing and moisture penetration.	Seals and lens mounting provisions being investigated.
Misalignment of tracking devices	Due to slippage in pulley cable individual panels misaligned.	Contractor testing new tracking design.
	Tracking motor fails. Mechanical drive fails.	Redesign of tracking mechanism and oiling mechanism.
	COLLECTORS — EVACUATED TUBE	
Thermal shock	Evacuated tube collectors fractured when stagnated and then filled with cool fluid.	Match the temperature of the fluid with the collector before filling.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
STORAGE TANKS

Problem Area	Problem Description	Corrective Action
Leaks	Leakage existed at fiberglass tank joints after tanks were assembled on site from two halves.	Careful assembly following the manufacturers recommendations using the recommended sealing materials is required.
Undersizing of expansion tank	Undersized expansion tank sized for water, not glycol water mixture.	Replaced with larger sized tank. Glycol mixtures expand more than pure water.
Heat loss	Fiberglass tanks leaked through "wicking" action in some fiberglass threads that extended through the tank.	Seal all exposed fiberglass threads.
	Buried concrete tank had water leakage through the tar seal, soaking the insulation and increasing the heat loss.	Changed to above-ground storage tank.
	Heat loss from domestic hot water tanks exceeded manufacturers specifications. Investigation showed the added solar piping and instrumentation provided an increased heat leak path.	Adequately insulated all exposed piping and instrumentation connected to the storage tank.
	Tank was too large for collector area and tank temperature never exceeded 57°C (135°F).	Replaced tank with one that provided 7.6 liters (2 gal.) of storage for each square foot of collector.
	Steel legs supporting storage tank were a were a large conductor of heat.	Thermally isolated supporting legs.
	Underground tank insulation was damaged due to lack of proper support in rocky soil. Maintaining watertight insulation on underground storage tanks was difficult. Water in insulation increased heat transfer.	Check waterproofing prior to installing, provide proper support, install carefully, patch any bad spots in insulation and backfill carefully.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
STORAGE TANKS
(Continued)

Problem Area	Problem Description	Corrective Action
Heat loss (Continued)	A heat exchanger for collector to storage heat transfer was installed too high in the storage tank. Under some conditions (particularly at lower insolation) the collector pump would start when collector temperatures result in transfer of heat from storage to collector.	Ensure proper location of heat exchangers and proper location and setting of controls.
	Heat transfer from collector loop through the heat exchanger into the storage tank was not as good as assumed.	A parallel heat exchanger was added. (This was considered less expensive than replacing with a more desirable larger single heat exchanger.)
	Water getting into insulation of buried tank increased heat loss.	Provide ground water drainage or provide waterproof insulation or locate above ground.
	High heat loss at night was thought to be through the tank insulation due to high ground water. Further investigation showed a faulty thermo-couple that allowed pump to run all night, rejecting tank heat to atmosphere.	Thermo-couple was replaced and subsequently failed again. It was then found it was not suitable for the temperatures experienced, and it was replaced with high temperature thermo-couples.
	Ground water around tank resulted in high heat loss.	Additional insulation and stones were placed under and around tank to improve drainage.
	An open-cell foam was applied to the tank due to lack of product research. This acted like a sponge, and increased heat loss.	Use closed-cell foam.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
STORAGE TANKS
(Continued)

Problem Area	Problem Description	Corrective Action
Material	Material planned for inside coating of storage tank melted at 82°C (180°F).	Changed to a compound stable at 145°C (250°F).
Corrosion	Investigation indicated that the corrosion condition of the ground itself might create problems with the underground storage tank.	Installed cathodic protection for the tank (sacrificial magnesium anodes) and coated tank with rubberized vapor barrier.
Flow restriction	Heat exchangers supposedly of refrigeration quality were contaminated with machine oil and metal filings.	Units were returned to vendor for cleaning.
	Heat exchanger tubes extended through manifold to far side of manifold and restricted flow.	Reworked manifold header to provide clearance.
Drainage	A sewer drain was installed under a rock storage bin to remove any water. The heat in the bin evaporated the water in the drain trap, letting sewer gas into the house.	Changed drain to a location outside rock bin.
Contamination	Algae was found in the tank and transport system after a long period of operation.	Algae was evaluated and proper biocide used.
Energy storage	High velocity input prevented stratification and reduced efficiency.	Diffusers were installed to minimize velocity.
	Flow from collector tank entered at bottom of tank. Flow back to collector was also from bottom of tank causing short circuit in flow path and eliminating benefit of stratification.	Flow from collector to tank should enter tank at top where water is hottest. Flow back to collector should be from bottom of tank (on opposite end from inlet if no distribution manifold is used.)

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
PLUMBING — PIPING

Problem Area	Problem Description	Corrective Action
Freezing of drain-down systems	Rubber hose connections from collector to manifold sagged and resulted in low spots that did not drain completely and froze.	Proper installation required so water can drain.
	Damage to piping resulted in low spot in pipe run. Pipe froze.	Careful installation procedures.
	Field modification to "fit" pipe run resulted in low spot in pipe run. Pipe froze.	All field modification should be carefully considered and well documented.
	Drain-down collectors retained water.	Air lines added to prevent water trap.
Leaks	Rubber hose connectors deteriorated due to ultraviolet radiation.	Use stable hose material or connectors.
	Many piping leaks found in systems. Oil systems leak more. Water systems experience evaporation problems.	Soldered connections are preferred to threaded connection. Good workmanship is required. Air test system before filling.
Air lock	Large systems hose resulted in air trapped in various locations which restricts flow.	Consider filling procedure. Provide air vent and bleeder valves.
Heat losses	Use of asbestos cement permitted high heat losses through pipe system.	Use conventional pipe insulation.

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
PLUMBING — PUMPS

Problem Area	Problem Description	Corrective Action
Flow rates	Excessive flow rates reduced system efficiency.	Throttle flow rate to improve performance. Order smaller pump.
Pressure drops	Larger than anticipated pressure drops in system caused reduced flow rates.	Used pumps in series.
	Heat exchangers had higher pressure drops than expected.	Changed heat exchangers.
	Pressure overload on pump caused thermal overload and resulted in shut-off of pump.	Adequate sizing of pumps and components ensure proper flow.
Seal failures	Corrosion in system resulted in failure of tungsten carbon steel seal.	Use seals compatible with system material.
	Seals failed in ethylene glycol solution due to material incompatibility.	Changed to oil transport medium compatible with seals.
Location	Pump on downstream sides of collector resulted in cavitation.	Relocated pump so that pump was pumping from tank to collectors.

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PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
CONTROLS

Problem Area	Problem Description	Corrective Action
System cycles on and off	Pumps and fans cycled frequently at start-up or shut-down reducing solar energy collection and reducing motor life.	Increase control differential and/or add time delay.
	Improper location of collector temperature sensor resulted in poor performance. Improper mounting of sensor resulted in poor performance.	Move sensor to pipe inside collector which is adjacent to absorber plate.
	System had been operating properly when malfunction began to occur. Sensor was found to be corroded.	Replace sensor.
	System operation malfunction resulted in investigation of sensor. Sensors were not according to design specifications.	Replace sensors. Check temperature sensors if control problem exists.
Tracking controls	Unstable weather condition caused tracker to be misaligned.	Contractor testing new control with less cloud problem.
Energy storage	A rock storage bed designed for horizontal flow had an air space left at the top, which permitted the air to bypass the rocks.	Redesign to use vertical flow through the rock bed. (Horizontal flow also reduces the desired stratification effect.)

PROBLEMS ENCOUNTERED IN THE
SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
SYSTEMS

Problem Area	Problem Description	Corrective Action
Freezing	Glycol mixture not sufficient to prevent freezing.	Installer required to add sufficient anti-freeze.
Freezing of coil	Night flow of air froze heat exchanger in duct work.	Adjust damper to seal against unwanted air movement.
Leaks in air systems	Homemade dampers did not seal properly, resulting in air loss.	Change to dampers that have flanges and seals to close against positive reading.
Power failures	Power failure prevented pump from circulating warm water from storage when freezing condition existed.	Backup drain system was added to provide added freeze protection.
Increased cooling load	Heat loss from solar storage in basement adds to summer cooling load in building.	Provide adequate insulation and exhaust unwarted heat to atmosphere.
Control strategy	During a warm evening three events happened simultaneously: the chiller was taking heat from storage to operate, the auxiliary boiler was operating and heating the building, and the collector pump was operating and rejecting heat from storage.	Analysis of control requirements, development of control strategy proper sensor location and proper control setting are required for correct system operation.
Backup	The design of the backup system for cooling called for additional heat input to storage if temperature was too low for chiller operation (Chiller COP= 0.6; Conventional cooling units COP = 4.0).	Integration of backup and solar requires analysis of overall system efficiency.
Overheating of fan motor	Placement of space heating coil resulted in temperatures in excess of design.	Relocation of coil to downstream position.

APPENDIX 3

SOLAR SYSTEM PERFORMANCE AND COST

ANALYTICAL AIDS AND SOURCES

SOLAR SYSTEM PERFORMANCE AND COST ANALYTICAL AIDS AND SOURCES

CONCERN	QUESTION	SOLUTION	REFERENCES
I. SELECTION METHODOLOGY	1. HOW DO I DETERMINE A CANDIDATE DESIGN?	I.1.1 DESIGN/PLANNING TEAM: THIS IS NOT A DO-IT-YOURSELF PROJECT. AN ANALYSIS MUST BE CONDUCTED BY A COMPETENT GROUP OF ARCHITECTS, ENGINEERS AND SOLAR DESIGNERS TO GENERATE A REPRESENTATIVE DESIGN AND COMPUTE THE SOLAR CONTRIBUTION. THE EXPERIENCE FACTOR IS IMPORTANT; BY THE TIME KEY PERSONNEL HAVE DESIGNED AND CONSTRUCTED TWO OR THREE SOLAR SYSTEMS THEIR EXPERTISE IS INCREASINGLY VALUABLE.	ORGANIZATIONS: • CONTACT AND REQUEST REPORTS FROM THE DEPARTMENT OF ENERGY TECHNICAL INFORMATION CENTER, OAK RIDGE, TENNESSEE • CONTACT THE NATIONAL SOLAR HEATING AND COOLING INFORMATION CENTER, P. O. BOX 1607, ROCKVILLE, MARYLAND 20850 FOR THE NAMES AND ADDRESSES OF ARCHITECTS, ENGINEERS AND DESIGNERS IN THE SOLAR ENERGY FIELD DOCUMENTS: • THE DEPARTMENT OF ENERGY'S SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM PROJECT SUMMARIES DOE/CS-0009 • SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM CONTRACTORS REVIEW PROCEEDINGS • UTILIZE THE DEPARTMENT OF ENERGY'S SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM KEY PERSONNEL DIRECTORY • BOCA BASIC BUILDING CODE/1975
		I.1.2 SYSTEM PRECEDENCE: THE TEAM SHOULD REVIEW ESTABLISHED SOLAR SYSTEMS IN ORDER TO SELECT REPRESENTATIVE DESIGNS.	
		I.1.3 CODES: REVIEW LOCAL AND NATIONAL CODES FOR RESTRICTIONS.	
	I.2 HOW DO I CALCULATE CANDIDATE DESIGN EFFECTIVENESS?	I.2 THE EFFECTIVENESS OF CANDIDATE DESIGNS IS DETERMINED THROUGH A COMPARISON OF PERFORMANCE AND COST-EFFECTIVENESS CALCULATIONS.	(SEE I.2.1 AND I.2.2)

CONCERN	QUESTION	SOLUTION	REFERENCES
	I.2.1 HOW DO I CALCULATE SYSTEM PERFORMANCE?	I.2.1 THE CALCULATION OF SYSTEM PERFORMANCE REQUIRES THE USE OF MODELING AIDS WHICH UTILIZE SOLAR AND METEOROLOGICAL DATA AND DATA ON EQUIPMENT PERFORMANCE CHARACTERISTICS.	

- MODELING AIDS: PERFORMANCE AND COSTING AIDS MUST BE UTILIZED TO CALCULATE THE SOLAR CONTRIBUTION AND ESTIMATE COSTS. COSTING AND PERFORMANCE AIDS AND MODELS ARE AVAILABLE. SOME ARE STILL IN NEED OF VALIDATION.

DOCUMENTS:

- "SOLAR HEATING AND COOLING SYSTEM DESIGN METHODS" PRESENTATION AT THE ARIZONA SOLAR COOLING AND COMMERCIALIZATION CONFERENCE, DEC. 12-13, 1977 BY DR. SUBRATO CHANDRA, PRC/ ENERGY ANALYSIS CO.

CERL

- "PREDICTING THE PERFORMANCE OF SOLAR ENERGY SYSTEMS" INTERIM REPORT E-98, JAN. 1977, CERL. AVAILABLE FROM NTIS 5285 PORT ROYAL RD., SPRINGFIELD, VA.

LASL-SLR (SOLAR LOAD RATIO)

- COMMERCIAL – ERDA FACILITIES SOLAR DESIGN HANDBOOK, AUG. 1977. ERDA 77-65 – AVAILABLE FROM NTIS.
- RESIDENTIAL – ERDA'S PACIFIC REGIONAL SOLAR HEATING HANDBOOK NOV., 1976, ERDA SAN FRANCISCO OP OFFICE AND LOS ALAMOS SCIENTIFIC LAB.

ORGANIZATIONS:

F-CHART

- UNIVERSITY OF WISCONSIN SOLAR ENERGY LABORATORY, 1500 JOHNSON DRIVE, MADISON, WISCONSIN 53706.

SOLCOST

- INTERNATIONAL BUSINESS SERVICES SOLAR GROUP, 1010 VERMONT AVE., WASHINGTON, D.C. 20005 (CYBERNET AND GE'S COMPUTER NETWORKS)

BLAST

- U.S. ARMY CERL, P. O. BOX 4005, CHAMPAIGN, ILLINOIS 61820 (CYBERNET COMPUTER NETWORK)

CAL-ERDA

- DR. F. WINKLEMANN, LBL, 50B-5238, BERKELEY, CA. 94720 (CYBERNET COMPUTER NETWORK)

TRNSYS

- TRNSYS ENGINEER, SOLAR ENERGY LABORATORY, UNIVERSITY OF WISCONSIN, 1500 JOHNSON DRIVE, MADISON, WISCONSIN 53706.

CONCERN	QUESTION	SOLUTION	REFERENCES
			DOCUMENTS: • NATIONAL PROGRAM FOR SOLAR HEATING AND COOLING OF BUILDINGS – ANNUAL REPORT, APRIL 1978 DOE/CS-0007 • HUD INTERIM PERFORMANCE CRITERIA FOR SOLAR HEATING AND COOLING SYSTEMS AND DWELLINGS NBSIR 75-636, DEC. 1974. • "INTERMEDIATE STANDARDS FOR SOLAR DOMESTIC HOT WATER SYSTEMS/ HUD INITIATIVE" NBSIR 77-1272. • THE SOLAR HEATING AND COOLING DEMONSTRATION PROJECT SUMMARIES, DOE/CS-0009, FEBRUARY 1978. • MANUFACTURERS AND THEIR REPRESENTATIVES
	I.2.2 HOW DO I CALCULATE THE SOLAR SYSTEM COST?	I.2.2 THE CALCULATION OF COSTS DEPENDS UPON DESIGN AND BID PACKAGE PREPARATION COSTS, COMPONENT COSTS AND CONSTRUCTION COST. • COSTS TO COMPLETE DESIGNS AND PREPARE BID PACKAGES ARE MOST ACCURATE FROM EXPERIENCED SOLAR PLANNERS. • COSTS OF COMPONENT PARTS ARE AVAILABLE FROM MANUFACTURERS. SOME CAUTION SHOULD BE EXERCISED IN COSTING PARTS BECAUSE WHERE SPECIFIC EQUIPMENT MUST BE MODIFIED OR CUSTOMIZED FOR THE INSTALLATION, PRICES WILL INCREASE.	ORGANIZATIONS: • CONTACT THE NATIONAL SOLAR HEATING AND COOLING INFORMATION CENTER, P. O. BOX 1607, ROCKVILLE, MD. 20850 FOR INFORMATION ON SOLAR MANUFACTURERS • CONTACT THE NATIONAL SOLAR HEATING AND COOLING INFORMATION CENTER FOR THE NAMES AND ADDRESSES OF SOLAR ARCHITECTS, ENGINEERS, AND DESIGNERS. DOCUMENTS: • UTILIZE THE DEPARTMENT OF ENERGY'S SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM KEY PERSONNEL DIRECTORY TO SELECT EXPERIENCED SOLAR PERSONNEL.

CONCERN	QUESTION	SOLUTION	REFERENCES
		• SOLAR AND METEOROLOGICAL DATA ARE REQUIRED INPUT TO THE PERFORMANCE AIDS AND MODELS USED FOR EVALUATING CANDIDATE DESIGNS. EXTENSIVE SOLAR AND METEOROLOGICAL DATA FOR SIX LOCATIONS CURRENTLY EXIST IN THE SOLAR DATA BANK. ADDITIONAL DATA IS BEING COLLECTED AND REFINED.	ORGANIZATIONS: • NATIONAL SOLAR DATA BANK TECHNICAL INFORMATION CENTER, OAK RIDGE, TENN. • NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • NASA • NATIONAL SCIENCE FOUNDATION • USDA • DOD
		• EQUIPMENT PERFORMANCE CHARACTERISTICS ARE REQUIRED IN THE UTILIZATION OF THE PERFORMANCE AIDS AND MODELS. DATA ON PERFORMANCE CHARACTERISTICS ARE AVAILABLE.	ORGANIZATIONS • NATIONAL BUREAU OF STANDARDS (NBS) • SOLAR ENERGY RESEARCH AND EDUCATION FOUNDATION (SEREF) DOCUMENTS • THERMAL DATA REQUIREMENTS AND PERFORMANCE EVALUATION PROCEDURES FOR THE NATIONAL SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM NBSIR 76-1137, AUG 1976 • HUD/FHA (MPS) MINIMUM PROPERTY STANDARDS (HUD 4930.2) • ASHRAE STANDARDS FOR COLLECTOR AND STORAGE SUBSYSTEMS (ASHRAE 93-77 AND 94-77) • INTERIM PERFORMANCE CRITERIA FOR SOLAR HEATING AND COOLING SYSTEMS IN COMMERCIAL BUILDINGS NBSIR 76-1187
		• CONSTRUCTION COSTS HAVE PROVEN TO BE DIFFICULT TO ESTIMATE. UNRELIABLE CONSTRUCTION COST ESTIMATES ON THE DEMONSTRATION PROJECTS RESULTED IN COST OVERRUNS. EXPERIENCE INDICATES THAT WHERE THE KEY PERSONNEL ARE EXPERIENCED WITH SOLAR PROJECTS THAT THEIR COST ESTIMATES ARE MORE ACCURATE.	

CONCERN	QUESTION	SOLUTION	REFERENCES
	I.2.3 HOW DO I EVALUATE THE COST/PERFORMANCE OF THE SYSTEM?	I.2.3 THE PAYBACK PERIOD AND DOLLARS PER BRITISH THERMAL UNIT (BTU) DELIVERED TO THE HEAT EXCHANGER AND BUILDING CAN HELP IN CALCULATING COST-EFFECTIVENESS. IT SHOULD BE NOTED, HOWEVER, THAT COST-EFFECTIVENESS DEMANDS INDIVIDUAL CALCULATIONS AS COSTS VARY GREATLY WITH EACH SYSTEM AND LOCALITY. IN ADDITION THE FUEL ESCALATION RATE WILL INFLUENCE THE LENGTH OF THE PAYBACK PERIOD.	
		• CALCULATE ECONOMIC FEASIBILITY BY UTILIZING SOLCOST, A CONVENIENT, EASILY USED TOOL THAT COST-OPTIMIZES PROPOSED SOLAR ENERGY SYSTEMS FOR SPACE HEATING, COOLING, AND/OR DOMESTIC HOT WATER. SOLCOST, A DIGITAL COMPUTER DESIGN TOOL FOR SOLAR ENERGY SYSTEMS, USES TWO NATIONAL COMPUTER TIME-SHARING NETWORKS (CDC's CYBERNET AND GE'S MARK III SERVICE). THIS COMPUTERIZED INFORMATION SERVICE PROVIDES A DEGREE OF STANDARDIZATION FOR THE TECHNOLOGY, LOWERS BARRIERS TO COMMERCIALIZATION, AND PROVIDES SMALL FIRMS WITH A COMPETITIVE POSITION IN RELATION TO LARGE FIRMS.	ORGANIZATIONS: • ACCESS SOLCOST THROUGH CYBERNET AND GE'S COMPUTER NETWORK. CONTACT: INTERNATIONAL BUSINESS SERVICE SOLAR GROUP, 1010 VERMONT AVE., WASHINGTON, D.C. 20005. (202) 628-1450.
		• CALCULATE PAYBACK	DOCUMENTS: • PROGRAM OPPORTUNITY NOTICE DSE 76-2 CLOSING DATE NOVEMBER 9, 1976, ERDA, DIVISION OF SOLAR ENERGY • PLANT ENGINEERING MAGAZINE, TECHNICAL PUBLISHING CO., DUN AND BRADSTREET & CO., 1301 SOUTH GROVE AVE., BARRINGTON, IL. 60010 OCT. 14, 1976, P. 123.
		• CALCULATE $ PER BTU/YEAR	• "CALCULATING THE COST PER MILLION BTU OF DELIVERED ENERGY: A SUGGESTED APPROACH", MAY 1978, R-1859. PRC
		• FUEL ESCALATION RATES	• ANNUAL REPORT TO CONGRESS, ENERGY INFORMATION ADMINISTRATION (DOE) VOL II 1977, (DOE/EIA – 0035/2)

CONCERN		QUESTION	SOLUTION	REFERENCES
2. RISKS				
• AVAILABILITY	2.1	ARE COMPONENTS USED IN SOLAR SYSTEMS READILY AVAILABLE?	2.1.1 STANDARD HVAC COMPONENTS ARE AVAILABLE. 2.1.2 SPECIAL ORDERS FOR MODIFIED COMPONENTS (SUCH AS STORAGE TANKS) REQUIRE AN EXTENDED LEAD TIME.	ORGANIZATIONS: • CONTACT THE NATIONAL SOLAR HEATING AND COOLING INFORMATION CENTER, P. O. BOX 1607, ROCKVILLE, MD. 20850 FOR NAMES AND ADDRESSES OF MANUFACTURERS AND LOCAL DISTRIBUTORS. DOCUMENTS: • BOCA BASIC BUILDING CODE/1975
	2.2	ARE QUALIFIED PERSONNEL AVAILABLE?	2.2 LISTS OF EXPERIENCED SOLAR ARCHITECTS, ENGINEERS, SOLAR DESIGNERS, AND CONTRACTORS ARE AVAILABLE. EXPERIENCE INDICATES THAT ONCE KEY PERSONNEL HAVE COMPLETED TWO OR THREE PROJECTS THAT THEIR ESTIMATES ARE INCREASINGLY VALID.	ORGANIZATIONS: • CONTACT THE NATIONAL SOLAR HEATING AND COOLING INFORMATION CENTER, P. O. BOX 1607, ROCKVILLE, MARYLAND 20850. DOCUMENTS: • UTILIZE THE DEPARTMENT OF ENERGY'S SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM KEY PERSONNEL DIRECTORY.
• RELIABILITY	2.3	WHICH COMPONENTS IN THE SYSTEM HAVE BEEN TESTED FOR RELIABILITY?	2.3.1 COMPONENTS ADAPTED FROM THE CURRENT INVENTORY OF HVAC MATERIALS HAVE BEEN TESTED FOR RELIABILITY. 2.3.2 NEW SOLAR UNIQUE COMPONENTS ARE NOW BEING TESTED FOR PERFORMANCE AND RELIABILITY THROUGH PROGRAMS DIRECTED BY THE NATIONAL BUREAU OF STANDARDS. CURRENTLY THE SOLAR COMPONENTS ARE NOT LISTED IN THE BOCA STANDARDS. EXPERIENCE INDICATES THAT ALTHOUGH PROBLEMS HAVE OCCURRED IN COMPONENT RELIABILITY THAT CAREFUL SELECTION SHOULD AMELIORATE THE PROB PROBLEMS. • COLLECTORS ARE NOW BEING TESTED AT THE SUNSHINE LABORATORY AND THE FLORIDA TEST CENTER. • STORAGE TANKS REQUIRE SPECIAL INSULATION AND COATINGS WHICH ARE STILL IN THE PROCESS OF BEING TESTED.	ORGANIZATIONS/DOCUMENTS: • BOCA • UNDERWRITERS LABORATORIES • AIR CONDITIONING AND REFRIGERATION INSTITUTE • AMERICAN GAS ASSOCIATION • CONTACT THE NATIONAL BUREAU OF STANDARDS (NBS) – NBSIR-77-1305, SEP 1977 – NBSIR-76-1137, AUG 1976 – NBSIR-76-1187, NOV 1976 • CONTACT THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) – NBSIR 76-1143, EARLY 1978 – NBSIR 77-1314, OCT 1977 • CONTACT THE AMERICAN SOCIETY OF TESTING & MATERIALS (ASTM) • CONTACT THE AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS (ASHRAE)

CONCERN		QUESTION		SOLUTION	REFERENCES
				• CONTROL SYSTEMS ADAPTED FROM HVAC. SPECIAL CONTROL SYSTEMS STILL NEED TO BE DEVELOPED AND REFINED FOR USE ON SOLAR SYSTEMS. • PLUMBING, EXPANSION JOINTS HAVE CAUSED SOME PROBLEMS. RESEARCH IS NEEDED IN THE AREA OF COMPONENTS AND PHYSICAL ALIGNMENTS. • LIQUID COOLANTS	ORGANIZATIONS/DOCUMENTS: • CONTACT THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
	2.4	WHAT IS THE EXPECTED SYSTEM LIFE?	2.4	CURRENTLY THERE ARE DATA AVAILABLE REFLECTING THREE TO FOUR YEARS OF EXPERIENCE IN THE SOLAR ENERGY FIELD. THE DEPARTMENT OF ENERGY IS SPONSORING A PROGRAM FOR ACCELERATED LIFE TESTING THROUGH THE NATIONAL BUREAU OF STANDARDS.	DOCUMENTS: • SEE APPENDIX A OF THE SOLAR HEATING AND COOLING DEMONSTRATION PROJECT SUMMARIES DOE/CS-0009 • HUD MINIMUM PROPERTY STANDARDS (MPS) SUPPLEMENT 1977 ED., SOLAR HEATING AND DOMESTIC HOT WATER SYSTEMS, 4930.2, JULY 1977. • HUD INTERIM PERFORMANCE CRITERIA FOR SOLAR HEATING AND COOLING SYSTEMS AND DWELLINGS, NBSIR 75-636, DEC. 1974 • INTERMEDIATE STANDARDS FOR SOLAR HEATING AND COOLING SYSTEMS/HUD INITIATIVE" NBSIR 77-1272 NATIONAL PROGRAM FOR SOLAR HEATING AND COOLING OF BUILDINGS – ANNUAL REPORT, APRIL 1978. DOE/CS-0007
• MAINTENANCE	2.5	WHO IS CAPABLE OF MAINTAINING THE SYSTEM?	2.5	EXPERIENCE INDICATES THAT A COMPLEX COMMERCIAL SYSTEM CANNOT BE ADEQUATELY MAINTAINED BY STANDARD HVAC MAINTENANCE REPRESENTATIVES. IT IS ADVISABLE TO UTILIZE THE SERVICES OF THE CONSTRUCTION COMPANY WHICH BUILT THE SYSTEM SINCE THE EXPERIENCE FACTOR IS AN ASSET. OTHERWISE IT WILL BE NECESSARY TO TRAIN MAINTENANCE PERSONNEL ON THE MAINTENANCE OF YOUR PARTICULAR SYSTEM.	ORGANIZATIONS: • CONTACT THE NATIONAL SOLAR HEATING & COOLING INFORMATION CENTER, P. O. BOX 1607, ROCKVILLE, MD. 20850 FOR THE NAMES AND ADDRESSES OF COMPANIES WHO ARE EXPERIENCED IN SOLAR SYSTEM CONSTRUCTION AND MAINTENANCE. DOCUMENTS: • UTILIZE THE DEPARTMENT OF ENERGY'S SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM KEY PERSONNEL DIRECTORY.

INVITED PAPERS

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Solar Heating System Applied at Rademaker Corporation Louisville, Kentucky

Richard W. Rademaker

GENERAL DESCRIPTION

Application: Heating with air and with liquid (two systems).

Collector Type: Solar Development, Inc., liquid collectors and Solaron Corporation air collectors.

Collector Area: 240 square feet gross area liquid collectors. 195 square feed gross area dry collectors.

Storage Capacity: 560 gallon water in steel tank liquid system. 110 cubic feet river gravel air system.

Owner/Builder: Rademaker Corporation.

PROJECT INFORMATION

Building: Existing office warehouse built in 1969. Structure is steel Butler Building with masonry front.

Climatic Data: Latitude 38°. Total annual degree days, 4660; for January only, 930. Average winter temperature is 42°.

Useful Heat Gain Available from Collectors during Month of January: 16,120 BTU per square foot.

BUILDING AND PROJECT DESCRIPTION

Occupant of building is Rademaker Corporation, Bluegrass Industrial Park, Louisville, Kentucky. Building was constructed in 1969. It is a Butler Building with a total area of 10,000 square feet. The front portion of the building is office space with 1080 square feet of ground cover. The front wall of the office is brick veneer with relatively large glass area. The solar heating system described herein is for space heating and for heating domestic hot water. Two systems are employed, one is a liquid heating system employing ethylene glycol through six collectors of 40 square feet each inclined at 53°, facing south. The second system is an air collector system employing ten panels of 19-1/2 square feet each inclined at 33°, facing south. The liquid system uses a 560 gallon water tank for storage. The air system uses 110 cubic feet of 1" diameter washed river gravel for storage.

The auxiliary energy employed to heat the building is natural gas. The solar heating system is, in fact, a retrofit to the gas heating system which was installed in the building during its original construction.

SEQUENCE OF OPERATION

The liquid system employs a heat exchanger built into the hot water storage tank which allows ethylene glycol to pump through the collectors when solar radiation is available, introducing heat to the stored water. A pump is provided in the stored water loop which will pump water from the storage tank to the hot

water coils of either of two air handlers when heat is demanded in the space. Control valves in each of the hot water coil circuits are operated from thermostats to allow water to flow to either or both of the water coils upon demand of their respective thermostats.

Domestic hot water is heated from the glycol circuit by a heat exchanger. The motor operated valve in the heat exchanger circuit controls the maximum temperature to which the domestic hot water can be heated.

A preheat glycol coil is provided in the perimeter office zone air handler to allow the glycol to be passed through the preheat coil to serve as an economizer within the glycol circuit, allowing the glycol to flow in series from the heat exchanger within the storage tank to the preheat coil, then back to the collector, provided that the storage water temperature has reached a predetermined minimum temperature.

The air collector system employs eight dampers, all of which are motor operated, together with a booster fan to introduce the air to the collectors and/or the rock storage bin to the respective air handling system for distribution to the space.

Return air taken from the space is allowed to flow through the collectors as long as radiant heat is available, then through the booster fan and into the respective zone requiring heat. If no zones demand heat, the dampers position themselves to allow flow from the collector through the rock storage, thus charging the rock storage with heat. When heat is not available at the collectors but is present in the rock storage and is demanded by the space, the booster fan will draw air, counterflow, from the rock storage bin and pass it into the respective zone demanding heat. If excess heat exists and if heat is demanded in the warehouse, heat will be passed from the collectors or from the rock storage bin into the warehouse, provided that no heat is demanded within the office space.

REASONS FOR DESIGN

The system employed on this project makes possible a true comparison of a liquid and an air system of solar heat collection. It is rare that a true comparison can be made of the two systems under exactly the same operating conditions, therefore, the intent of this project was to make two workable systems function side by side. The advantages and disadvantages can be very readily observed.

HOW IS SYSTEM PERFORMING

The system was placed in operation in the fall of 1976 and has gone through the complete winter of 1976-77 and has functioned continuously since then except when it was shut down for a short period for the addition of the monitoring system. First of all, with respect to quantity of heat recovered, there has been no monitoring system in operation long enough to evaluate the output of solar versus the auxiliary heat, however, the observation of the writer (based upon last winter's operation) would indicate that the solar data used for the Louisville, Kentucky, area (which was obtained from the latest information available at the time the proposal was submitted) was not accurate. Accurate data for this

part of the country will only exist after this winter has passed and a solid recording of insolation is published. Generally, the quantity of sunshine available was nowhere near what the books would have indicated. It was anticipated that there would be some heat left over to dump into the warehouse, but results of the operation indicated that this could not be accomplished without severe reduction in the stored heat, making it necessary, therefore, to go to booster heat for morning warmup of the office spaces.

The performance of this sytem has generally been satisfactory from the control point of view. In view of the fact that Rademaker Corporation is in the temperature control business, considerable emphasis was put upon this subject to assure a minimum of "human intervention."

One specific conclusion which can be reached by the comparison of the liquid and air systems is that, upon initial start-up, the air system more immediately supplies the demands for heat in view of the fact that the solar heat can be immediately introduced from the collector to the air handler. The liquid system, on the other hand, has the inertia effect due to the lag of heating the water which, in turn, must heat the air. The result is that the air system tends to provide heat to the space in the mornings and continuously during the day when the sun is shining. The amount of heat stored, therefore, is considerably less than that which is stored in the liquid system. The liquid system then carries the load through the night and provides the warm-up for the next day. In effect, one system supplements the other, each offering a distinct advantage within itself.

PROBLEMS

To say that there were no problems with this system would not be correct, however, they were certainly minimal. The first problem observed was a simple "stuttering" of the differential temperature controls which operated the fan on the air system and the pump on the liquid system. The manufacturer of the control had assured me that this could not happen, sent me replacements, and, upon installation of these, we found that it happened exactly the same as the original controls. We, therefore, installed time delay relays and eliminated the problem.

The second problem which began to show up on the air collector system during the late fall was a deposit of white film between the two layers of glass on the collectors. Condensation also occurred between the glazing. We were assured by Solaron that this would have no material effect upon the performance of the collectors and they were correct. It did not seem to make much difference as the white deposits got worse, however, the appearance of the collectors was bad and the manufacturer then did send us replacement glass. Prior to replacement of the glass, a local prankster apparently shot a rifle at one of our collectors and caused breakage of one collector cover. The replacement of the glass occurred in the spring of 1977.

With respect to the glazings on the liquid system, it was determined that Kalwall had allowed some material to get to the field which was not properly quality controlled, therefore, we were advised by the supplier, Solar Development,

Inc., to replace this Kalwall, which we did also in the spring of 1977. The newer Kalwall product appeared to be much more clear and the results so far this year would indicate that there is a distinct difference in the performance.

With respect to freezing of the liquid collectors, we experienced a very cold winter in early 1977. The quantity of antifreeze in the system had been maintained at 20% instead of 40%, since we had proposed to install a monitoring system in the fall of 1976. We left the 20% solution in and found that it became "mushy" enough when its lower temperature limit was reached to prevent flow through the system. Generally, this would "thaw out" after two or three hours in the morning, however, in one particular instance on a very sunny day, the rate of increase in pressure in the collectors exceeded the rate of thawing in the pipes, thereby preventing flow of liquid from the collector to the relief valve. The collector's pressure must have reached 200 pounds since the relief then occurred through the gasket of one of the motorized valves within the system. We learned from this that a 40% solution of glycol is the minimum which should be proposed. It might be pointed out at this time that we attempted something since we had our system opened for a few days, in that we tried to work a drain down concept in the cold weather. We decided to determine if the systems would freeze, we at least would find it out on our own installation. One thing we concluded as positively predictable. They will freeze even when we drain them down. It's not a matter of "if," it's a matter of "when," and it usually occurs at the bends of the collector. Repairs were made to the collectors with some short period of shut down during the late winter.

Another point which might be of importance relative to quantity of liquid flow in the collectors is that during summer operation, the tank temperature seemed to level off at 160°. This was the point at which the losses equaled the input and we could not raise the temperature unless we reduced the flow through the collector system. We did install a proportioning valve in parallel with the balancing valve in the discharge of the pump on the glycol loop. A proportioning differential controller reduces the volume of flow as required to maintain continuous input to the tank.

Another problem which we realized existed after observing the system in operation was that the quantity of heat exchange surfaces within the tank had not originally been calculated properly. The writer had assumed better heat transfer on the water side than actually occurred. A second loop of copper in parallel with the first was installed within the tank and each of the two were vented at the high point inside the tank to assure no air lock problems. The increased surface did improve performance. In retrospect, however, it would have been better to have had one single series loop instead of two parallel loops but it was far more feasible to install the second parallel loop when the change was made. It does perform satisfactorily as it is now.

HOW IS INDUSTRY STIMULATED

Our building is located in the Bluegrass Industrial Park. It is rather obvious to passers-by that our building is solar heated. When the system was first completed, we had people dropping by all during our working day and, in fact, on Saturdays and even Sundays when a car happened to be parked in our driveway. We

finally had to put a sign up outside that indicated we could show our solar heating system only if a person choosing to look at it were in the company of his heating contractor or his consulting engineer. It got to be a serious time consumer. Even this did not work well, so we put a second sign on our door so a person had to look at it prior to entering, "Solar Heating System Shown by Appointment Only." We still, to this day, have considerable interruption of our normal business by people wishing to see the system. We have worked out a very worthwhile situation where we suggest the contractor for them to call, who in turn will make an appointment with us. If they are really serious about solar heating, we then end up showing the system to them. It is not our intention nor, in my opinion, is it the intent of this program for the demonstration project to be an educator of the public on a <u>one by one</u> basis.

We have had considerable coverage on TV and in the newspapers and the writer has been invited to speak on various occasions to both technical and non-technical groups in the local area.

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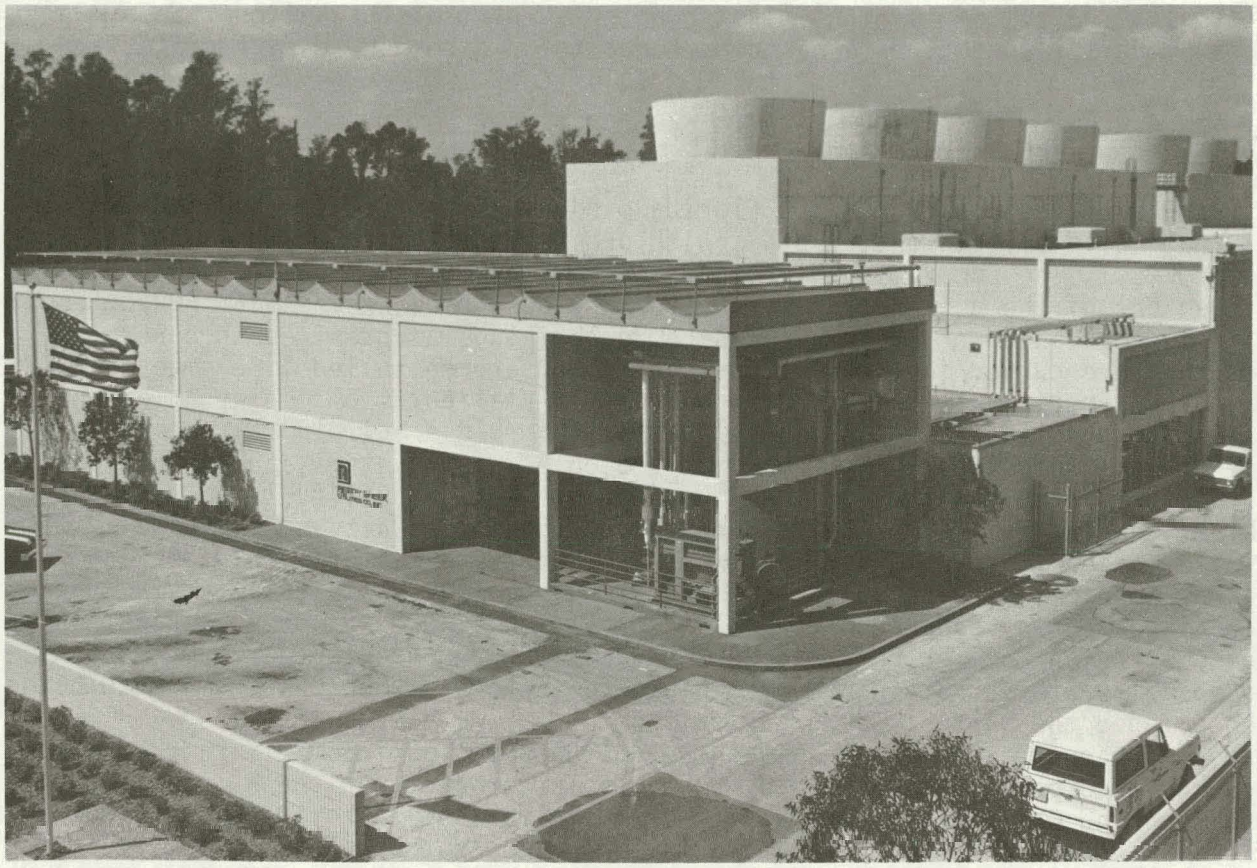
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Solar Office Building
Reedy Creek Utilities Co., Inc.
WALT DISNEY WORLD

Harvey C. Jones



The Solar Powered Office Building at WALT DISNEY WORLD

INTRODUCTION

In November 1977, the utility company servicing WALT DISNEY WORLD put into operation a new two-story office building, specifically designed for a unique solar energy system designed by the AAI Corporation of Baltimore, Maryland. Building design was by WED Enterprises of Glendale, California, the Walt Disney design organization. Solar energy powers air conditioning, space heating and potable hot water supply. The solar collectors are the roof of the building. They are horizontal parabolic mirrored troughs which focus on tracking absorbers, moving in one dimension, and filled with water. There is dual storage, 10,000 gallons of hot water and 10,000 gallons of chilled water. The chiller is a commercially available 25-ton lithium bromide absorption unit and utilizes an existing cooling tower system as the heat sink. The building has 5,625 square feet of air conditioned space and the collector area of the roof is 3,840 square feet. There is no redundant nor auxiliary energy system for space heating nor ot water. There is a connection to the utility company's chilled water distribution system as the alternate cooling mode. The building was built with the support of the Department of Energy of the United States as one of those selected

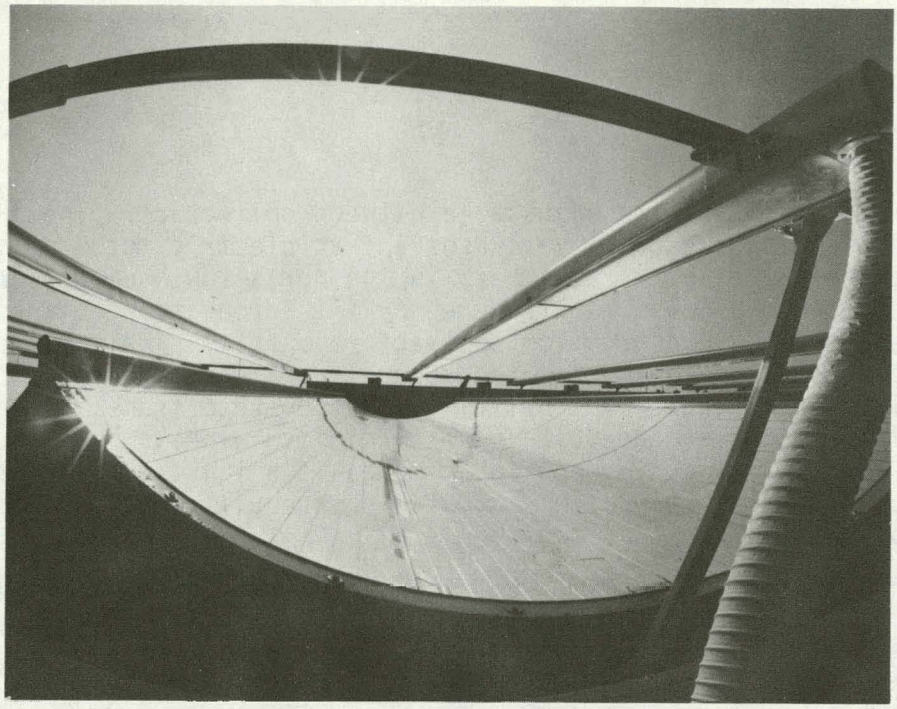
in the November 1975 PON submissions for space heating and cooling of commercial buildings. The system is highly instrumented as part of the National Solar Data Program. Performance to date has been equal to or exceeded, design criteria.

EVOLUTION

Walt Disney conceived of his Florida project as a place to show and operate in a real world environment, systems with promise for the future. He called his concept EPCOT, The Experimental Prototype Community of Tomorrow. This philosophy has been one of the dominant criteria for the design of WALT DISNEY WORLD resulting in much advanced or prototype design, such things as prestressed concrete beams that are curved in three dimensions, computer controlled life-size characters for entertainment, vacuum garbage systems, utilidors, a co-generation energy plant, assembly line fabricated hotel rooms, fiberglass building facades, epoxy block building construction, linear motor people-mover systems, and a multitude of others. As the realization that the expiration of fossil fuels posed a major problem, the Walt Disney organization started looking at alternate energy systems. One with which it had no experience was solar energy. The original thinking in 1974 was to utilize plate collectors and discussions were started with manufacturers involved in advanced plate collectors. Tests were run on the existing large absorption chiller units at WALT DISNEY WORLD to examine performance at the reduced temperatures obtainable with plate collectors. When ERDA came into being, it encouraged the Walt Disney organization to work with organizations with more advanced concepts. One of these was the AAI Corporation in Baltimore, Maryland which had accomplished the Timonium School solar project for the National Science Foundation and was doing experimental work with various forms of focusing collectors. The AAI Corporation produced a follow-on concept of a solar facility using parabolic reflecting surfaces with a movable collector. A modification of this concept was the one adopted. The purpose was to gain experience in solar energy, to further the state of the art, to demonstrate feasibility before constructing large solar energy systems in the middle of public operations.

CONCEPT

AAI Corporation proposed that the roof be shaped in parabolic troughs to focus solar energy on collectors, or conversely that the normal roof be omitted from a building and that the collector panels serve as the weatherproofing. This would cut the cost of the actual building construction and make solar energy more economical. Florida, as the most southern of the mainland states, uses four percent of its energy for space heating, 18 percent for air conditioning, the reverse of the average in the United States. The collectors as the roof, are most efficient when the sun is directly overhead which is when air conditioning demand is the greatest. With modification, parabolics could be angled or pitched on the roof of the building at other latitudes to optimize the collector angles. The system was designed to be of modular components that could be mass produced. The solar system roof was integrated into the architecture of the building. The system was optimized for a weekly cycle, that is, collect solar energy seven days a week and normally use the office spaces on a five-day schedule. No redundant heating or hot water were to be provided, only



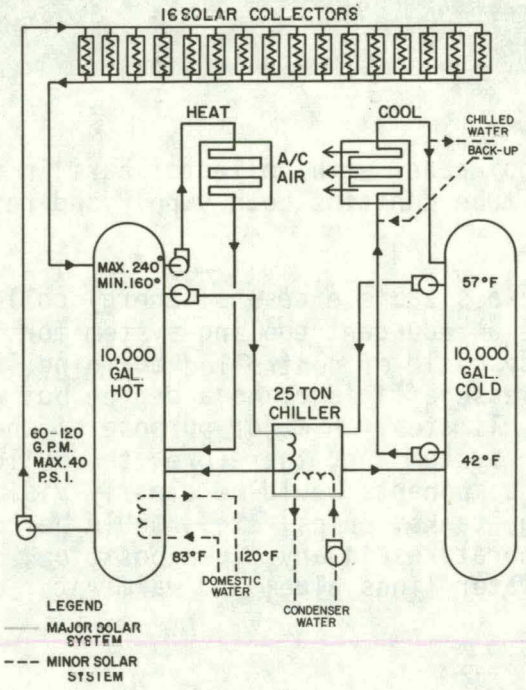
A mirrored roof panel with collector bars in focus.
The flexible tube contains both supply and return lines.

solar, since there would be a sizable excess of energy collected during the heating season. There would be a redundant cooling system for long periods of cloud cover. An energy efficiency cycle of controlled building louvers is incorporated in the design and does increase efficiency to a degree but would be even more effective in more northern climates. A major purpose of the building was to showcase or demonstrate a solar system and, therefore, the building was specifically designed so that all major components would be clearly visible and that the mechanical features, piping, tanks, pumps, etc., would be color-coded to facilitate understanding the temperatures in any given position, e.g.: the hot water storage tank is red; cold water lines blue; and warm water, pink.

CONSTRUCTION

AAI Corporation designed and manufactured the solar components in Cockeysville, Maryland. The AAI parabolic roof panels are eight feet on the arch, seven and one-half feet on the cord, 32 feet long. They are a sandwich of aluminum, poly isocyanurate foam, aluminum, mastic, and mirror. They are shipped with lifting eyes. They include stiffeners on which can be hung lighting, air ducts or sprinklers. They are oriented in an east-west line. The saddles which support the parabolic panels fit on top of the building wall, serve as the interface, provide appropriate structural tie, transmit lateral loads and provide joint sealing. Saddles were shipped in 30-foot lengths. The collector bar or receiver is made of a 36-foot long aluminum extrusion which serves as the structural backbone and weather cover. Inside is a grooved or mechanically selective aluminum plate which is the collector plate and is painted with black epoxy paint. Copper tubes are swaged to the collector plate, with a water white tempered low iron glass covering the plate. The 16 collector bars are each supported at their ends by rocker arms, and are connected horizontally by tie bars or struts forming

a parallelogram. Tie bars are adjustable between collectors. The entire system is kept in focus by an electric eye sensor and an electric motor driving a screw-jack activator which moves the absorbers in the north-south direction. The electronic control panel was also manufactured by AAI Corporation. Tanks and piping insulation were done by construction contractors on-site. Walt Disney used its own Buena Vista Construction Co. as the general contractor and subcontracted the more critical parts of work. The building is a concrete frame, concrete block wall, heavily insulated office building with minimum windows. This design,plus the fact the roof is reflecting sunlight, makes it a low energy consumer. Construction proceeded with no problem in matching prebuilt solar panels and saddles to the building.



Solar Energy System Schematic

OPERATION and MAINTENANCE

The office building is an addition to an existing central energy plant of fairly sophisticated systems. The personnel who maintain the solar facility also maintain the jet engine co-generation system, chiller plant, high temperature hot water distribution system, high voltage electrical generation system, instrumentation and computer systems serving WALT DISNEY WORLD. They were already in the prototype business which makes maintenance of the facility relatively easy. Tuning and learning how to operate has been an interesting process and only now is coming to a satisfactory point. The longest learning experience has been the operation of the absorption chiller to minimize cycling losses, to de-bug the related condensor water system, and to realize the .6 design coefficient of

performance of the chiller. Modification of the sun position sensor was necessary because of moisture and overheat problems.

The system has five operating modes and one central control system.

- The first mode is the collection process thru hot water storage. The collector focusing does not commence until there is sufficient light intensity on the photo electric cells to make the expenditure of energy in moving the collector worthwhile. When that occurs, the collector bars are brought into focus over the parabolic trough mirrors. When the absorber plates in the collector bar reach a temperature 20°F. higher than the temperature of the water at the bottom of the hot water storage tank, the circulating pump is activated. This loop is from hot water storage to collector and return.

- The second mode is space heating. When the building temperature falls below the setting of the thermostat, a pump is activated to move hot water from the top of the storage tank into the air handler and return. There is no other system to heat the building.

- The third mode is for potable hot water. When a hot water tap is opened, domestic water flows thru a heat exchanger in the side of the solar hot water storage tank to a wash basin. There is no other hot water heating system.

- The fourth mode is the production of chilled water. When the water at the bottom of the chilled water storage tank is above 45°F. and when the water at the top of the hot water tank is above 180°F., hot water is circulated thru the absorption chiller and condensor water from the cooling tower is cycled thru the chiller. Water from the cold water storage tank is then cycled from the cold tank thru the chiller and return. The chiller remains in operation until the bottom of the cold tank reaches 45°F. or until the hot water tank goes below 165°F., whichever occurs first.

- The fifth mode is space cooling. This again is activated when the room temperature in the building gets warmer than the thermostat's setting, at which time chilled water is pumped from the bottom of the storage cold water tank to the air handler and return. When the bottom of the cold water storage tank exceeds 57°F. and building temperature exceeds 80°F., the water produced from solar energy is stopped. The valve to permit auxiliary cooling by the flow of chilled water from the Central Energy Plant thru the air handler is then opened.

PERFORMANCE

The first month of data collection was March 1978 and resulted in many adjustments in the data collection as well as the mechanical part of the solar system itself. The first month of reasonable data is for April 1978. Those results:

- Collector and hot water storage mode (167°F. to 226°F. actual):

Insolation, total incident	232MBTU
Collected energy	68MBTU
Efficiency total	29%
Efficiency during collector operation	37%
Electrical operating energy	1.8MBTU
Storage losses from the tank	12.3MBTU
Hot storage efficiency	82%

Note: The 12.3MBTU storage loss includes the energy used to heat the potable hot water for the building.

- Potable hot water mode:

Consumption is so small that installed meters were not accurate. Estimated demand was .4MBTU for the month which was included as a hot water storage loss.

- Space heating mode:

With minor exception, the building was heated throughout a below normal temperature winter while equipment was being adjusted.

No heating demand was recorded after data collection was inaugurated.

No problem with 100% solar heating foreseen.

- Chilled water production mode:

Solar energy consumed	53MBTU
Chilled water produced	8MBTU

To cooling tower	38MBTU
To atmosphere	12MBTU
Overall indicated COP	.15

Note: Because of sensor problems in the data collection system, these figures are highly suspect. Control temperatures of supply hot water and produced chilled water have been changed to reduce cycling of chiller. Also, a condenser water supply problem has been corrected. Latest COP's measured in field range from .4 to .7.

- Space cooling mode:

Solar energy consumed	53MBTU
Total heat removed	7.6MBTU
Solar energy chilling	5.4MBTU
Auxiliary chilling	2.2MBTU
Cold storage efficiency	93.4 %

To date the National Solar Data System has been very beneficial to adjusting our facility mechanically and operationally. Although accuracy of initial data above is suspect in several instances, we are confident the present program of correcting deficiencies will produce a very accurate measuring of performance.

COSTS

Total project	$1,000,000
Solar energy system	650,000
DOE funding to RCUC	396,000

The project as a prototype had the usual first-of-a-kind cost control problems. Panels which lend themselves to production line techniques, were hand built. In addition, design was pointed at high quality, long life components and showcasing of all solar components for public visibility. Proposals for major cost reduction are described below.

RECOMMENDATIONS for CONCEPT DEVELOPMENT:

Experience to date indicates that this concept has promise of acceptable performance. Costs to date are not acceptable. Walt Disney organizations and AAI

Corporation separate and joint review indicate sizable savings possible, as follows:

- Use building industry technology in solar system fabrications, e.g.:
  - Replace aluminum foam panels with precast, prestressed lightweight concrete.
  - Use tilt up wall construction with saddles precast, or incorporate saddles in precast panel.
  - Cast units in local precast plants with mirrors added either as sagged glass sheets or pre-positioned strips placed much as tile work in residential construction.
- Develop foam-in-place for receiver insulation and simplify cover glass assembly. Possibly redesign receiver drive from rocker arm to an overhead track with roller supports, or use sleeve bearings in lieu of roller bearings or rocker arms.
- In building design:
  - Use solar panels as diaphram for lateral loads.
  - Add windows on low solar sides to reduce lighting demand.
  - Install insulation and vapor barrier on exterior of building.
- In mechanical design:
  - Place solar and HVAC in center of building.
  - Eliminate showcasing features, e.g., place storage in most economical position.
- Use micro processor controller now available in lieu of conventional electronics.

System technical improvements for increased efficiency:

- Utilize low temperature Rankine driven chiller to improve COP. With storage available in this project, a three-ton chiller would satisfy the 15-ton maximum demand.
- Add a cycle to utilize night low temperatures to charge chilled storage. This is a small modification of existing air handler and appropriate control logic for chilled water loop.

CONCLUSIONS:

This solar prototype will meet its design criteria of 100% heating and hot water and over 80% chilling. The concept is worth pursuing in order to eventually obtain cost effectiveness.

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Installation Experience on a Modernized Fifteen Ton Solar Air Conditioning, Space Heating and Domestic Hot Water System Using Reflector Augmented Flat Plate Collectors

William T. Hudson

INTRODUCTION

The North Georgia Planning and Development Commission's solar system was completed in May, 1978. The installation of this fifteen ton solar space cooling, heating and domestic hot water system took seven weeks from delivery of equipment to operational status. Final acceptance of the system was made two weeks later by Department of Energy and Customer Project Managers.

Premanufacturing a modularized solar system made possible this short installation schedule. The addition of system controls which allowed the installer to override the automatic solar and conventional system controls made it possible to "bring up" the system in less than a week and to complete the acceptance test in two days.

CRITERIA FOR ESTABLISHING SOLAR SYSTEM MODULES

As is the case for most on site installation operations, the fewer number of pieces to be handled at the site, the faster the installation and the smaller the installation cost and the exposure to non-controllable cost is minimized. To this end, ILI fabricates large sub-system modules which are transported to the site for attachment to the building and subsequently are interconnected. The North Georgia project is an example of this modularized/premanufactured system and the time savings which can be effected when the concept is implemented on a new construction project. (The elapse time required to install the solar system in retrofit project is less since there are few scheduling requirements imposed by organizations not under the solar contractor's control.)

The large sub-system modules for the North Georgia project were: 1) Fifteen (15), 150 sq. ft., collector modules with upper and lower headers mounted in structural support frames ready for attachment to the building roof. 2) Fifteen (15) large scale, 200 sq. ft., reflector modules assembled into structural support frames made ready for attaching to the building and the collector modules. 3) Solar control unit containing all pumps, automatic valves, check and hand valves, circuit setters and other hydronic components which were pre-connected and tested as well as the electronic control system containing all of the temperature, pumping, and other controls for the solar system as well as the controls for the conventional HVAC system.

In addition to pre-manufacturing the system, all items of equipment were staged at the ILI facility in Norcross, Georgia to ensure availability of the equipment once we reached the Dalton job site which is 100 miles from the ILI plant. This technique is used on most of our solar projects but is considered essential where the project is too far from the base facility to permit the installers to return home each evening.

The sequence of operations required to install the North Georgia system or any solar system is:

1. Move the equipment to the job site.
2. Place and attach the equipment to the facility permanently.
3. Interconnect the equipment.
4. Bring the system up and make it operational.
5. Demonstrate system operation and performance by conducting a formal pre-defined test with appropriate accept/reject criterion.

SYSTEM INSTALLATION

The equipment was delivered to the North Georgia site on two 40 foot and two 20 foot flat bed trailers. This included all collectors, reflectors, the control system, condenser unit, two thermal storage tanks, interconnect piping fitting, insulation, paint for the insulation, nuts, bolts, screws, and all other miscellaneous items of hardware and equipment including spare parts. The equipment was in a large sense "prepackaged" and delivered under a single bill of material, i.e.; one complete 15 ton solar air conditioning system.

Some of the collectors and reflectors are shown in Figure 1 as they arrived at the site. Subsequent placement and attachment of the collector system and other equipment took 1-1/2 days and is depicted in Figures 2 through 10. Figure 2 shows a large scale collector module being lifted from the flat bed and transported to the building roof, Figure 3 where it is lowered into position, Figure 4 and 5. The attachment of the collector to the reflector structural frame, Figure 6, forms two legs of a triangular superstructure which is designed for a 100 mile per hour wind load. The roof forms the third leg of this triangle. This actual attachment to the roof is made to curbs which are anchored to the roof bar joist. A curb and some of the saddle type attachment feet are visible in Figure 5 and 6. The intersection of the two structural members are welded to prevent any movement between the two superstructures (concern exists over the use of bolts in this application since the wind loading would apply a force perpendicular to the bolt axis. Since the integrity of the connection depends on the nut and bolt maintaining absolute tightness, a welded connection is preferred.) The completed collector array is shown in Figures 8 and 9 along with the 3,000 gallon hot water storage tank (right side of Figure 9); the 6,000 gallon chilled water storage tank (left side of Figure 9); and the condenser unit (Figures 8 and 9). The solar control unit is shown in Figure 10 as it was being moved into the mechanical equipment room. This entire operation of installing the collectors, reflectors, chiller, control unit, thermal storage tank, buffer tank, condenser boiler (for backup heat) and the domestic hot water tank took exactly 1-1/2 days to complete. The installation crew consisted of eight installers, a crane operator and his assistant and crane.

The subsequent interconnecting operation is the most difficult and time consuming of all operations. This operation was spread over a period of six weeks. Part of this time was required to permit other subcontractors time to provide utilities for the solar system, i.e.; electric power, water, duct work, air handler. After the required hookups were made, approximately one week was required to complete the system shakedown and make it operational. The only problem encountered in the interconnecting of the system was in leaks.

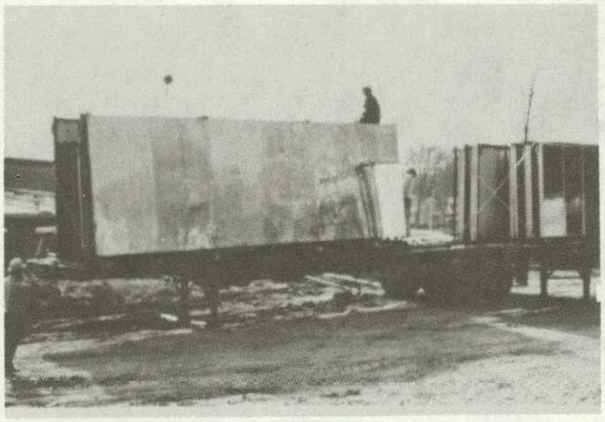


Figure 1.
Transport of Large Collector Modules

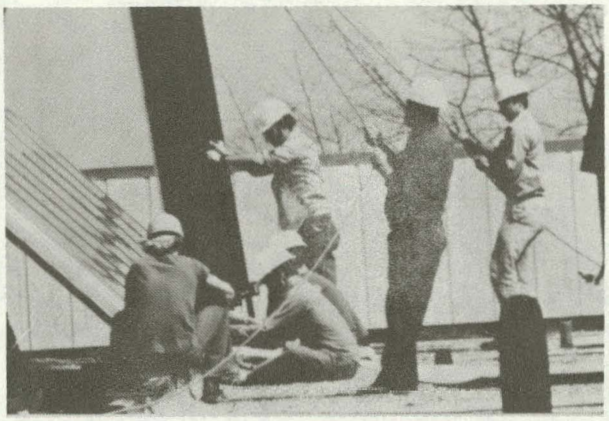


Figure 4.
Reflector Being Positioned on Curb



Figure 2.
Spreader Bar Used for Crane Operation

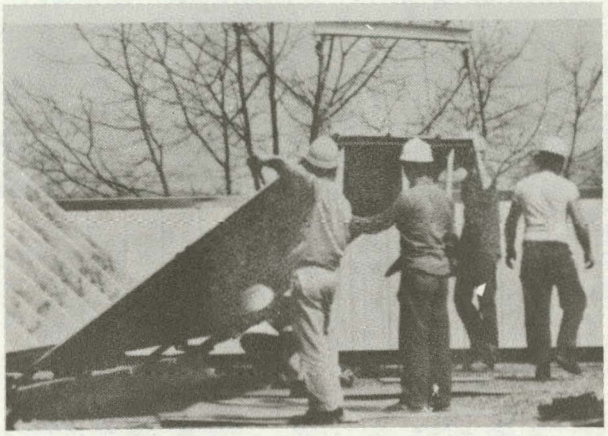


Figure 5.
Reflector Angle Positioning

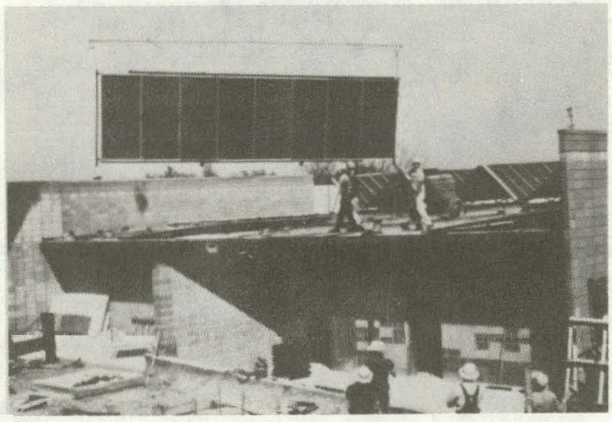


Figure 3.
Collector Being Lowered to Roof



Figure 6.
Collector Being Positioned for
Attachment to the Reflector

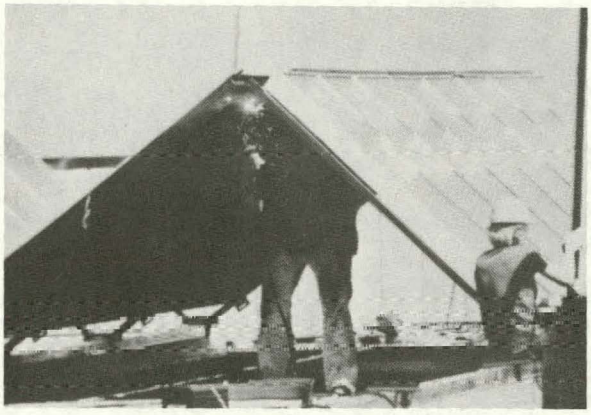


Figure 7.
Welding the Collector & Reflector Frames Together

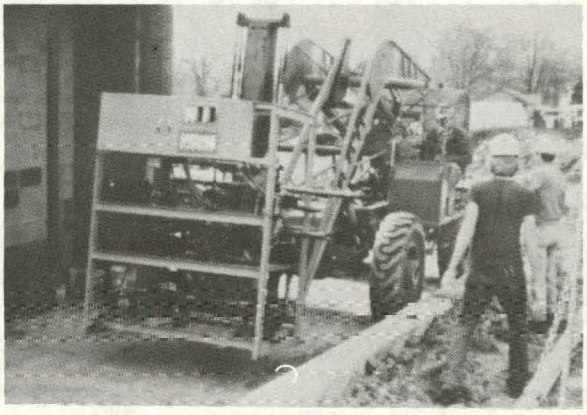


Figure 10.
Solar Control Unit



Figure 8.
Completed Collector/Reflector Array

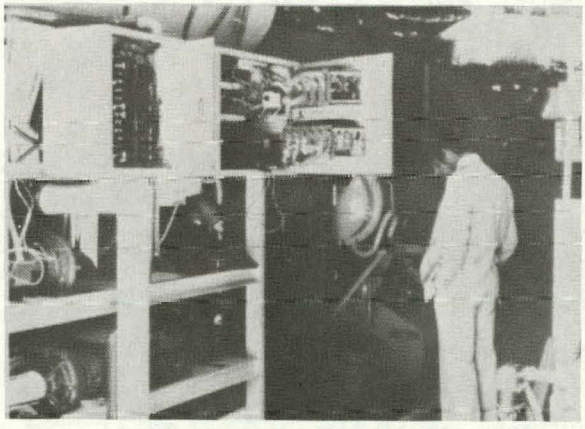


Figure 11.
Solar Control Unit Electronic Control



Figure 9.
Solar Thermal Tank and Condenser

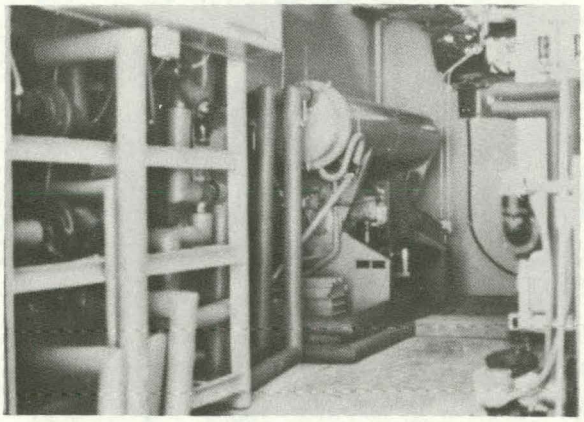


Figure 12.
Mechanical Equipment Room

Due to the large number of joints, a certain number of leaks are to be expected. To prevent these leaks from resulting in costly repair operations, air leak tests are performed before the system is filled with water.

Figure 11 shows the solar control unit electronic cabinet and some of the hydronic section as it appeared during systems acceptance test nine weeks after the equipment arrived on site. Figure 12 shows the hydronic section of the control unit, the 25 ton Arkla chiller, the air handler, and part of the boiler and domestic hot water unit (right side).

Problems which have been encountered since the ATP are: 1) A leaking pump shaft gasket and 2) a defective motor winding. There was no apparent cause for the failure and are considered at this time to be normal infant mortality problems. Both failures are warranty items.

SYSTEM PERFORMANCE

In terms of performance, the system out performs the design expectations. During ATP, the air conditioning unit delivered 17 tons peak against a design peak of 15.2 tons. The collector temperature rise of $12^{o}F$ is 20% higher than design calculations. The collector operating temperature for the conditions being experienced was $189^{o}F$, $4^{o}F$ above the design expectations. The solar system power consumption was 6.6% lower than design calculations which suggests that the head resistance of the interconnecting system is lower than expected.

CONCLUSIONS

The emphasis placed on pre-assembly of large modular units for this system was instrumental in ILI's finishing the project on schedule and within budget. Its applicability to other solar projects has been well established by ILI in system installations in various parts of the southeast and in the Mid East where recently a 3 ton solar air conditioning system was installed in 36 hours from the time the "prepackaged" solar system was delivered to the site.

ACKNOWLEDGEMENTS

Special thanks is given to Mr. Douglas Westrope of Marshall Space Flight Center in Huntsville, Alabama who provided assistance throughout the project as DOE's technical monitor and to Mr. Don Koleburg, ADPC's Solar Project Manager, for his support and cooperation in making the project successful.

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Operating Experience: The Trinity University Solar Heating and Cooling Project

Gene Clark and C.H. Treat

INTRODUCTION: BACKGROUND FOR SOLAR PROJECT

Trinity University (San Antonio, Texas) received $1.1 million dollars in Federal funds from the 1975-76 Commercial Solar Energy Demonstration Program. The University contributed an additional $0.5 million. These monies have resulted in one of the largest solar heating and cooling projects in the world.

The Trinity project is a retrofit of an existing central plant which provides space heating, space cooling and domestic hot water for the campus athletic center and 5 dormitories housing about 500 students.

This central plant serves nearly 300,000 square feet of floor area and with the exception of fans and pumps, was previously powered entirely by natural gas.

In a typical year, this central plant required 63 billion Btu per year of natural gas energy. Between 1972 and 1975 the cost of this natural gas rose 600 percent to $120,000 per year. The threat of continuing cost increases and eventual gas shortages provided the motivation for Trinity to seek a solar retrofit.

In the following we discuss some of the lessons learned during construction and operation of the project since its completion in April, 1977. In order to place the following discussion of problems in the proper context, we note that Trinity does consider the project a sound investment of University funds. In fact, Trinity has extended its commitments to the application of solar energy beyond the demonstration project. In addition to beginning 2 major research programs in solar energy, the University has created a graduate program in Applied Solar Energy which in only 2 years has become one of the largest graduate programs in the University. These solar energy students are able to utilize the demonstration project as a unique laboratory.

System Design

This solar energy system was designed by Frank Bridgers (Bridgers and Paxton, Albuquerque) and utilizes 16,080 square feet (lens area) of Northrup tracking, concentrating collectors and 40,000 gallons of hot water storage in 2 buried steel tanks. Solar powered cooling is provided by a 350 ton Carrier lithium bromide absorption chiller which was already in the central plant. Non solar cooling is now provided by a 630 ton electric centrifugal chiller installed as part of this project.

INSTALLATION AND START UP PROBLEMS

Of the many problems to be expected in any complex construction project, 2 problems were particular to a solar energy system. The solutions involve simple system design changes.

1. The collectors are arranged in banks of 16. Each bank has its own independent tracking system and for maintenance the bank can be isolated by valves from the rest of the system. At start-up one bank was isolated, but the tracking system was not disabled. Late in the afternoon sufficient pressure built up to rupture one absorber in a spec-

tacular explosion. Fortunately, no one was injured but the event illustrated the need for fail-safe, over-pressure prevention, which will protect against pump failure, human error, or vandalism.

A simple solution is to include a frangible disc in any isolable part of the system. The tracking system can easily be designed to track away from the sun when pressure limits are exceeded.

2. At start-up, much entrained air was present in the collector loop and always returned after repeated attempts to bleed the system. The air was apparently disrupting normal flow through the collectors and decreasing collected energy.

   We believe that this problem has been solved by the addition of an automatic air bleed valve on each bank of collectors. However, our experience indicates that standard float valve air eliminators are not satisfactory. Each evening as the solar heated water cools and contracts, the float can remain open to the atmosphere.

SYSTEM OPERATION

Detailed evaluation of system performance is not yet possible because the government provided instrumentation and data acquisition system (government contracted to IBM) has not yet provided dependable results. This is due in part to the fact that 94 sensors are involved. Much redesign, re-installation and re-calibration of the instrumentation has taken place during the more than 18 months since the instruments were installed. Progress has been made and we are hopeful that we will soon receive the first report on the performance of our system. Our present evaluation of the system performance is based only on spot checks with our rudimentary instruments - typically mercury bulb thermometers and pitot tube flow meters.

One measure of system performance could be the utility savings. Only the gas consumption in the central plant was separately monitored by the University. Comparing natural gas consumption and costs during comparable periods before and after installation of the system:

April - December, 1976 35.0×10^6 cub. ft. $69,203

April - December, 1977 3.6×10^6 cub. ft. $ 9,214

The portion of the $60,000 savings which was due to the solar energy system will not be clear until reliable data is received from IBM. Much of the savings is due to the switch to more efficient electric air conditioning which was made as part of this project. Data on electric energy consumption is not yet available. Additionally, the University instituted strong energy conservation measures in 1977.

The computer simulation estimates of the effects of collected solar energy in this project are listed in Table 1.

Table 1. Typical Year Energy Distribution at Central Plant.

Energy Required +	Estimated Solar Fraction of Energy Used in Central Plant
Space Cooling: 58.5×10^9 Btu/year *	.05
Space Heating: 0.8×10^9 Btu/year	.66
Domestic Hot Water: 2.4×10^9 Btu/year	.66

+ If supplied by solar energy. If supplied by gas the requirements will be about 40% greater due to gas boiler inefficiency.

* If space cooling is provided by the absorption chiller with C.O.P. = 0.6.

We are certain that the space heating and domestic hot water furnished by solar energy are at least as large as these estimates. In fact the natural gas boiler was not used at all between June and October of 1977.

We did successfully operate the absorption chiller from solar energy during the summer of 1977. This Carrier chiller is a 25 year old design and was rated 350 tons at 280°F. We have operated the machine at inlet generator temperatures between 180 and 210°F and estimate that it is providing as much as 200 tons of cooling.

The typical strategy of chiller operation was to increase the storage tank temperature to about 220°F during a clear weekend of low load. On a clear summer day the collected and stored energy would maintain chiller operation for as long as 5 hours.

We have not been able to operate the chiller since late Fall, 1977. Initially, this was due to the influx of cloudy weather. However, since Spring the difficulty has been the increasing number of disabled collectors. (This problem is discussed in the following section.)

Our operational strategy has been to provide solar energy for cooling only when there is more than sufficient solar energy to meet the domestic hot water and space heating loads. This strategy is due in part to the fact that the solar energy can be collected more efficiently at 140°F or less required for heating than at 180°F or more required for cooling. Furthermore, the chiller utilizes the solar energy with a C.O.P. of only about 0.6 and thus solar energy is not used as efficiently for this purpose as for heating.

The great majority of the cooling is provided by the electric centrifugal chiller; this device operates with a C.O.P. in excess of 3.5 and at current local utility rates will provide cooling at about half of the cost of natural gas powered absorption cooling. Data on electric chiller power consumption has not yet been received.

Evaluation of other details of system performance must await receipt of accurate performance data. On the basis of our rudimentary measurements we are especially concerned about:

1. Energy rejected by the collectors when operating at high temperatures under partly cloudy conditions.

2. Energy rejected by the collectors when warm water is pumped from storage in order to prevent freezing of the collectors.

These energy losses can be minimized by very careful choice of flow controlling temperature sensors and equally careful choice of sensor placements.

MAINTENANCE AND DURABILITY PROBLEMS

The basic structure of the solar system has been quite durable. We have experienced 2 hailstorms and winds up to 55 mph without damage. In fact, the only collector damage sustained was the loss of 3 collector lenses to baseballs from the adjoining field.

However, there have been difficulties with the durability of the drive mechanisms for the collector tracking systems and with the rotating seals which attach the collectors to the stationary headers. As a result an average of 15% of the collector array has been immobilized and this problem is increasing with time. At present, more than 50% of the collectors are disabled by leaking seals.

The leaks result from the fact that each of the 1608 collectors has two O-ring sealed rotating joints between the rotating collectors and the stationery headers. Since the collectors are mounted in banks of 16, a single leak from any of the 32 rotating seals in a bank causes the entire bank to be shut down. Corrosion and side stresses in these rotating seals have led to a number of leaks. In addition, we have experienced motor mounts being torn loose and motors seizing. The table below lists the components which were replaced during the first 13 months of operation.

Collector Components Replaced
April, 1977 through May, 1978

Drive Motors	113	of	104	(Some were replaced twice.)
Control Boxes	64	of	104	
Rotating Seals	300	of	3216	
Circuit Boards	51	of	104	
Photo Cells	11	of	104	

In fairness to the collector manufacturer, it must be stated that Northrup, Inc., has been working quite closely with us and supporting us with modifications as they have been developed. For example, in order to defeat the leaking seal problem we are currently in the process of installing the fourth type of rotating seal, one attached to a flexible hose. While Northrup is donating the hardware, Trinity is supplying the labor, the cost of which is not insignificant. We estimate, for instance, that it will take four labor-months to get all 3216 of the new hose-seals in place.

SUMMARY

The Trinity University Solar Project is unusual in utilizing a large area of concentrating collectors to provide space heating and cooling and domestic hot water to six large buildings from a central plant.

The first year of operation has been encouraging, but because we still have no performance data many of the conclusions are tentative.

The solar energy system has in general been quite dependable and durable. However, chronic maintenance problems have been experienced with the collector tracking drive system and with the rotating seals which join the rotating collector to a stationary header.

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Combined Active and Passive Solar Heating System For Two Commercial Buildings in Santa Clara,Ca.

by Harry T. Whitehouse and Michael A. Kast

INTRODUCTION

Twin 50,000 square foot industrial buildings, incorporating both active and passive solar design elements, are nearing completion in the Oakmead Industrial Park, Santa Clara, California. The single story buildings, pictured in Figure 1, feature slab floor construction and "tilt-up" concrete walls. A structural facia on the north extreme of each building provides a 45o support for approximately 2900 square feet of high-performance flat plate collectors. These liquid-based collectors form the basis for an active solar subsystem which includes a unique control logic to manage energy in a "Second Law sense". The south-facing, vertical "tilt-up" concrete wall has been modified to accommodate some 1200 square feet of air-based collector fashioned after a Trombe design. The tilt-up wall fabrication technique is commonly used in commercial and industrial building construction, and shows promise for ready adaptation to solar heating applications.

The combined active and passive subsystems are expected to provide approximately 90% of the annual energy requirements for heating and hot water. With the addition of absorption cooling equipment to the active subsystem, a significant portion of the annual cooling requirements will also be satisfied.

The climatology of the locale- situated thirty five miles southeast of San Francisco- is characterized by mild winters and temperate summers. Some 2600 heating degree-days accrue annually and winter design temperatures are in the vicinity of 34oF. Only 350 cooling degree-days accumulate during the summer months, although this figure is a poor measure of cooling requirements in a non-residential environment due to the impact of internal loads.

BUILDING ENVELOPE

The buildings have been developed by Renault and Handley Industrial Real Estate for long-term lease to firms in the semiconductor industry. The speculative nature of the project required that the buildings satisfy guidelines which would prove attractive to a broad sector of the industry. Nearly square, the buildings feature expansive work areas and provide the necessary security for the development of proprietary electronic components. The northern sections of each building are dedicated to office and conference space while southern portions typically house fabrication and warehousing operations.

The basic architecture- developed by Habitec Architecture and Planning- incorporates a number of inherent energy saving features. Window areas are modest in size and double glazed. Landscaped berms and a stringent insulation program serve to reduce winter heating loads. The roof and all exterior surfaces are light in color to reflect the summer sun and hence reduce cooling loads. East and west fenestrations feature coated glass for solar control. Positive ventilation has been provided for the attic plenum so that lighting and equipment loads can be partially dissipated during the summer months. Finally, the southwall collector system features a six foot overhang to reduce solar loads on that wall during the summer months.

BUILDING ENERGETICS

Inasmuch as these buildings were developed speculatively for lease , the solar design efforts were complicated by poor definition of the building use patterns. A key variable in heat load



Figure 1. Renault and Handley Solar Buildings
Santa Clara, California

determination (and hence collector array sizing) is the internal heat generation due to lighting and equipment loads. Certain tenants could be expected to support warehousing operations with minimal internal heat generation. In contrast, others might produce significant internal heat loads from manufacturing operations or component testing. These ambiguities led to the establishment of "benchmark" design criteria which were considered representative of an "average tenant". These benchmark criteria included expected occupancy schedules, combined lighting and equipment loads of 4 watts per square foot , and recommended hot water use schedules for industrial environments. This information formed the basis for computer simulation of the building energetics over a typical design year. For computational purposes, each building was divided into five major zones- the core and four distinct sections of the building perimeter. The analysis provided a complete profile of daily, monthly, and yearly energy requirements for heating and cooling.

The results of the computer analysis were used to size the liquid- and air- based collection systems. Based on the aforementioned assumptions, the combined systems are expected to supply in excess of 90% of the annual energy requirements for heating. This rather high fraction was somewhat encouraged by the large area available for the southwall collection system. However, given the spectrum of potential uses for the buildings, the actual heating fraction will be best determined experimentally by the National Solar Data Program.

SPACE-CONDITIONING SYSTEM

The exact details of the space conditioning system are determined by the specific tenant. At this writing, Building No. 1 has been leased and a preliminary HVAC system design has evolved. The following paragraphs describe the salient features of this system and its interface with the solar equipment.

Heating requirements are addressed by north and south perimeter duct systems depicted in Figure 2. Both duct runs receive energy from hot water coils which are part of the active solar heating subsystem. The south duct run has additional input from the southwall, air-based collector. Auxiliary energy is supplied by two duct-mounted, gas-fired furnaces. No active heating is provided for the building core.

The cooling requirements of the perimeter and the core are met with distributed, rooftop air handlers- each containing a single, direct expansion (DX) coil. The DX coils are served by a centrally located mechanical compressor working in conjunction with an evaporative condenser. Provisions have been made for the insertion of a chilled water coil in the largest air handler when a solar driven absorption machine is added to the system.

The cooling system has been provided with an economizer cycle to take full advantage of the temperate outside air conditions enjoyed year around in the Bay Area. A variable air volume distribution and control approach has been adopted. Perimeter zones, which can experience heating or cooling requirements , are served by a modulating air control system. The system features a number of automatic damper boxes which work in pairs. When heating is required, one damper box closes the cooling air supply completely while the other admits heated air at volumetric rates proportional to the load. As cooling is needed, the damper boxes reverse operation to provide refrigerated air to the load center.

ACTIVE SOLAR SUBSYSTEM

The flow schematic for the liquid-based subsystem is shown in Figure 3. Approximately 2900 square feet of flat plate collectors supply energy to Building No. 1. The collectors are mounted on a 45o concrete facia at the north extreme of the building. The 3′ x 8′ modular units feature a black chrome selective surface and a single layer of water white crystal glass. The collectors are manufactured by Revere Solar and Architectural Products, Inc..

The collector array is interfaced with storage and load through the primary heat exchanger. The heat exchange step has been included so that positive, chemically-based freeze protection methods can be employed. This approach also allows for the use of less expensive unpressurized tankage for thermal storage and serves to minimize fluid expansion problems. Exchanger sizing was guided by the effectiveness-NTU method . The design effectiveness of 0.55 will reduce overall system performance (as compared to an alternative with no heat

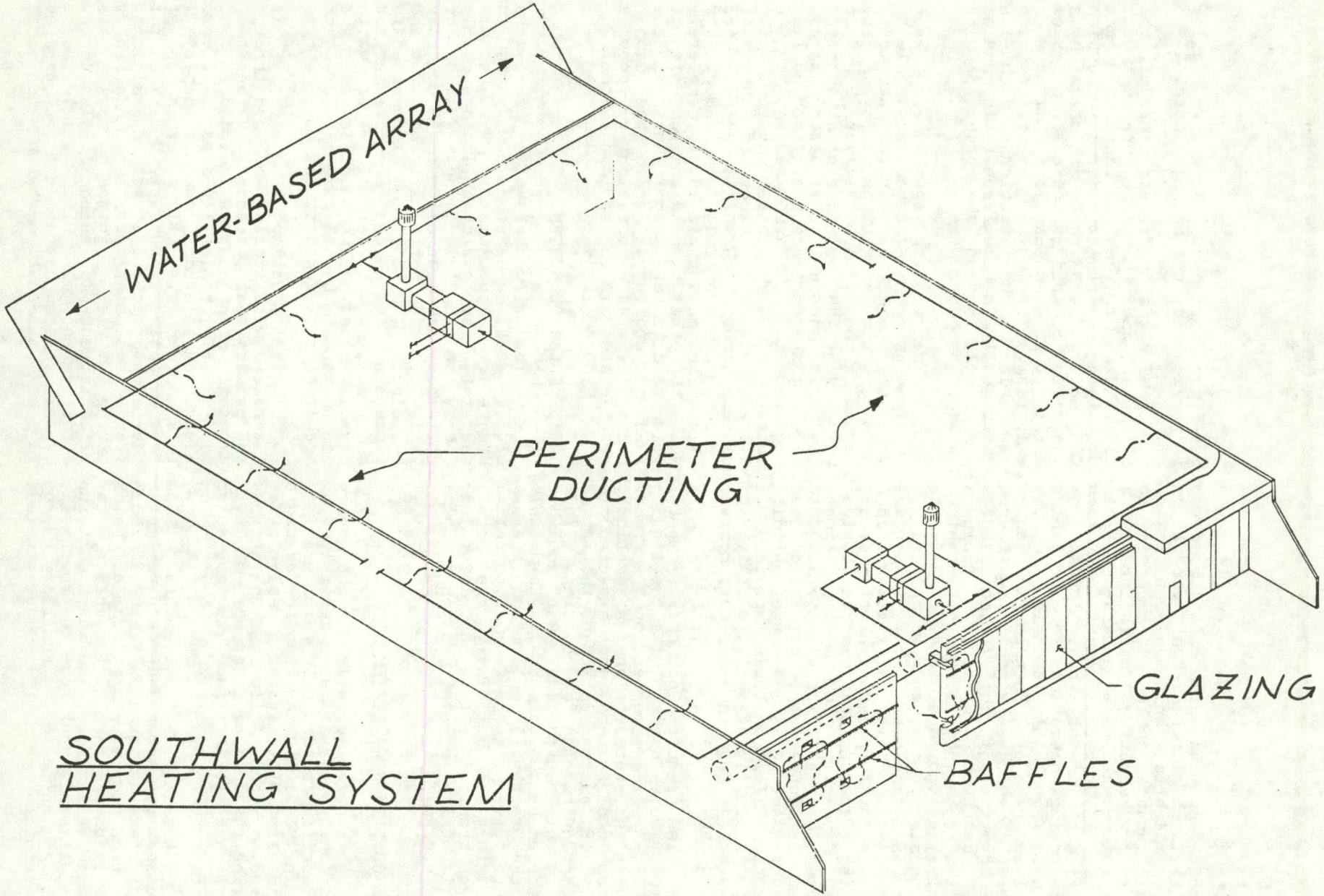


Figure 2. Schematic of Perimeter Heating System and Southwall Collector

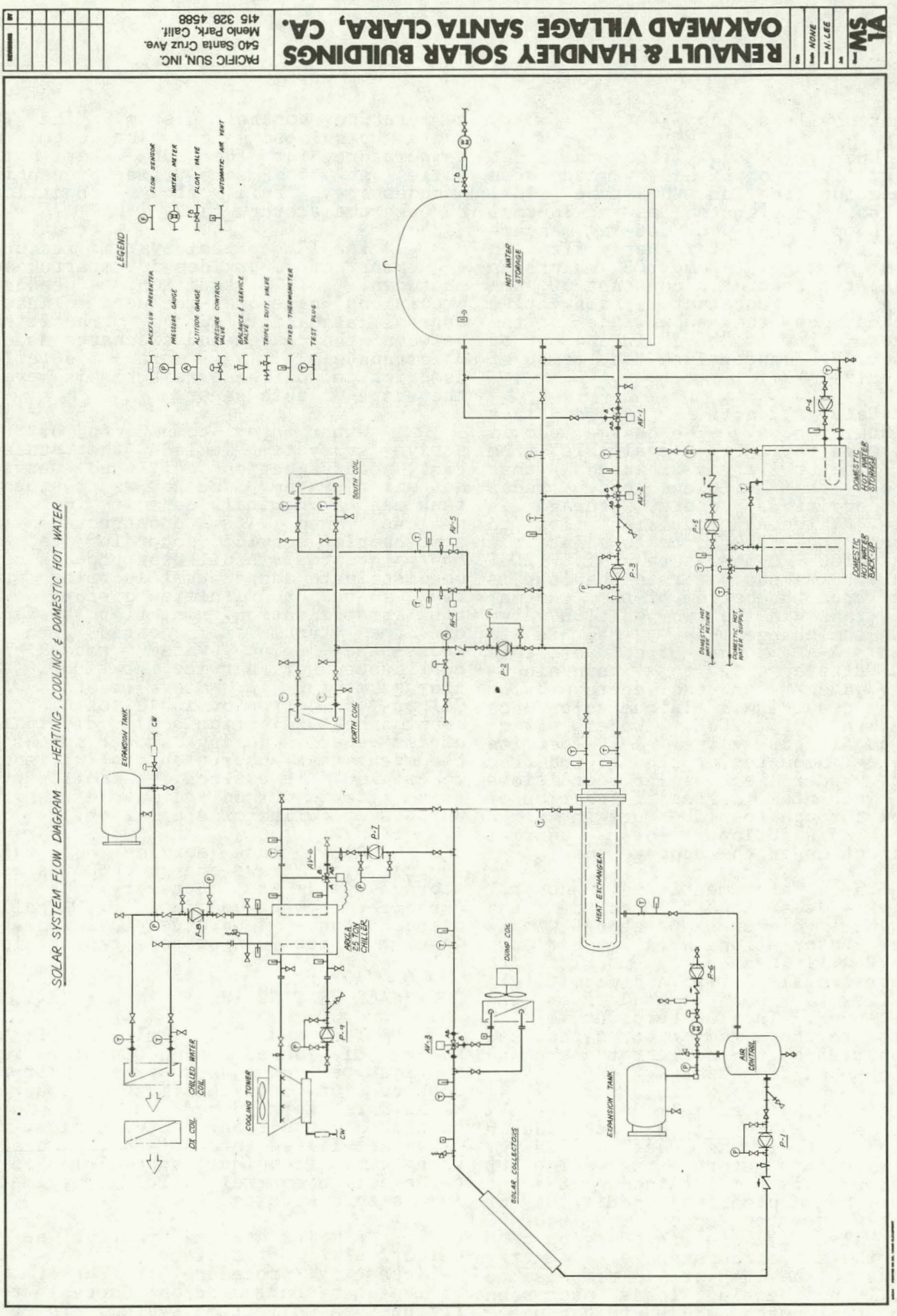


Figure 3.

Active Subsystem Schematic

exchanger) by less than 7%.

Energy removal from the heat exchanger is accomplished by means of a recirculation loop on the tube side. This loop, designated as a Thermal Control Loop (TCL), provides a measure of "quality control" for energy flows to and from storage. Pump P3 maintains flow in the loop at a constant 50 gpm- assuring a constant convective coefficient on the tube side of the exchanger. Flow is "bled" in and out of the loop by appropriate modulation of mixing valve AV2.

Valve AV2 acts in two distinct operational modes. The charge mode is engaged when the energy available from the collector array exceeds that required by the building load. Under these conditions energy storage is possible. Valve AV2 modulates flow to and from the tank so as to maintain a minimum TCL temperature of 120oF (nominal). Makeup water to the loop is provided from the bottom of the thermal storage tank via the two position valve AV1. In the charge mode , AV1 is in position A-AB. The effect of this control strategy is to maintain a "quality check" on the energy being stored by requiring a minimum acceptance temperature of 120oF. Under strong solar conditions valve AV2 permits increasing amounts of flow to and from storage. Under weak solar conditions AV2 recirculates a greater fraction of the flow through the TCL- preventing a gross disruption of thermal stratification in the storage tank.

The aforementioned control strategy does not preclude the attainment of higher temperatures within storage. Under strong solar conditions, valve AV2 will eventually modulate to its operational limit and permit full design flow (50 gpm) to and from the storage tank. The TCL temperature will then rise to those temperatures that can be supported by the collector operating conditions and tank status.

In the discharge mode, valve AV2 assumes a "reverse acting" attitude in order to control the rate of energy removal from the storage tank. The TCL temperature is maintained at the setpoint by appropriate additions of warm water from the top of the storage tank. Valve AV1 is in position B-AB under these circumstances. Energy additions to the loop are in response to the building heating loads as seen through the north and south hot water coils . Pump P2 circulates water to these coils upon demand from the temperature control system. The TCL logic provides a constant operating temperature for the hot water coils while at the same time preventing unnecessary, full flow conditions through the storage tank.

The TCL control system features a number of overrides for startup and shutdown. In addition, deadband provisions have been included to insure control stability during transitions between the charge and discharge modes. Unfortunately, a more detailed description of these features is beyond the scope of this paper.

Other major components of the active subsystem include the storage tank, heat rejection coil and service hot water system. The hot water storage tank has a nominal capacity of 6500 gallons and is constructed for atmospheric service according to API 650 standards. A diffuser pipe is used to distribute and control incoming mass flow so as to minimize disruption of tank stratification. Interior surfaces of the tank are coated with an epoxy-based paint system rated for continuous wet service at 220oF. The storage medium is water treated with Calgon CS corrosion inhibitor. A roof mounted heat rejection coil dissipates excess energy during summer months in the event that absorption cooling is not undertaken. In essence, the coil serves as an interim method to avoid lengthy periods of collector stagnation.

A two tank service hot water system will draw energy from the main storage system as necessary. A heat exchanger- located in a 120 gallon preheat tank- separates the potable water from the main storage tank fluid.

SOUTHWALL HEATING SUBSYSTEM

The southwall air collector system is based on a popular wall fabrication technique known as "tilt-up" construction. In this method, concrete walls are form-poured on site in a horizontal position. After curing, the walls are lifted into place by crane. Using this technique, an efficient crew can erect an entire building perimeter in a single working day.

A major design objective was to effectively interface with the wall-casting procedure in order to arrive at a configuration adaptable to a Trombe-type collection system. To this end, forms for the southern walls were modified to include inlet and outlet

ports for air flow. The ports are spaced on 9 foot centers and have a vertical spacing of 9 feet. Figure 4 shows the erected wall without glazing.

The thickness of the concrete wall, 5.5 inches, is identical to that of the east and west walls. While the tilt-up technique can be easily extended to a variety of thicknesses, this particular dimensional choice served to standardize the casting procedure for the entire building. The thickness was also considered to be compatible with the projected use profile of the building. Daytime heating is stressed-leading to a system which seeks to de-emphasize the storage effects of the wall mass. (By way of comparison, a residential-based Trombe wall would be on the order of 18 inches thick.) The reader is referred to [1] for a discussion of the wall and a complete thermal analysis.

The absorptivity of the wall surface has been enhanced with a field-applied black paint. Other design details include horizontal perforated sheet metal strips to control lateral air flow, and a field installed glazing system (c.f., Figure 5). The glazing system consists of of a double layer of low-iron, tempered glass attached with standard concrete fasteners and flashing details. A six foot overhang shades the vertical collector system during the summer season.

During operation, return air is drawn into the southwall system via the lower registers . The air rises within the 2" gap formed between the wall and glazing. Flow is induced, in part, by natural thermosyphon effects and, in part, by slight vacuum created in the perimeter duct distribution system. The heated air returns to the building interior via the upper ports and then enters a collection plenum. The collection plenum is ,in turn ,connected to the south perimeter distribution system. Discharge air from the southwall can be further conditioned by a hot water coil supported by the active solar subsystem. An auxiliary, duct mounted gas heater serves to meet demand in the event that the combined efforts of the solar subsystems are insufficient to meet the load.

PROVISIONS FOR ABSORPTION COOLING

While the systems currently nder construction address space heating equirements only, the active subsystems of each building have been designed to accommodate absorption cooling at a later date [2]. The interface of the chiller is depicted schematically in Figure 3. As proposed ,the system would utilize a single 25 ton ARKLA WFB-300 and a reflector arrangement used to augment the liquid-based collector system.

The chiller integration was guided by visits to earlier solar cooling demonstration projects around the country. In discussing these systems with their designers, several themes appeared recurrently. First, most of the collector arrays had been sized for the more energy-intensive task of space cooling. This resulted both in considerable capital expense to meet the more severe cooling load ,and an array size which was generally oversized for the heating load. System cost effectiveness necessarily suffered-particularly during the heating season.

Difficulties also seemed to stem from the total dependence on the absorption equipment to meet the cooling load. During marginal solar conditions an auxiliary gas boiler would supply hot water to the generator of the absorption unit. This type of auxiliary interface requires considerable control sophistication. The designer must maximize the solar contribution and simultaneously prevent unwanted migration of thermal energy from the boiler to the other portions of the solar subsystem (e.g., storage, collectors). Too, the operation of absorption chillers with natural gas is less energy efficient than operating mechanical chillers from electrical sources. The energy inefficiency is due both to the relatively low COP of the absorption device and , perhaps more importantly, the significant pump horsepower required to circulate water to and from the cooling tower, chilled water coils and collector array. Frequently, these "parasitic" power requirements can completely offset the net energy benefits of a solar-driven absorption cycle chiller system.

Finally, data from previous demonstration projects suggest that the chiller can not be operated effectively from a hot water storage system. This fact is probably attributable to the unavoidable degradation of energy quality during the storage operation . The pumping energy requirements can also serve to undermine overall system performance. These effects were particularly pronounced in facilities using the older generation ARKLA machines which required minimum firing

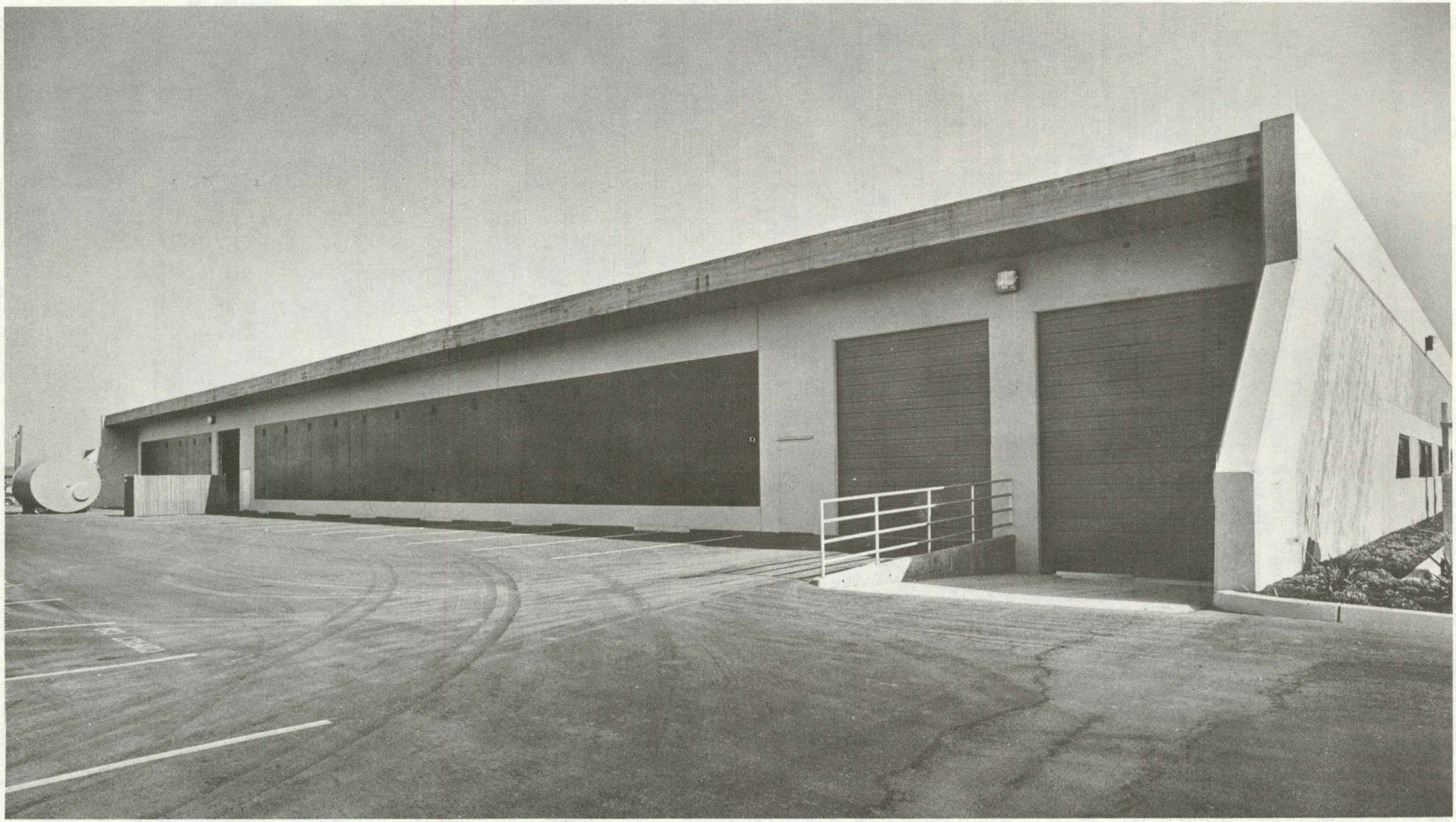


Figure 4. View of Southwall Absorber Surface

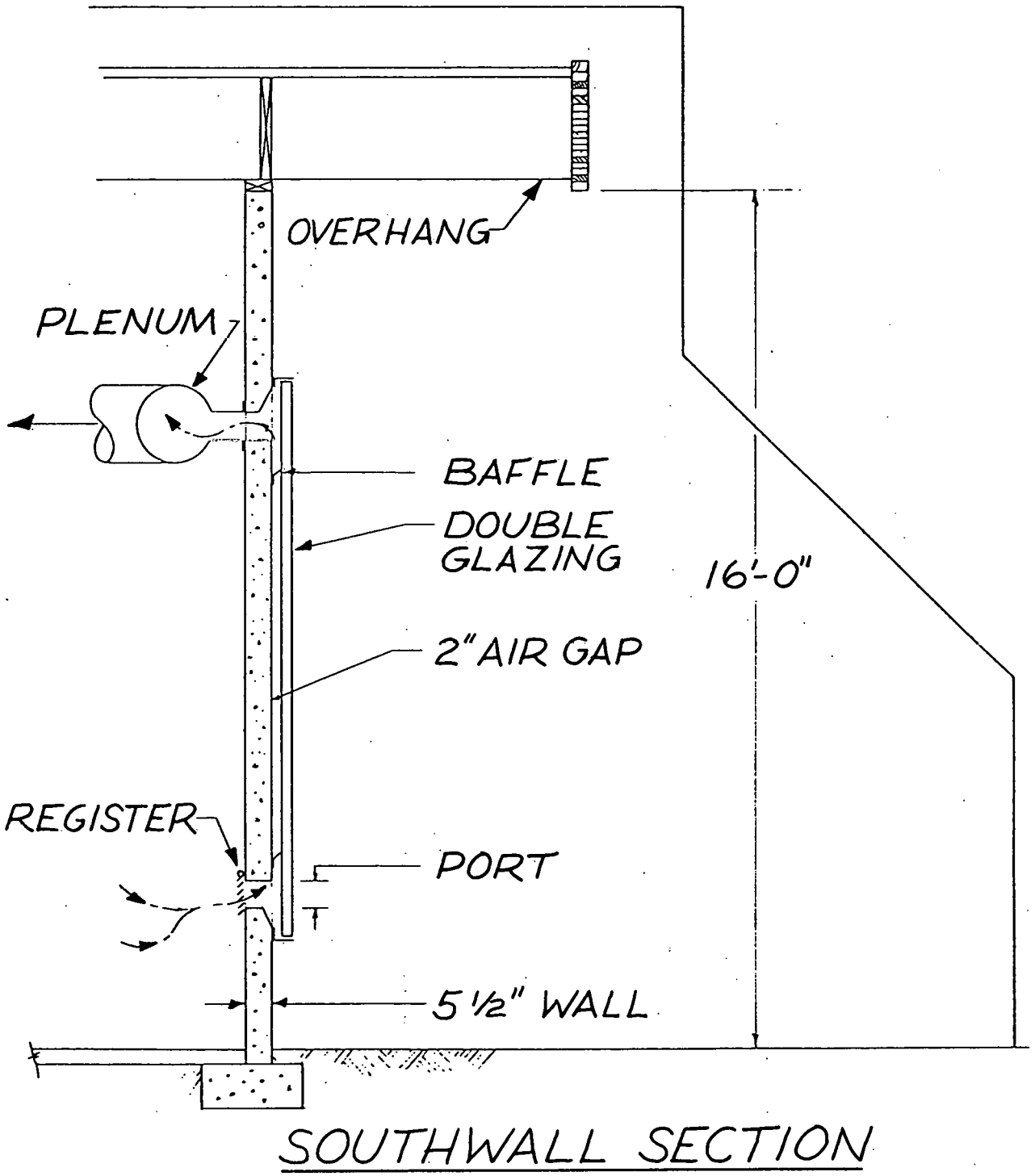


Figure 5. Southwall Section

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temperatures in the vicinity of 200oF. It was generally concluded that direct heating from the primary collector loop provided the best chiller performance.

The aforementioned factors led to a structured design philosophy for the proposed cooling subsystem. First, the collector array is sized primarily by the heating and DHW load rather than the (larger) cooling load. Necessarily, the chiller operation is constrained to the energy available from the heating array during non-heating months (approximately 18 tons peak in this design). Second, the bulk of the cooling capacity is provided by electrically powered mechanical units with the absorption machine providing a relatively modest fraction. Given the relative size of the chiller compared to the load, the entire output of the absorption machine can be used at any given instant. This load matching frequently obviates the need for chilled water storage. Third, the absorption cycle is not operated unless sufficient energy is available from the collector array. A gas fired auxiliary boiler is not employed. Finally, energy is supplied to the absorption chiller directly from the primary collector loop. No attempt is made to drive the chiller from the hot water storage tank.

Given the above tenets, the solar cooling subsystem simplifies considerably. Project cost effectiveness is increased since the collector array is sized for the minimum energy load (usually heating in commercial buildings) and, therefore, used year around. The economics of cooling are then governed by the incremental costs associated with the chiller, cooling tower, chilled water coil, connecting plumbing, and in the proposed system, a reflector array used to augment collector performance.

Chiller operation and control is particularly streamlined. Since the chiller capacity will be small as compared to the total cooling load, the bulk of the cooling will be borne by the mechanical chillers. The absorption chiller is essentially used to shave peak loads - generally during the crucial afternoon hours when demand charges are in effect.

In sum, the solar driven absorption chiller system described uses energy available from the array in the summer to provide a significant, but not overwhelming , fraction of the cooling load. Used in this way, the improved utilization factor for the collector array very nearly offsets the additional capital costs for the absorption chiller and peripherals. The net effect is that the system "payback period" is comparable to the "heating only" option.

PRELIMINARY COST ESTIMATES

Preliminary cost figures for the solar heating subsystems on Building No. 1 have recently been made available. The 2900 square foot active array has an installed cost of $130,000, or $44.80 per effective square foot of collector surface. Major cost elements include $35,000 for the flat plate collectors and $7500 for the storage tank. Costs for the southwall collector system total to $22,000. The latter figure includes $16,000 for the installed glazing system, $3000 for the collection plenum sheetmetal work, and $1000 for painting and miscellaneous details. These figures lead to an installed cost of $18.33 per effective square foot of southwall collector. The latter figure does not include the cost of the architectural overhang.

The overall cost for the heating subsystems amounts to $152,000 for a combined collector area of 4100 square feet . The average price per effective square foot of collection area is approximately $37.10 per effective square foot . System payback, assuming Bay Area natural gas prices escalate at a uniform rate which is 15% greater than the discount rate, is on the order of 17 years. The latter figure excludes the effect of the 25% California State Income Tax Credit and DOE funding assistance.

SUMMARY

It is hoped that the combined active/passive subsystems described in this paper will provide yet another avenue for the economical application of solar energy in the commercial sector. The use of tilt-up concrete wall technology for the fabrication of southwall collector systems holds considerable promise - particularly for warehousing and light industrial applications. The energy management aspects of the liquid-based system are expected to address the important questions relating to energy quality and Second Law availability in solar heating systems. Finally, an absorption cooling subsystem has been proposed which acknowledges the inherent limitations the solar-driven absorption cycle and strives to optimize its performance.

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[2] "Solar Cooling Subsystem for a Commercial Building" , A Proposal to the DOE Cycle III Commercial Demonstration Program, Pacific Sun, Inc., January, 1978

ACKNOWLEGEMENTS

Construction costs for the solar subsystems have been shared equally by the Department of Energy's Cycle II Demonstration Program and the building owner, Mr. Raymond G. Handley. The authors wish to thank the designers of earlier commercial projects for their willingness to discuss their experiences.

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Solar Air Heating System for First Baptist Church

by Delano D. Erickson, AIA

This project is a solar air collector system for space heating and domestic hot water preheating. The system consists of approximately 1,400 sq. ft. of Solaron collectors covering the entire area of the south-oriented portion of the roof of the worship center of the church. The collectors primarily provide heat for the 7,000 sq. ft. worship center zone, and heat is stored in a rock storage bin under the floor of mechanical rooms.

My firm, BWBR ARCHITECTS of St. Paul, Minnesota, is the design architect for the First Baptist Church and solar system. We associated with a local firm, Herges, Kirchgasler & Associates in Aberdeen, South Dakota, for working drawings and supervision. Our mechanical and electrical consultants, Michaud Cooley Hallberg Erickson & Associates, engineered the system which was installed by City Air Conditioning of Aberdeen, South Dakota, the building mechanical contractor.

The system is a very standard application of solar air collectors and was selected for this simplicity. The regular building contractor was able to install the system with a small amount of training obtained from the manufacturer. The integration into the building system and controls utilizes standard construction techniques; and therefore, did not present any signficant problems.

While the project is comparatively simple, there are some unique characteristics. The solar panels were not part of the original building program; but due to our previous experience with solar, the building design contemplated the future possibility by orienting a large portion of the roof due south. Further, the building's orientation of entrance and openings was to the south, making use of passive solar. On the north, an earth berm was used against the walls to reduce heat loss and make use of the earth's heat. The demonstration program opportunity enabled the Church to incorporate the solar system we had contemplated even as the building was under construction. This did involve some critical timing to integrate the change to solar during construction without unnecessary costs. The reasons for going to solar were 1) pollution-free energy, 2) high visibility of the church, and 3) economics. Since conventional energy is electricity at approximately $10/MBTU, the payback made solar logical.

The volume and cost limitations of the worship center established the roof slope at 30° above horizontal, which is less than the optimum angle for solar at Aberdeen, South Dakota. An analysis of the optimum angle versus 30° revealed a 10% annual difference which did not justify cost for special support to tilt panels. We feel that aesthetics are improved when collectors are a physical part of the building; further, these collectors serve as the roof facing and are flashed to provide a waterproof seal with the rest of the roof.

The collector array consists of 72 air panels manifolded together in 9 groups of 8 with a "Z" flow pattern produced by a connection at lower left and at upper right panels of each group. These connections go through the roof to ductwork headers located in beam furring in the worship center. The ducts are routed to the mechanical room where all the equipment and storage box are located.

Engineering Design Philosophy

Before selecting the type of solar collector, we analyzed the various solar collectors available in the market along with their advantages and disadvantages. Concentrating type of solar collectors were ruled out since the intended use of the solar energy was for space heating and domestic hot water heating and did not require high temperatures. Flat plate solar collectors, both hydronic and air type, were considered for this project. The following is the summary of the two types of solar collectors:

	Hydronic Collectors	Air Collectors
Winter Freeze Protection Required	Yes	No
Summer No Flow Protection Required	Yes	No
Possible Damage Due to Leakage of Fluid	Yes	No
Maintenance Requirements	Regular	Minimum
No. of Heat Exchangers Required for Domestic Water Heating	Two	One
Duct/Pipe Size for Energy Transport	Small	Large
Solar Energy Storage	Water	Rock/ Water

It was decided that air collectors are more suitable for this project than the hydronic collectors. The disadvantage of large air ducts for supply and return air (as compared to small pipes for hydronic collectors) was not significant in this project since all of the ductwork was hidden behind the suspended ceiling and no valuable space was used. The solar energy storage was also accomplished by burying the rock bed under mechanical room, thus not using floor area.

In this project, hot water was being used for heating with no antifreeze solution required in the heating system. If we were to use hydronic collectors, it would have been necessary that the entire heating system should be changed to a glycol/water heating system, thus requiring an additional heat exchanger and extra cost for auxiliary system.

The other major advantage in favor of air collectors is that they are virtually maintenance free. The only maintenance requirement is changing the air filters and checking the fan blower bearings once or twice a year.

A total of 1,404 sq. ft. of solar collectors is estimated to provide approximately 28% of total space heating and 50% of domestic hot water heating requirements. The excess solar energy, if available on clear sunny days, would be stored in a rock bed which is located in an insulated underground pit. The pit has been strategically located below the occupied space, thus any heat loss from it would ultimately come back to the space above it. We have provided an access to the pit through a 24" x 24" air duct. There also is a provision for water drainage in case water enters into the pit by some unforeseen way.

In the heating season, mixed air which is a mixture of return air and cold fresh air is always at a lower temperature than the return air. The solar collectors operate at high operating efficiency if entering air is at low temperature. Therefore, in this project, mixed air is passed through the collectors, heating it for direct use and final temperature by ducting through auxiliary furnace.

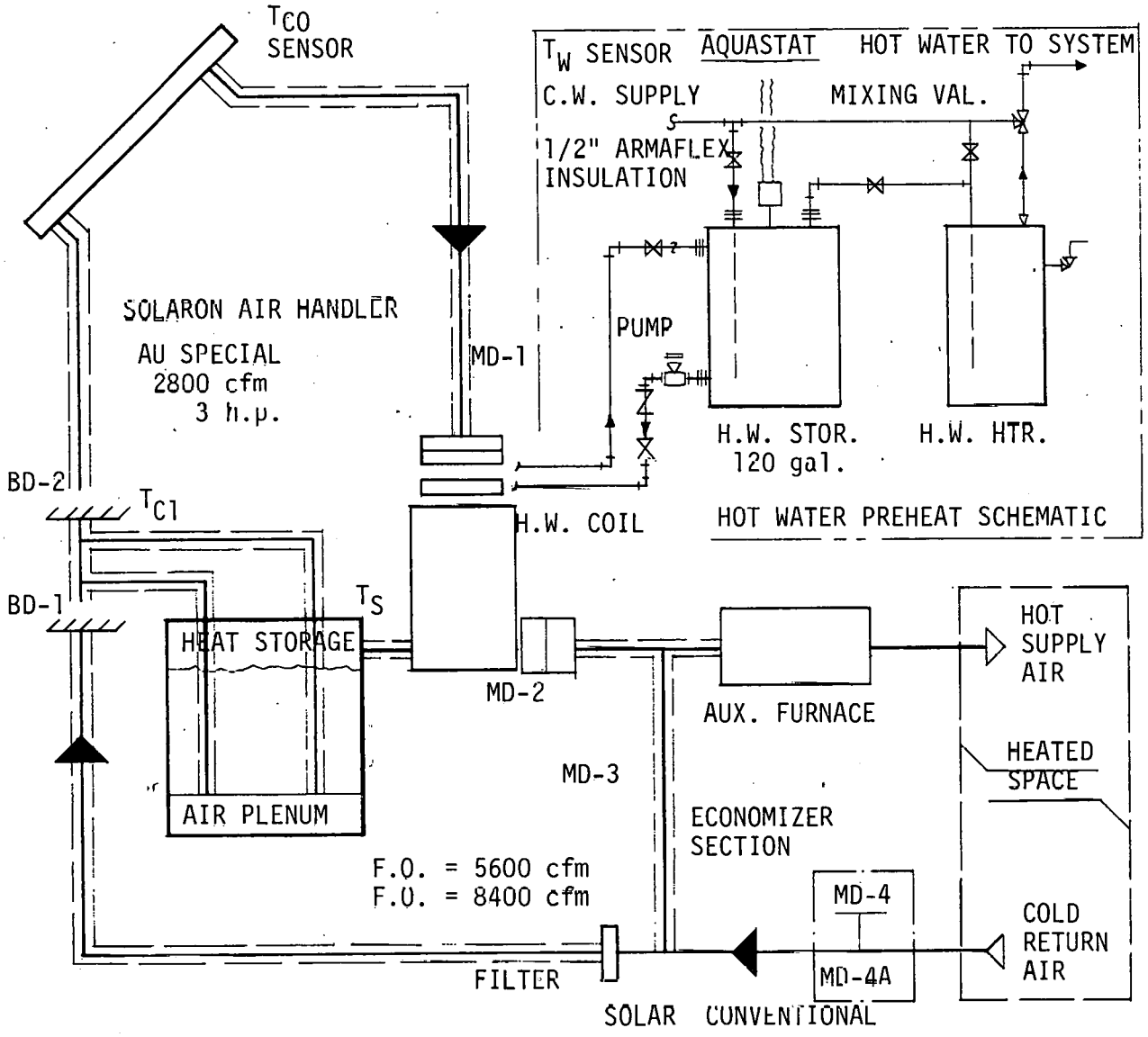
In summer months, air would be circulated in a closed circuit without going through the rock storage pit. If there is some excess energy available, it would be stored in the water storage tank. The advantage of this summer arrangement is that it does not steal air-conditioned air from the space and also produces high temperature water.

Figure No. 1 shows the diagrammatic of the system with appropriate damper controls to operate system in 5 different modes, depending on seasonal and demand requirements.

The project is under construction and near completion with the total process being right on target in terms of time schedule. The final balancing and testing has been provided for with adequate volume control dampers in the total system to allow good flow control. All system components are off the shelf items and no problems are anticipated in the maintenance or replacement.

SOLAR HEATING FLOW SCHEMATIC

COLLECTOR
Array: 6H x 4W x 3
No: 72
Ft.Sq: 1404



O = OPEN
C = CLOSED

SEQUENCE OF OPERATIONS

PO = PARTIAL OPEN

MODE	MD-1	MD-2	BD-1	BD-2	MD-3	SOLARON AIR HAND	AUX. FURNACE FAN	AUX. FURNACE HEATER
HEATING FROM COLLECTOR	O	O	O	O	P.O.	ON	ON	OFF
HEATING FROM STORAGE	C	O	O	C	P.O.	OFF	ON	OFF
STORING HEAT	O	C	C	O	F.O.	ON	ON	OFF
COOLING	O	C	C	O	F.O.	OFF	ON	OFF
WATER HEATING (SUMMER)	O	C	C	O	F.O.	ON	OFF	OFF

Conclusions

The application of solar to this project has been relatively easy to accommodate. I think this is due to use of standard equipment, a proven solar collector and engineering to integrate with the building system using standard techniques which the building contractor understood with additional training to install the collectors.

While performance has not been totally proven by a full year usage, the owner has been very satisfied with the project. The Church has a commitment to the solar energy future and feels a certain pride in their accomplishment.

Based on our experience in this project as well as four other solar projects, we feel this one points up the value of simplicity by providing a very workable system on time and in the budget with the least problems in the process. I feel that solar collectors are an integral part of a building and should be expressed thus, not as a mechanical device but as the building's surface, be it wall or roof. The First Baptist Church of Aberdeen, South Dakota, has accomplished that goal.

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SOLAR-ASSISTED HEAT PUMP OPERATION AND START-UP
LITTLETON CENTER - LITTLETON, COLORADO

Richard G. Supple

INTRODUCTION

The purpose of this paper is to review the events that took place and problems that arose during the construction, start-up, and initial operation of a 150-ton solar-assisted heat pump system located at the Littleton Center in Littleton, Colorado. While each solar project seems to introduce circumstances peculiar to that particular design, there are several situations common to many solar designs that have been placed in operation to date. Several of these common problems will be discussed along with specific situations applicable to the Littleton Municipal Center solar system.

PROJECT

The solar energy system consists of flat plate solar collectors, storage tanks, heat exchangers, pumps, piping and controls required for a solar-assisted internal source heat recovery heat pump system. The Littleton Center serves City government administration and is a multi-use building with office space for City personnel, public space for City Council meetings, a small Police Station in operation 24 hours per day, and an Emergency Operation-Communications Center which also is occupied 24 hours per day. The two-story building has approximately 56,000 sq.ft. of floor area and is of masonry and prestressed concrete tee construction.

The construction contract documents included all of the solar system equipment as a part of the contract. The solar system was designed as a working system with potential for reducing fossil fuel consumption rather than as a demonstration project introducing solar to the community. The DSE 76-2 Program Opportunity Notice proposal was submitted well after the bidding process, so that it was possible to use competitively bid pricing in the proposal.

The solar energy system consists of 9,000 gross sq.ft. of flat plate solar collectors as manufactured by Sunworks. These collectors are installed on the roof at a 60 degree elevation above horizontal. Other equipment associated with the collectors includes two 13,900 gallon underground storage tanks, two solar water to tank water heat exchangers, two domestic hot water heat exchangers, two solar collector circulating pumps, two tank water pumps, one domestic hot water pump, and all associated piping, collector supports, insulation, and appurtenances.

Solar heat is transferred from the (35% by volume aqueous solution of ethylene glycol and water) solar loop circuit to the water in the tanks by shell and tube heat exchangers. The hot water in the tanks is used for domestic hot water heating through another heat exchanger, direct building heating whenever the tank temperature is above 110°F, and as a heat source for the heat pumps to heat the building whenever the tank temperatures are not adequate for direct heating. All building exhaust air passes through air to air shell and tube type heat recovery devices and the heat is used to temper the ventilation outside air during the winter cycle or cool the ventilation outside air during the summer cycle. Basic air distribution is accomplished via three low velocity multizone units with a separate independent water-to-air heat pump system serving only the Emergency Operation-Communication Center. This system is provided with emergency

power and is designed to operate throughout any type of disaster without relying on any part of the basic air conditioning system (other than the solar storage tank water).

Because this system was designed as an operating solar-assisted heat pump system before any ERDA or DOE involvement was considered, the only instrumentation provided under the contract was that necessary to observe and operate the mechanical systems. Visual flow meters were provided for direct reading in gpm of the solar tank water flow, the chilled water flow, the condenser/hot water loop flow, the east solar loop and the west solar loop.

CONTROL SEQUENCE

The control of the heat pumps, boiler, and centrifugal pumps is completely automatic. An outdoor master thermostat provides change-over for the heat pump cycles for heating and cooling. Below 30°F outside air temperature, the chiller capacity is controlled by the heating requirements to furnish 110° hot water off of the condenser. Above 60° outside air temperature the chiller capacity is controlled by the cooling thermostat to maintain 55°F return water temperature. Between 30°F and 60°F outside air temperature, the chiller capacity is determined by the output pressure of the master heating and cooling controllers and selects the higher of the two branch pressures. The two 75-ton heat pump-chillers are controlled from lead-lag switches as well as manual heating-cooling-automatic selector switches. In both the heating and cooling control modes, the second chiller is not energized until the system capacity requires its operation. Each chiller is equipped with hot gas bypass to allow a greater operating range of chilled water temperature for the heating cycle and to prevent short-cycling for light loads and low chilled water temperature. Time delay devices are employed to prevent both chillers from starting with a light load condition on start-up. Tank water circulating pumps run continuously and when the tank temperature reaches 110°F or when the outside temperature is above 60°F, the economizer controls on the three multizone unit mixing boxes are actuated. When the tank water reaches 110°, it is used for direct heating, and if the outside temperature is below 60°F the chillers are cycled off so that heating is provided by direct heating from the storage tank and cooling is provided by outside air. Whenever the tank temperature is below 60°F or the water temperature to the heating coils in the heat pump cycle is below 100°F, the auxiliary electric boiler is automatically energized. One of the three multizone units supplies air to an office type occupancy which allows the air handling equipment to be de-energized when the office wing is not occupied. The Community Meeting Room and small Court Room areas are served by a second multizone unit and can also be cycled off during unoccupied periods. The third multizone unit serves the Police Station wing and operates continuously.

START-UP AND OPERATION

The cooling tower must be capable of automatic year-round operation because seasonal draining is not possible in Colorado where a 35°F daily temperature range is common. This design used an outdoor cooling tower with an electric resistance sump heater rather than an indoor sump. The heater was specified clearly and the thermostat shown, but the specifications were not specific as to

who furnished the thermostat. One of the first problems encountered was that the sump heater was found to be wired in such a manner that it was in continuous operation. The cost of operation was a surprise to the Contractor responsible for paying the utility bills until acceptance of the system.

Air balancing and water balancing was specified to be under the control of an independent testing and balancing company. Specific instructions for checking water flow rates and outside air and exhaust flow rates were included in the specifications. Because outside air in the form of infiltration or damper leakage represents a major heating load, the pressure relationships within the building were checked to reduce infiltration as much as possible at the building entrances. Adjustments were made so that only the minimum outside air required for ventilation would pass through the outside air dampers.

One other important area of concern involved the pressure drop of the components. The plans and specifications clearly specified the maximum pressure drop for both air and water equipment. This is important on the air side where air to air heat recovery devices are utilized because the horsepower required to recover heat is significant, and the careful checking of submittals is in order to insure that air pressure drops are within the specified range. Some temperature control contractors are accustomed to selecting control valves at a fairly high pressure drop. Because the condenser/hot water circuits take several different paths depending on the mode of operation, the pressure drop across valves in series needed to be limited. In some cases a 2 psi drop was specified, and this has impact on the first cost of the valves. Similarly, the pressure drop across the heat pump evaporator and condenser is significant because these pumps operate year-round.

The design heat loss for the building was approximately 920,000 Btuh. Normally, one heat pump would be sufficient to carry the heating load with the second heat pump as standby. In the Littleton design, an electric resistance boiler was used as the standby heating source in the event both reciprocating heat pumps were inoperative. A 920,000 Btuh output boiler requires 270 kw which is approximately four times the energy required by one heat pump. If the controls allow a large electric load to come on line at full load, the cost penalty due to the demand charge is significant. For this reason many steps of control were specified for this 270 kw load. Unfortunately, the controller for these steps of control is not as yet functioning, and until the step controller is operable, it is possible for the electrical demand in a 30-minute period to offset the savings possible with the solar-assisted heat pump system. If demand charge is based on one hour operation, the problem is significantly worse, and sufficient controls in the form of time delay relays between increments of electric resistance loading need to be employed. This problem is a very real problem and applies to electric domestic hot water standby heating as well as for hot water standby heating.

In any condenser piping circuit using 110°F water, the possibility of cutting off the machine on high head pressure is present. Usually this high pressure safety employs manual reset which requires the attention of the operator. In the Littleton system, the ambient temperature of dormant water, when introduced to the condenser upon morning start-up, caused the high head device

to actuate. A chiller lockout was required until the condenser water temperature normalizes.

Another problem involved the automatic sequence of controls. The tank water pumps are designed to run continuously so that the heat collected in the tanks can be used in any of the various operating modes. The importance of utilizing the automatic controls was thoroughly stressed throughout the instruction period to the operating personnel. Unfortunately, the tank water pumps were furnished with hand-off-automatic switches which had a dead leg in both the automatic as well as the off position. The operators, being very conscientious and remembering their instructions to run all equipment in the automatic position, dutifully switched the tank water pump switches to the automatic position which unfortunately turned them off. The first operating month occurred this past January during a severe heating season, and most of the heat for both building hot water and domestic hot water heat was provided by electric resistance elements. The electric bill for the first full month of operation was excessive.

One common problem associated with solar piping circuits involves the ability of the system to vent air from the solar piping circuits. A little bit of air in a small solar pipe quickly changes to steam and can effectively block the flow of water through that pipe. If this situation is repeated frequently, entire banks of collectors can become inoperative due to air binding. The practice of using manual air vents to bleed air from this solar piping circuit was not successful, and automatic air vents had to be installed in place of the manual air vents.

As a result of the frequency of callbacks involving control components on the Littleton Center, it has been concluded that the control specifications in Division 15 need to be changed substantially. The control sub-contractors simply do not have enough money in their proposals to properly shake down and check out all of the control circuits necessary to operate a solar-assisted heat pump system in all of its modes of operation. The specifications need to be improved by stipulating the minimum number of hours required by the control sub-contractor (and associated disciplines such as the testing and balancing sub-contractor and electrical sub-contractor). This breakdown should include time for the start-up phase, the shakedown phase, and a thorough instructional period where the operating personnel can learn to be at home with all of the operating controls. Too frequently, for one of many reasons, the automatic operating sequence was disturbed or changed, and at the beginning it was necessary for the controls sub-contractor to appear on the job site at a frequency not consistent with prior conventional jobs. The education process by the controls sub-contractor for the operating personnel is vitally important on a solar-assisted heat pump system compared to conventional projects.

CONCLUSIONS

With all of the effort given to designing a mechanical system to conserve energy, many situations occur which can quickly obliterate the intended result. Particular attention must be paid to setting up the automatic controls so that all modes of operation can take place automatically as well as to carefully

instruct the operating personnel to the point where they become familiar with these controls. Other energy using devices such as electric resistance boilers used for supplemental heating, if improperly controlled, result in demand and operating electrical charges that can defeat the savings incorporated in the design.

ACKNOWLEDGEMENTS

The City of Littleton is appreciative of the award of funds resulting from the 76-2 Program Opportunity Notice. The City has assigned qualified personnel to administer this contract as well as to operate the equipment.

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SOLAR ASSISTED HEAT PUMPS FOR MOTEL APPLICATIONS IN LA QUINTA MOTOR INN, SALT LAKE CITY, UTAH

Marvin Rubin - La Quinta Motor Inns, Inc.
Henryk Orlowski - Travis-Braun & Associates, Inc.

GENERAL

Solar energy systems designed for the La Quinta Motor Inns interface between two newly developing mechanical technologies, solar energy and the water source heat pump. The low temperature thermal requirement of a water source heat pump makes it an excellent match for the use of low temperature solar energy, and as such adds the benefit of a smaller solar energy system, with its lower associated cost.

The owner of the projects, La Quinta Motor Inns, Inc. has pioneered the development of solar energy along with Travis-Braun and Associates.

This system concept was first put into operation at the La Quinta Regal Row Motel on January 19, 1977. The pilot solar addition consisted of a 35 room expansion. This system served as a bench mark for the design of further systems. This pilot project, funded totally by funds from the La Quinta organization consisted of 18 Northrup flat plate solar collectors, which provided warm water (approximately 100°F) for space heating via heat pumps and served as a domestic water pre-heater.

This pilot project was undertaken on an addition to the particular motel. The solar/heat pump provides 25% of the heating requirement from solar energy and 61% of the domestic hot water. The incremental cost for the solar system was $40,000.

Presently a project funded under ERDA and now administered by DOE is being constructed in Salt Lake City, Utah. This project represents the learning experience of the previous project, plus the benefit of a much developed heat pump technology.

The Salt Lake City project will consist of 122 rooms utilizing a net collector array of 3000 square feet, which is anticipated will provide 25% of the heating requirement and 61% of the domestic hot water. Total installation cost is anticipated to be $250,000.

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DESIGN PHILOSOPHY

Water Source Heat Pump

Heat Recovery Systems use less energy resulting in lower utility costs. Decentralized heat pumps provide complete, individualized climate conditioning of multi-room motels. They utilize effectively energies that normally are wasted--heat from lights, people, sun, etc.

Water source heat recovery systems consist of packaged refrigeration reverse cycle units interconnected to a loop of circulating water. They are supplied, if and when required, by a supplimentary means of rejecting excess heat or adding heat.

When cooling is required, heat is absorbed from the space being cooled through an air coil, transferred by refrigerant and absorbed by water circulating through a water coil. When heating is required, heat is absorbed from the water coil and transferred by refrigerant to the air coil for use in the area being heated.

In the water source heat pump system utilized in the La Quinta Motor Inn, Salt Lake City, Utah, one unit on the cooling cycle adds enough heat to circulating water to support two similar units for heating without a significant change in water temperature of the loop. This temperature is held between 70° and 95°F.

While certain units are on cooling and adding heat to water, other units are on heating and are absorbing this heat. Energy is recaptured, efficiently used within the system without inputs from expensive outside heat sources.

Climatic requirements differ from area to area within any building. This is caused by lighting loads, occupant usage, machinery, sun load, shaded areas, construction features, insulation, glass and outside extremes. Heat recovery systems give heat which is absorbed, recovered and transferred to areas which require heat.

In some cases, system water heat loss in areas being heating equals system water heat gain in areas being cooled, minimizing need for supplemental heat from a boiler.

The specific advantages of a water source heat pump are:

Water pipes do not have to be insulated because water range varies between 60°F and 105°F.

The only constant operation of the auxiliary equipment is the pump system. Water heater and cooler operate individually when required to maintain supply water temperature within a range of 70°F to 95°F.

Extreme water system temperature demands are eliminated providing maximum efficiency in fuel and energy use year-round.

Where codes permit, plastic piping can often be used because of the low water temperature, saving installation time, labor and pipe costs.

In addition to the heat recovery water source heat pump, a solar energy collector system has been incorporated into the design to absorb solar energy for storage and system operation, greatly reducing water heater use.

Solar Collector Array Sizing

The transient nature of the thermal requirement of the water source heat pump plus the inherent diversity present in any motel necessitated the development of new sizing procedures as well as the utilization of a variety of computer simulation models. Several other factors have been taken under consideration. Since the winter load is significantly larger than the summer load, the peak system performance is obtained for a tilt angle of 48°. The solar energy system performance for heat pump assistance and hot water demands tends to increase directly as a function of temperature energy systems storage tanks capacity. The heating portion will utilize 205×10^6 BTU and hot water heating will utilize 477×10^6 BTU from 735×10^6 BTU collected through solar system. Due to specific requirement of water source heat pump, only a portion of the load needs to be supplied by the solar system during the heating cycle. The remaining portion of heat will be supplied by the heat pump principle.

The collector array consists of a single bank of 144 collectors arranged in two rows of 72 collectors each. Each collector is connected to supply and return header by 3/8" connector. The header piping and all piping in the solar collector loop will be

copper isolated from collectors by di-electric unions. Balancing valves on the outlet side of each header will permit balancing flow throughout the collector array, as well as providing a convenient way to measure flow rates.

The working fluid is a 50/50 ethylene glycol (Prestone II) water solution which contains corrosion inhibitors to protect steel and admiralty brass, among other materials. The collector loop is a pressurized system with relief valves located on the roof array, set at 60 p.s.i. This pressure permits rate operation at the highest design operating temperatures.

A circulating pump is activated through a thermal switch when temperature of collector fluid will be higher than 20°F from temperature of Storage #1. In the event that Storage #1 exceeds 220°F, full flow is automatically diverted through an over-temperature control heat rejection fan coil unit as long as required.

Based on previous experience and computer programs, the combination of 144 collectors to 10,000 gallons of storage capacity were selected.

Collector Array Flow

The manufacturer recommendation was 0.017 gallons/per minute per square feet of collector.

144 collectors x 21 square feet x 0.017 GPM/Ft^2 = 51 GPM

The pressure loss in the collector array will be 55 feet. Thus selected pump to be operated by 1-1/2 HP motor.

Collector Array Temperature Difference

Ambient Temperature	T - 95°F
Design Collector Temperature	T - 160°F
Summer Solar Insolation	I - 287 BTU/Ft^2/Hr
Loop Fluid	50% Prestone II/50% H_2O
Flow Rate	51 GPM
Specific Gravity @ 160 F	1.07

Specific Heat @ 160°F .85 BTU/LB°F

$$\frac{(144 \times 21\ Ft^2)(269\ BTU/Ft^2Hr)(43\%\ Efficiency)}{(51\ GPM)(8.34 \times 1.07\ lb/gal)(.85\ BTU/Lb^oF)(60\ Min/Hr)} = 15^oF$$

The heat exchangers, all pumps and auxiliary equipment has been sized, based on established principles.

Storage Tank Location Consideration

Since in the 1972-1973 period a number of designers all over the country have maintained different opinions regarding storage tank configuration and location. Travis-Braun & Associates, Inc. design team made some determinations and reasoning for storage location and design. The required volume of storage falls between 1.4 and 1.8 gal/per/sq. ft. of installed net collector area. The storage tank is located above ground for several reasons:

1. Easy access in event of leakage or malfunction.

2. Cost of tank burial is excessive.

3. Underground storage has a greater tendency towards damaged insulation.

In view of these aspects, our decision was to locate storage tank above ground for this demonstration program. We feel the tank should be visible to the public.

The storage system is comprised of two tanks containing a total of 10,000 gallons. Due to the size of the vessels and the basic building module of this motel, it was not feasible to locate them internally. Their placement was therefore adjacent to the motel. Multiple tankage was utilized so that the maximum benefit could be derived from load sharing.

Yet another advantage was to be obtained from the utilization of thermal storage. During the night, the cooling tower can be activated and cool water may be stored. Obviously, night temperatures are cooler than day temperatures. The stored "coolth" permitted the heat pumps to operate at a higher C.O.P.

Balancing Valves vs. Reverse Return

The system was originally designed as a reverse return piping

system. However, the cost penalty assessed against this system after bidding dictated the abandonment of this reverse return in lieu of the less expensive two-pipe system employing balancing cocks.

It has been determined that over-heating in collectors, when it occurs, causes rapid degradation of the collector absorber plate and absorber coating. This system, as well as all solar systems designed by Travis-Braun, employs a system to control and avert over temperature situations. However, the nature of this installation, as well as the designed temperature limits, renders the likelihood slim.

Control System

Several different alternatives have been considered to provide efficient systems control with systems design. Solar collector loop control has been arranged to provide circulation through heat exchanger installed inside of the storage tank, whenever temperature of the return from the solar collectors is above the temperature of the storage tank.

The exchange between storage tanks will be based on seasonal control whenever the temperature of either tank will be greater than another. The above function is limited by temperatures in Storage Tank #2.

Cooling tower loop control will be arranged to provide circulation through the closed cell cooling tower whenever temperature of heat pump loop exceeds the set point. For most portions of the day, the 7500 gal. storage tank should be utilized as heat sink. At night time when ambient temperature is lower, heat can be easier dissipated using less energy. Motor inn potable water shall utilize energy in heat pump water loop and/or energy Storage #1 to preheat water supply to conventional water heater.

BARRIER TO ADOPTION

The primary barriers to the development were:

1. Motels as an industry are reluctant to deviate from a proven method or product. Both solar and heat pump present an uneasy change from the accepted methods.

2. The heat pump still retains a large measure of consumer fear and reluctance as a hold-over from the numerous failures prevalent during the introduction of heat pumps during the 1950's.

3. Developers retain a high level of suspicion regarding the additional cost associated with both the heat pump and its associated solar option.

4. Many developers are not convinced of the inevitability of continued utility rate increases, and as such are reluctant to accept economic projections of cost savings.

TECHNICAL PROBLEMS

Problems which were experienced in the pilot project have been eliminated in the present design. These included:

1. Pump connection fractured, due to rapid expansion caused by rapid thermal rise.

2. In the pilot project, numerous air pockets appeared. This has been overcome by additional air vents.

3. Due to the reluctance of maintenance personnel to adequately monitor the circulating fluids and buffer the circulating fluid, we have adopted in lieu of a manual shot feeder, an automatic chemical feeder, thus reducing the likelihood that human error will lead to problems.

4. We learned that a larger alternate heat source was required than was originally throught necessary. This heat source only came into play during winter start-up under extreme conditions.

5. Further innovations were adopted in regard to freeze protection.

   A. Drain down of cooling tower basin.

   B. Drain down of all piping connected to cooling tower.

   C. A 50% glycol buffered solution to prevent system freezing.

6. Additional experience was gained regarding the use of solar collectors. The Pilot project employed flat plate collectors manufactured by Northrup Industries. These collectors proved very early during the project life, to have some problems. Collector covers of tedlar failed frequently, black paint peeled off in some areas.

IMPLEMENTATION

Upon completion of the design, the plans were reviewed by DOE. Their comments were directed especially toward the collectors' mounting details and flashing system. After a series of trials, the final design was accepted by DOE and the project went into the bidding process. The first quotation turned out to be excessively over the estimated and projected cost of the project. This was due to:

1. Inflation: The cost pricing proposal was submitted approximately 18 months prior to commencing construction at the Salt Lake City, Utah project site and did not reflect any inflationary factors.

2. Underestimating required piping insulation. Pipe insulation was originally estimated at $3,000. However, the cost of providing insulation is $10,000.

3. Underestimating administration costs to administer the project in the proper manner.

Changes to Design

At this time, due to the cost increases and the necessity to lower project costs, the following changes have been performed to the project scope:

A. Exchanging solar piping material. Piping specified for the project was schedule 40 steel pipe, due to collector absorber plate made out of steel. During pricing negotations, the material has been changed to copper with di-electric unions at collector entry and exit.

B. Eliminating lining in storage tank due to using inhibited water in heat pump system.

C. Exchanging electrical controls as specified to pneumatic controls by Johnson Control.

At the present time, the curbs for the collectors are erected on the roof and the collectors have been delivered. The mechanical contractor is attaching solar collectors to the frames and placing them on the roof. Mechanical piping interface has been completed. No special problems have been observed. The solar project is expected to be in operation on or about July 1, 1978.

ADDENDUM

The following are initial observations as concerns the solar hot water/space heating installation at the La Quinta Motor Inn, Salt Lake City, Utah. Initial start-up for system testing was accomplished July 12 - 13.

1. Hose bibs should be provided on the roof for washing collector surfaces. We have estimated that collection efficiency drops as much as 30% when the collectors' surfaces are heavily coated with dust, and salt deposits which are peculiar to Salt Lake City.

2. Provision should also be made for flushing-out the closed-loop with a chemical solution prior to filling the loop with the glycol solution.

3. Only one of the 144 collectors showed signs of leaking pin holes.

4. Due to the mechanical contractor's lack of experience with solar installations, he created an additional expense for himself by providing gate and balancing valves for each collector; whereas one gate and balancing valve per bank is sufficient (as was shown on the drawings).

5. Solar system installation experience by the mechanical contractor is important but not necessary as long as the contractor is proficient and conscientious as concerns the installation. It is vitally important that plans and specifications be read properly and adhered to, plus the contractor's confidence in his own good judgement and professionalism.

6. Special care towards system balancing is vitally important.

7. Of equal importance is the choice of a proper control system. A poor control system can negate the efficiency

of an otherwise proper engineering design and excellent installation by the mechanical contractor.

8. We have a very good control system in Salt Lake City, Utah. However, after initial observation during the initial start-up phase several discrepancies were noted. Therefore, the control system is in the process of re-calibration. Overall, special care should be taken during installation and for calibration of the control system.

9. As presently installed on the roof of the motor inn, the aesthetics of the collector array is sorely lacking.

10. Although performance expectations are high for this system, it is too early to make conclusive statements concerning this system as it is still in the testing phase as of this date.

11. The mechanical contractor did install the system in a neat and highly professional manner.

St. Charles High School Solar System, St. Charles, Illinois

Harry T. Gordon, R.A.

INTRODUCTION

The Solar Energy Committee of the St. Charles High School District No. 303, Kane County, Illinois retained the firms of Unteed, Scaggs, Fritch and Nelson, Buchanan, Bellows & Associates, and Burt Hill Kosar Rittelmann Associates to respond to the Department of Energy Program Opportunity Notice DSE762. Working with the cooperation of the Illinois Development Board, the state Agency responsible for the construction of elementary and secondary schools. A proposal was submitted in which cost sharing was provided by both the school district and the Development Board.

With the receipt of the grant from the Department of Energy, work was done in the preparation of contract documents during the latter portion of 1977 and early 1978. Bids were successfully received in the spring of 1978, and the solar energy system is currently under construction with a predicted completion date toward the end of 1978.

SYSTEM DESCRIPTION

Analysis conducted during the preparation of the proposal indicated that a solar energy system combined with a heat recovery rotary chiller was the most effective method of providing space conditioning in the project. The building had been carefully designed for the future addition of solar energy, including the provision of solar storage tanks during the original building construction, and the selection of a heating distribution system sized to achieve the design heating requirements with low temperature water. This choice benefits both the solar energy utilization and the heat recovery operations. In addition, the structural system of the school was designed to accommodate the future addition of solar collector panels and the accompanying support structure. These early choices on the part of the St. Charles School District were important considerations since the project was under construction during the time the solar energy proposal was being prepared.

Figure 1 shows a mechanical system schematic in one of the seven operational modes:

1. Space cooling with heat recovery.
2. Solar collection and heat storage.
3. Direct heating from solar storage.
4. Direct heating from heat recovery (chiller storage).
5. Heating to the heat pump from the solar storage tanks, (shown in Figure 1).
6. Heating with the heat pump from heat recovery tanks.
7. Heating with auxiliary electric boiler.

An analysis was conducted of the solar mechanical system operation by studying an average day in each month of the heating season, September through May. A dynamic computer program was used to analyze the building heating and cooling requirements and solar collector production on an hourly basis. An

example of the results of this analysis is shown on Figure 2, a comparison of building thermal requirements and solar production on an hourly basis through the month of February. Note that the building operation was analyzed for both occupied and unoccupied days.

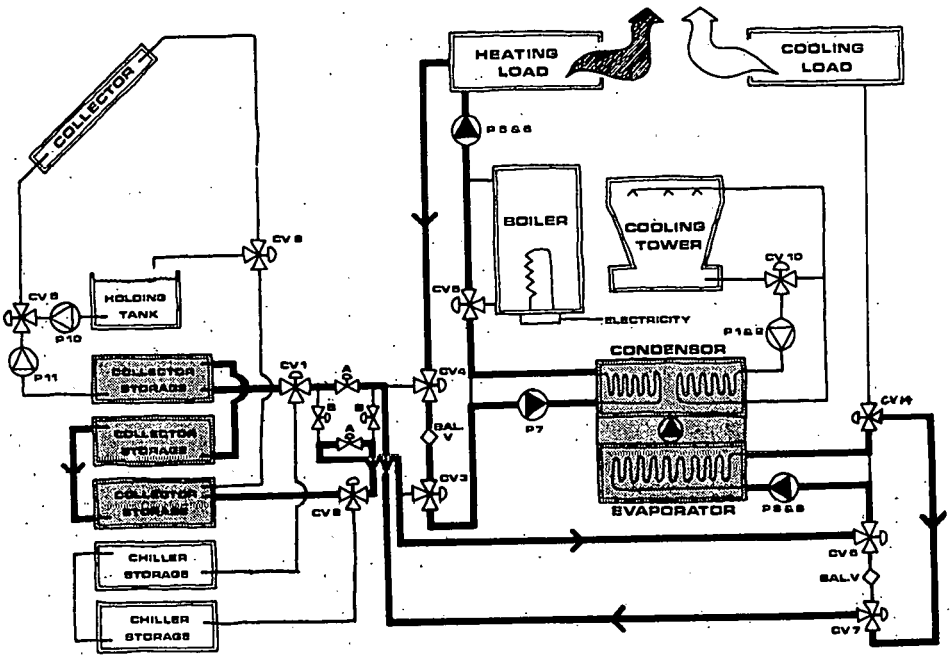
Based upon the results of the foregoing hour-by-hour analysis, and calculation of the resulting storage tank temperatures, the operational modes of the system could be determined for each hour in a manner identical to that in which the system is actually controlled. In this manner, the energy requirements necessary to accomplish each mode of heating or cooling could be determined and a thorough analysis of the energy savings obtained. This analysis was conducted for both the solar assisted heat pump system and a conventional (nonsolar) heat pump system for occupied and unoccupied days for each of the nine months of the heating season. Figure 3 shows the typical results of this system energy comparison for an occupied day in February. It can be seen from this figure that the analysis indicates an energy savings by the solar system of per day.

It should be noted that in the preparation of the proposal the system was designed to provide 15,000 square feet of aperture area in the solar system. As indicated in the abstract, and explained in the Bidding and Construction portion of this paper, the system, as constructed, will comprise 13,120 net square feet.

The configuration of the solar collection sub-system consists of seven parallel saw-toothed rows each of which contain 98 solar collectors at 18.677 square feet per panel. In the proposal, eight rows of solar collectors were indicated; one row was identified in the bidding as an alternate to allow cost control of the total system cost.

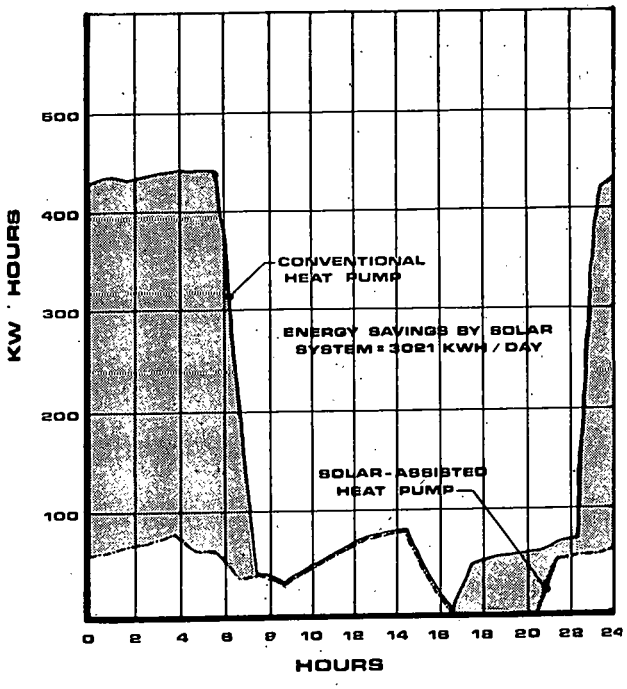
Each of the seven rows of solar collectors consists of 49 pairs of collectors connected vertically in series. The piping connections occur at the center of the collector array in a reverse return configuration. Thus, there is a maximum of 25 parallel circuits in any one loop of the piping system. This approach was taken to minimize the difference in flow rate between the collectors in any given loop.

Freeze protection for the system is provided by draining the contents of the solar collectors and the above roof piping into a separate drain back storage container. This is accomplished by the use of automatic control valves which isolate the pressurized distribution system of the building from the solar collection loop when it is desirable to fill or drain the collectors. There are extensive protections which are employed to provide system protection in the event of failures in the operation of individual pumps or valves, or in the event of an incorrect signal to the components from the control sub-system. Consideration was given to the employment of an anti-freeze method of freeze protection, but this was rejected due to the extensive maintenance requirements as well as the undesirable results of adding additional heat exchange requirements to the solar system.



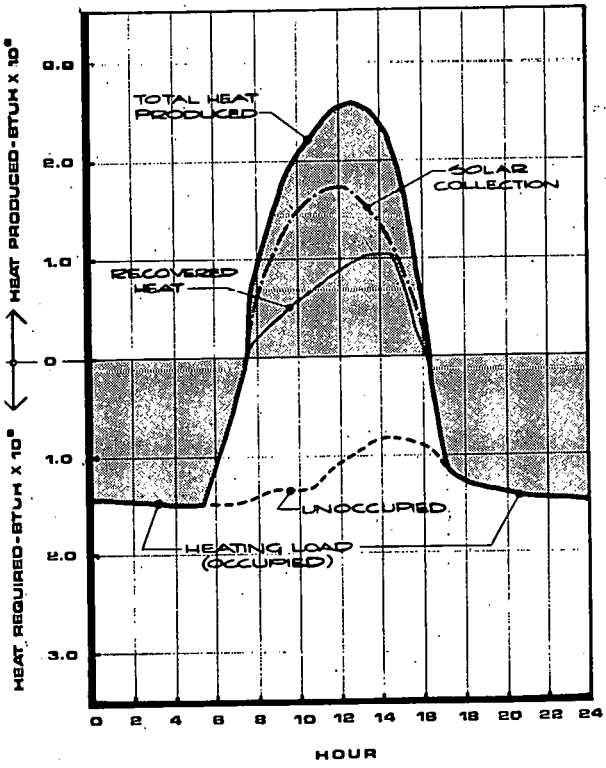
MODE E - HEATING (HEAT RECOVERY FROM SOLAR STORAGE)

Figure 1



SYSTEM ENERGY COMPARISON
OCCUPIED DAY — FEBRUARY

Figure 2



BUILDING THERMAL REQUIREMENTS / SOLAR PRODUCTION
FEBRUARY

Figure 3

PREPARATION OF CONSTRUCTION DOCUMENTS

Upon receipt of the award, the three professional corporations employed to prepare the proposal began the preparation of contract documents for the bidding phase. These contract documents consist of drawings and specifications which fully describe the solar energy system and its operation.

An important step in the preparation of contract documents was the identification of the collector manufacturer for the project. This was accomplished by conducting a separate bidding procedure prior to the initiation of the contract documents. A specification was developed to permit competitive bidding of the solar collectors by several manufacturers identified in advance. Using this technique, Sunworks, Inc. was identified as the apparent low bidder and the preparation of the contract documents was accomplished based upon the characteristics of the Sunworks Collector. All of the manufacturer's were required to submit evidence of compliance with testing procedures conducted in accordance with ASHRAE Standard 93-77, and to submit evidence of the capability of their units to undergo stagnation temperatures without substantial depreciation.

Additional stage in the preparation of contract documents was the discussion with the rotary chiller manufacturer, Dunham Bush Inc. Modifications to the in-place chillers permits more compatable operation with the characteristic temperatures produced in the solar collection system. These modifications were identified as an alternate in the bidding of the system for control purposes.

BIDDING

Early in 1978, bids were received on the specifications to supply solar collectors to the St. Charles School District for installation by others. The bids were received in the form of a base bid for 13,118 square feet of solar collector and an alternate bid for 1,458 square feet of collector. In addition, a stipulation of unit price was identified for the addition or deletion of collectors from either the base or alternate bids. This technique provided a method for collector manufacturers who provide panels of various sizes to compete equally. In addition, it allowed some modification to the system configuration during the detailed design and layout of the panels.

The successful bidder was Sunworks, Inc. with a price of $10.10 per square foot of net absorber area. The next lowest bid received was approximately $10.30 per square foot of net absorber. The two other bids which were received were substantially higher.

After the notice of intent to award had been made to Sunworks, Inc., the contract documents were prepared on the basis of the collector module which they were to provide. Bidding on the construction of the solar system was conducted in early April, 1978. The results of the bidding are shown in the following table. It should be noted that the base bid consists of the installation

of 13,122 square feet of solar panel, and the alternate consists of the installation of the remaining 1,458 feet of panel.

Bidding Results ($ in Thousands)

	Estimate	Low Bid Received
Structural Base Bid	126	215 (1)
Structural Alternate Bid	18	28
Mechanical Base Bid	300	296
Mechanical Alternate Bid	112	126

(1) $143 when rebid

As the table indicates, the bids received in the structural portion of the work were substantially higher than the estimate. The primary reason for this discrepancy appeared to be a poor competitive situation, since bids were received from only one structural contractor. For this reason, the structural bidding package was somewhat modified and re-issued. Successful bids of $143,000 were obtained in the second structural bidding. The overall project budget is approximately $566,000. It can be seen that the technique of identifying one row of solar collectors as an alternate was critical in the successful bidding of the project. The total bids received for collectors (132,000), structure (143,000) and mechanical installation (296,000) exceed the project budget by approximately $6,000. The St. Charles School District agreed to fund this amount. It can be seen that the total bidding was within 3 percent of the estimated cost. The overall costs for the installation of the solar energy system totals $43.61 per square foot of net absorber area. It should be noted that a major advantage was achieved in pre-bidding the solar collector panels from two aspects. First, it eliminated the pass-through markup which would have been applied by the installer had the collectors been bid in a more usual manner. Secondly, it permitted the preparation of contract documents which were exactly descriptive of the panel which would be used. This provides a more substantial advantage in the bidding of the installation of the system.

ADDITIONAL PROJECT ASPECTS

During the preparation of contract documents, the analytical techniques which were used in the preparation of the proposal were verified with a Westinghouse dynamic computer analysis. In addition, one year of operating data has been obtained with the building in a finished state (without the solar energy system). These two methods of verification agreed very closely with the analytical results predicted in the proposal.

An additional aspect of the project which was not included in the proposal is the provision of solar energy to provide swimming pool heating in an adjacent recreation center which is not directly identified with the project. The installation of piping to allow this transfer of heat will not be conducted using government funding. But the use of solar collectors during those portions of the year when excess solar energy is produced will further benefit the overall life cycle cost of the system.

One portion of the proposal which was disallowed by the reviewers was the data recording equipment to verify the actual operation of the system. Funding is being sought separately from DOE and other sources to allow the installation of monitoring and data gathering equipment to increase the educational aspects of the system for both the students and the solar community.

CONCLUSIONS

The project team feels that the overall project has been a substantial success to the present, and anticipates relatively few difficulties in the completion of the installation. Several important lessons were learned, particularly in the bidding of solar collector systems. Although tie confidence level of installing contractors is improving, there is still wide variation in bids received, making the estimation of system costs rather difficult. It should also be noted that the rather prolonged process of submitting a proposal, having it evaluated, receiving a contract, and designing and completing the system, has produced no major difficulties in this project, but must be taken into account in those projects where sequencing of operations in a fixed time schedule is important. Harry T. Gordon is a registered architect with the firm of Burt Hill Kosar Rittelmann Associates, 400 Morgan Center, Butler, Pennsylvania.

Northview School, Howards Grove, Wisconsin

Richard Linde, A.I.A.

Application - - heating system, forced warm air, zoned.
Collector Type -- fixed, non-selective, flat plate, 2 pass air.
Collector Manufacturer-- Sun Stone Solar Energy Equipment
Collector Area--2277 sq. ft.
Storage Capacity--1500 cu.ft., rock bin.
Total BTU's per year--378 x 10^6BTU/yr.
Owner/Contractor-School District of Howards Grove, Wisconsin
Designer--Linde·Groth Architecture

INTRODUCTION

The advent of solar heating for public school buildings in central Wisconsin confirms the dawn of maturity for solar energy alternatives in the western hemisphere. From now on the question will not be "is solar energy practical?", but "which solar energy system will be most cost effective for these criteria?". The practical considerations will now center on the problems of providing industrial capacity to meet the gushing demand for solar energy equipment of demonstrated effectiveness.

DESIGN PHASE

Relating Solar Heating Concept to Owner

The owner was faced with providing additional classroom space, and the public utility had declared that natural gas would not be available as a heating fuel, leaving only oil as a reasonable alternative fuel. The recent price hikes in the cost of fuel oil due to embargos, and exploration costs encouraged the owner to seek advice concerning solar alternatives. After reviewing the various types of systems and costs, the air type system was proposed by the designer and preliminary studies were authorized. The preliminary proposal suggested that a system large enough to provide between 50% and 60% of the annual building heat requirement could pay for itself in about 12 years on the basis of oil saved and a 10% per year increase in the cost of fuel oil. The proposal was accepted by both the School Board and the District Electors. (Ref. 1)

Solar Design Considerations

Maximizing solar effectiveness required minimizing heat losses.

1. Minimum window area - insulated glass.
2. Air lock type entrances.
3. 3" thick, rigid polystyrene wall insulation.
4. 3-1/2" thick mineral and urethane roof insulation.
5. Minimum ventilation air.

Also considered were orientation of solar panels, minimum shading, ease of installation and maintenance, and length of servicability.

278-755 O - 78 - 11

Designing the Solar System

1. Thermal analysis of the building was provided by consulting engineer. (Ref. 2).
2. Solar analysis of the integrated system was performed on computer program F Chart 2. (Ref. 3).
3. Control system for building heating system were isolated from solar control system to reduce costs.
4. The controlling aesthetic consideration was the appearance of the collectors. The panels were held back from the roof edge, and the color of the external surface was selected to match the color of the building sheet metal trim.

Integrating Solar Structure With Building Structure

The steel joist roof members were designed and spaced for the positive and negative live and dead loads of the collector system. Openings were framed for supply and return ducts to each array. The rock thermal storage bin was raised above the ground water level.

Preparing Contract Documents

The only significant variation in the preparation of the contract documents for this project and the previously typical building project was the addition of a fifth prime contract for the solar system, the definition of the lines of demarcation between the solar contractor and the other prime contractors, and the addition of an alternate to omit the solar panels should they prove to be outside the budgeted costs.

CONSTRUCTION PHASE

Thermal Storage Bin

Soil borings indicated a water level five feet below grade and therefore, since the borings were made during the dry season, it was decided to raise the thermal storage bin about 1.5 feet above this water level and to provide waterproofing and subsoil drainage around the perimeter of the bin foundation. The first problem encountered in the bin construction revolved around the insulation. The specified insulation was rigid to prevent crushing by the 2" rocks. However the insulation delivered was very compressable even though it was the specified material. The manufacturer had misrepresented his product in his literature. There was a considerable delay until the proper insulation could be delivered and installed. The second problem involved the rocks. They were to be 1-1/2" to 2" in size and washed. After several samples were submitted and rejected, suitable rocks were eventually supplied and placed.

Ducting System

The building duct system consists of underground cement asbestos air distribution pipes and overhead sheet metal return air ducts. Since the perimeter foundation walls were well insulated below grade, it was decided that the below grade supply ducts need not be insulated, but that they should be sealed against ground water infiltration. The solar supply and return air sheet metal ducts were sealed at all joints and seams, and insulated with 1-1/2" fiberglass duct insulation on the exterior.

Since all these ducts were above the acoustic tile ceiling, some adjustment of location was required to avoid interference with light fixtures and return air ducts. Special attention was given to the design of the sheet metal shrouds where the solar supply and return air ducts penetrate the roof structure at the center of each solar collector panel array.

Collection System

Steel channels were welded between roof joists at four foot centers under each collector array to transmit positive and negative live loads from the collector system to the roof structure. Compression plates above the roof membrane set in cold roofing cement provide the bearing points for the collector support framework. After setting, leveling and alligning the support framework, the collector panels were attached, anchored and all joints sealed against air leakage.

Control System

A differential controller with one sensor in the bottom of the rock bin and one sensor in the collector operates the solar system independently of the building heat control system. When adequate insolation strikes the collector and the differential controller senses that the collector air is 20°F warmer than the thermal storage air the following sequence is initiated:

1. The controller opens the 12 motor operated isolation dampers below the collector arrays.
2. When the damper blade is fully open it closes a micro switch to the solar fan relay.
3. The relay operates the switch to provide power to the solar fan.
4. The solar fan draws the warmed air from the collectors and distributes it across the top of the thermal storage bin.
5. The air is forced down through the rocks transfering the solar heat energy to the rocks.
6. The cool air is forced back to the collectors through a plenum at the bottom of the storage bin, to be reheated by the collectors. The air is filtered at each cycle.
7. When the sensors determine that the temperature differential between the collectors and the storage bin is less than 3°F the solar fan is turned off and the isolation dampers are closed.

The building heating system controls are designed to use all the stored energy in the thermal storage bin before adding heat from the oil fired system.

General Problems

The sheet metal union indicated its concern that the solar contractor was non-union by picketing the site for several days. The problem was solved by having the solar contractor work only on Saturdays.

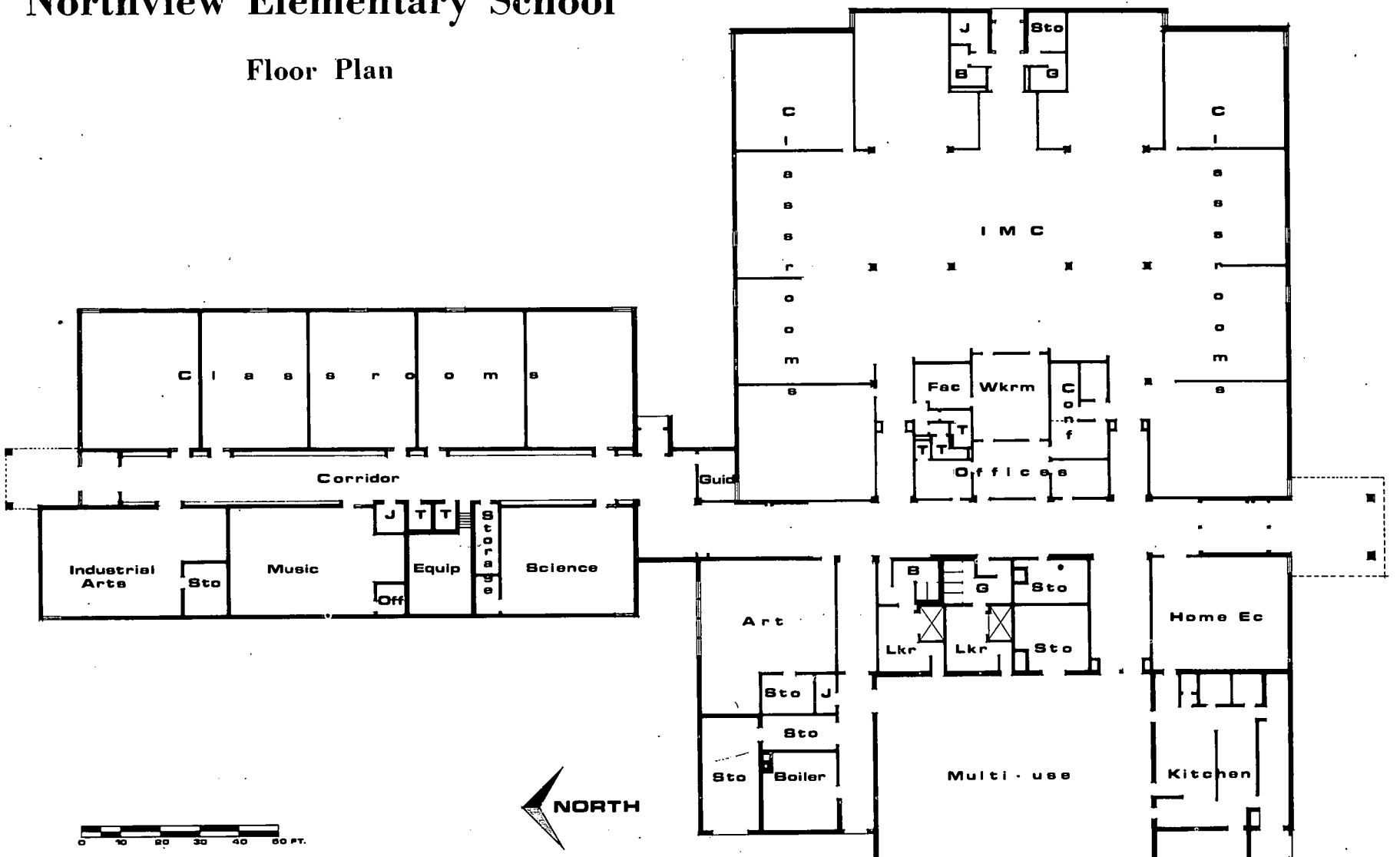
This site was selected for full instrumentation and a site data acquisition system. This caused several problems, primarily in the placing of flow meters to measure air volumes. Most of these problems were resolved by having the heating contractor provide air straighteners at appropriate locations to insure uniform laminar flow at the sensor location.

After the initial balancing of the air flow it was discovered that there was considerable air volume loss between the building fan and the zoned air supply ducts. Several leaks in the ductwork and zone dampers were discovered and corrective measures taken.

As part of its requirement under the agreement with D.O.E. to make the solar heating system available to the public a simplified schematic diagram of the system along with a brief explanation of the system operation was prepared in the form of a free handout to all interested visitors to the site. (Ref. 4 and 5).

Northview Elementary School

Floor Plan



Reference 1

M MECHANICAL CONSULTING ENGINEERS, INC.
GREEN BAY, WISCONSIN

HEAT LOSS CALCULATIONS: SHEET

JOB NAME NORTHVIEW SCHOOL ADD'N.

LOCATION HOWARDS GROVE WI
DESIGN ZONE #3

DESCRIPTION BUILDING ADDITION

WISCONSIN
WM. P. HARRINGTON E-9404 GREEN BAY WIS.
PROFESSIONAL ENGINEER

COEFFICIENTS OF TRANSMISSION & INFILTRATION

INDOOR DESIGN TEMPERATURE 67 °F %R.H. INSIDE ___
OUTDOOR DESIGN TEMPERATURE -15 °F

SURFACE R-FACTORS COMPONENTS	WALL	ROOF	GLASS	FLOOR	DOOR			
OUTER FILM	0.17	0.17						
OUTER SURFACE	6" SPANCRETE 0.61	BUILT-UP 0.33						
BACKING			INSULATING DOUBLE					
INSULATION	3" STYRO 15.0	3" 20.0	THICKNESS					
INNER SURFACE	½" D.W 0.45	AC. TILE						
INNER FILM	0.68	0.61						
TOTAL R-FACTOR	16.91	21.11						
U FACTOR	0.060	005	0.65		0.64			
SURFACE MULTIPLIER U × TEMP. DIFFERENCE	4.9 BTUH/FT²	4.4 BTUH/FT²	56.6 BTUH/FT²	40 BTUH/FT²	55.7 BTUH/FT²			

CODE	INFILTRATION	CFH / FOOT CRACK	MULTIPLIER BTUH/FT$_C$
A	NON-OPENABLE SASH	25	40
B	OPENABLE SASH	50	80
C	SECONDARY ENTRY	100	158
D	MAIN ENTRY	200	315

THERMAL PERFORMANCE:

$$\frac{98947 \text{ BTUH}}{17900 \text{ FT}^2} = 5.5 \text{ BTUH/FT}^2$$

BUILDING H.L. = 156,741 BTUH
O.A. LOAD = 165,929 BTUH
322,670 BTUH LOAD

BOILER OUTPUT = 452,000 BTUH

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1,LIQUID SYSTEM=2.....	1.00	
2	COLLECTOR AREA.....	2277.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.83	
4	FRPRIME-UL PRODUCT.....	0.99	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS.....	1.00	
6	COLLECTOR SLOPE.....	50.00	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).....	0.0	DEGREES
8	STORAGE CAPACITY.....	14.22	BTU/F-FT2
9	EFFECTIVE BUILDING UA.....	2366.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION.....	0.0	BTU/DAY
11	(EPSILON)(CMIN)/(EFFECTIVE BUILDING UA).....	2.00	
12	HOT WATER USAGE.....	0.0	GAL/DAY
13	WATER SET TEMPERATURE.....	140.00	F
14	WATER MAIN TEMPERATURE.....	50.00	F
15	CITY CALL NUMBER.....	88.00	
16	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.....	1.00	
17	ECONOMIC ANALYSIS YES=1, NO=2.....	2.00	

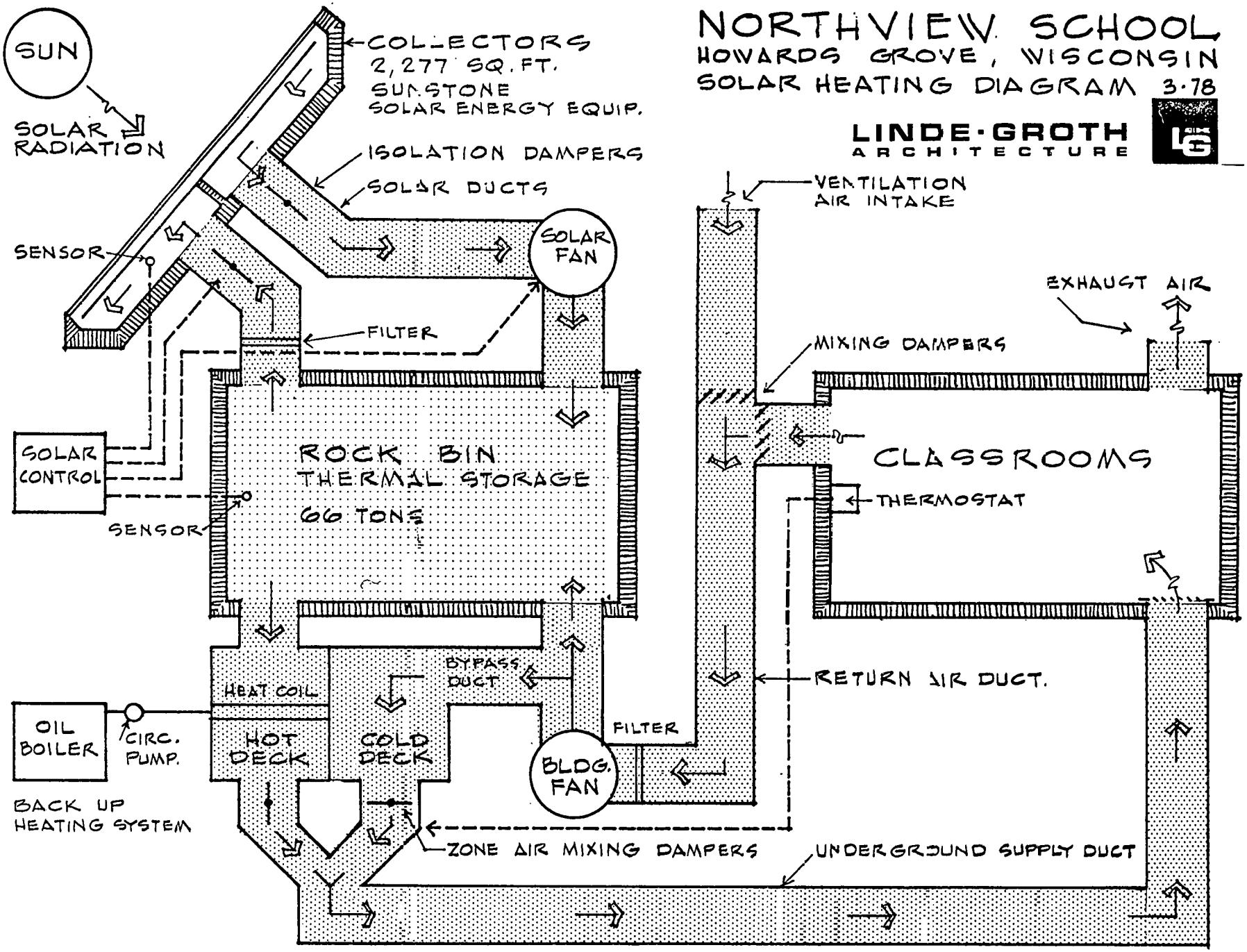
TYPE IN CODE NUMBER AND NEW VALUE

MADISON WI 43.08

NORTHVIEW ELEM SCHOOL ADDITION
HOWARDS GROVE, WISCONSIN
FCHART 2
ANALYSIS
JUNE 30, 1977

****THERMAL ANALYSIS****

TIME	PERCENT SOLAR	INCIDENT SOLAR (MMBTU)	HEATING LOAD (MMBTU)	WATER LOAD (MMBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	45.5	79.75	84.84	0.0	1494.	19.
FEB	57.6	82.98	71.09	0.0	1252.	21.
MAR	85.1	111.29	61.27	0.0	1079.	32.
APR	100.0	99.30	33.56	0.0	591.	45.
MAY	100.0	105.51	16.86	0.0	297.	55.
JUN	100.0	110.66	4.09	0.0	72.	66.
JUL	100.0	118.74	0.80	0.0	14.	70.
AUG	100.0	115.31	2.21	0.0	39.	68.
SEP	100.0	115.36	9.83	0.0	173.	59.
OCT	94.3	106.10	26.92	0.0	474.	50.
NOV	59.0	68.51	51.62	0.0	909.	34.
DEC	46.5	74.90	75.86	0.0	1336.	23.
YR	66.1	1188.41	438.94	0.0	7730.	


NORTHVIEW SCHOOL
HOWARDS GROVE, WISCONSIN
SOLAR HEATING DIAGRAM 3·78
LINDE·GROTH
ARCHITECTURE
SUN
SOLAR RADIATION
COLLECTORS
2,277 SQ. FT.
SUNSTONE
SOLAR ENERGY EQUIP.
ISOLATION DAMPERS
SOLAR DUCTS
SOLAR FAN
SENSOR
FILTER
VENTILATION AIR INTAKE
EXHAUST AIR
MIXING DAMPERS
SOLAR CONTROL
SENSOR
ROCK BIN
THERMAL STORAGE
66 TONS
CLASSROOMS
THERMOSTAT
BYPASS DUCT
RETURN AIR DUCT.
HEAT COIL
OIL BOILER
CIRC. PUMP.
HOT DECK
COLD DECK
FILTER
BLDG. FAN
BACK UP HEATING SYSTEM
ZONE AIR MIXING DAMPERS
UNDERGROUND SUPPLY DUCT

Northview School, Howards Grove, Wisconsin
Description of Solar Heating System - March 1978

1. Collectors There are six (6) arrays of 23 solar collector panels each on the roof of the addition. Each panel has a net face area of 16-1/2 sq. ft. for a total collector area of 2277 sq. ft. The panels are fixed in place on an aluminum framework attached to the roof structure with bolts. The collectors face due south and are mounted at a tilt angle of 50° from horizontal. The collectors use air as a heat transfer medium. The glass covers are 3/16" thick tempered glass. Metal ducts connect the collectors to the heating system.

2. Thermal Storage Underneath the utility room is a large insulated masonry box containing 66 tons of stone to store heat energy. When the rocks are heated to 120°F by the solar energy they contain enough heat energy to heat the building for about 8 hours on the coldest day.

3. System Operation The solar control is connected to 2 sensors; one is in the collector and the other is in the thermal storage rock bin. When the sun heats the air in the collector to 20°F warmer than the air in the thermal storage, the differential thermostat in the solar control closes an electrical switch which opens the isolation dampers and turns on the solar fan. The fan draws the coolest air from the thermal storage bin through the collectors. The air is heated by the absorber plate in the collectors. The hot air from the collectors is blown down through the rocks in the thermal storage bin where the heat is transfered to the rocks. The now cooled air is returned to the collectors for reheating.

The building fan runs continuously when the building is occupied. Return air from the classrooms is mixed with outside ventilation air before it reaches the building fan. The air leaving the building fan goes in two directions; part is directed through the thermal storage rock bin to the hot deck and the other part is directed through the by-pass duct to the cold deck. A thermostat in each classroom controls a pair of zone air mixing dampers that varies the amount of air from the hot deck and cold deck that goes to that classroom. The mixed air from the zone air mixing dampers travels through underground ducts to each classroom. When the solar heat stored in the rock bin is used up, the boiler provides hot water to the heat coil in the hot deck as required to keep the building warm. The boiler is large enough to completely heat the addition on the coldest day.

Reference 5

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A Review of Three Solar Energy Demonstration Projects in the Midwest

Emil L. Martinec

INTRODUCTION

Due to the rising costs and eventual depletion of fossil fuel, solar energy has become an important alternate energy consideration. Many recent solar heating clients, many building owners, in order to expand the knowledge and use of solar energy seek to communicate the possibilities and advantages of solar heating to the public.

Three projects initiated for these economic, ecological, and educational reasons are described in this paper. Though in many cases the entire project expectations were not met, the results are encouraging. Of the three projects, two have air systems and one has a liquid system.

Northview School, Howards Grove, Wisconsin

When it became necessary to plan an addition to Northview School, the owners, concerned over rising oil prices and the inavailability of natural gas, investigated solar heating. The forced warm air system seemed economically feasible. The payback was estimated to be 12 years, taking into consideration a 10% per year oil price rise.

Another consideration of the Northview School, as an educational institution, was that it be a demonstration of the practicality and necessity of solar heating systems. A view of the collector system installed on the roof of the school is shown in Figure 1.

The 17,900 sq ft classroom addition to Northview School was designed by Linde-Groth Architecture and the solar system was supplied by Sun Stone Solar Energy Equipment Co. The solar system uses air as heat transport medium and operates under four modes. Modes 1 and 2 are similar in that fresh air is drawn from the outside for classroom ventilation and the heat from the solar collectors is stored in a rock bed or used to supply some heat.

Mode 2 mixes return air from the room and mixes it with fresh air rather than using all fresh air as in Model 1. These modes are generally used during the warmer months when the school is occupied. Mode 3 is used in cold weather when the building is occupied and heat is supplied by the solar system and a conventional heating system (oil-fired boiler). Mode 4 is used in cold weather when the building is unoccupied and air from the rooms is heated by recirculating through the rock bed with supplemental heat supplied by oil-fired boiler, as needed. A schematic of the solar system is shown in Figure 2.

Esslinger Clinic, Traverse City, Michigan

Drs. John and Valentine Esslinger, in need of a new medical office building and aware of the increasing costs of conventional heating fuels decided to build a completely solar structure. The owners also wanted to draw public attention to the eminent depletion of our natural resources and the uses of solar energy to alleviate this problem. The building's location, across the street from a busy hospital, was ideal. The building was specifically constructed as an office

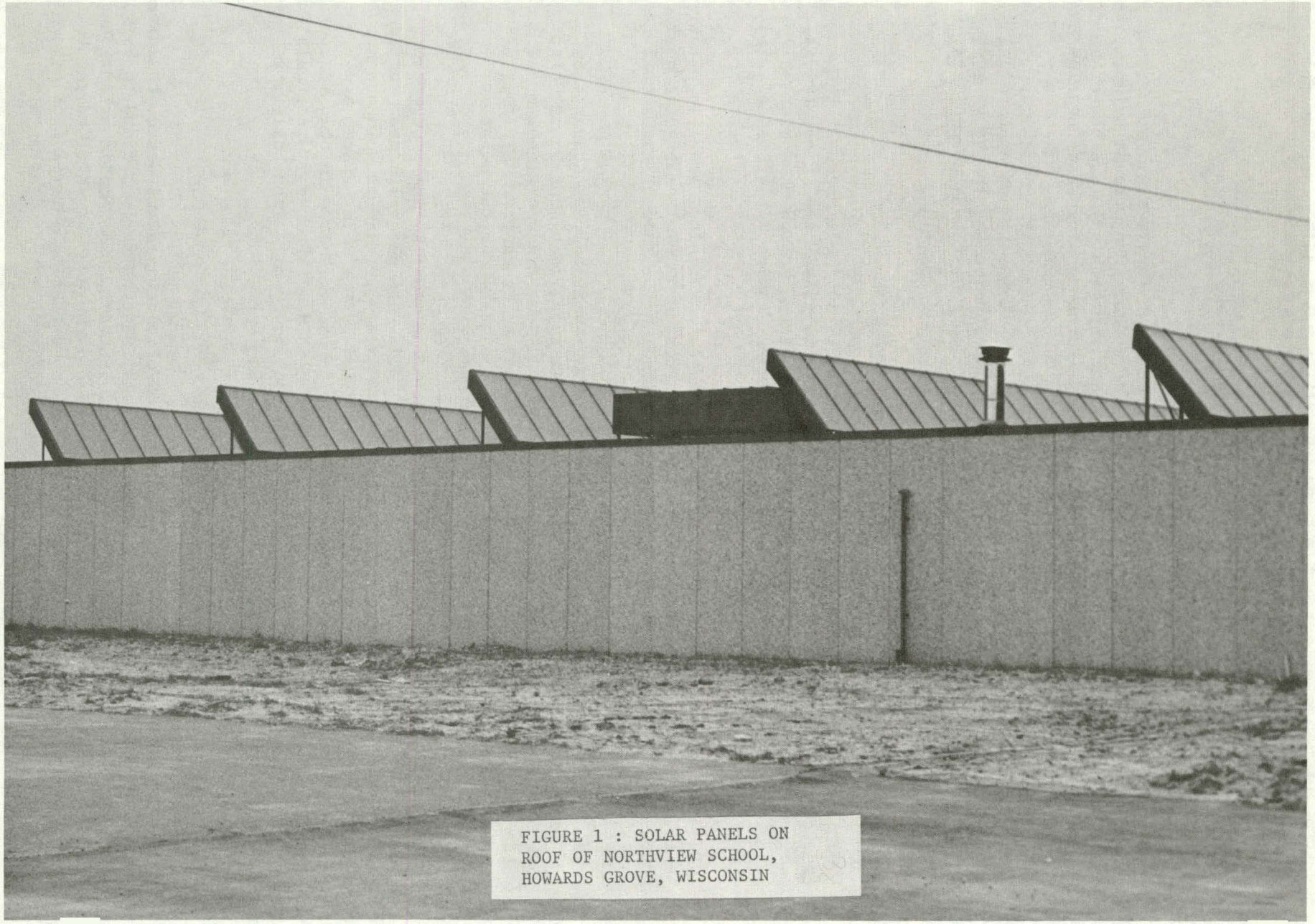
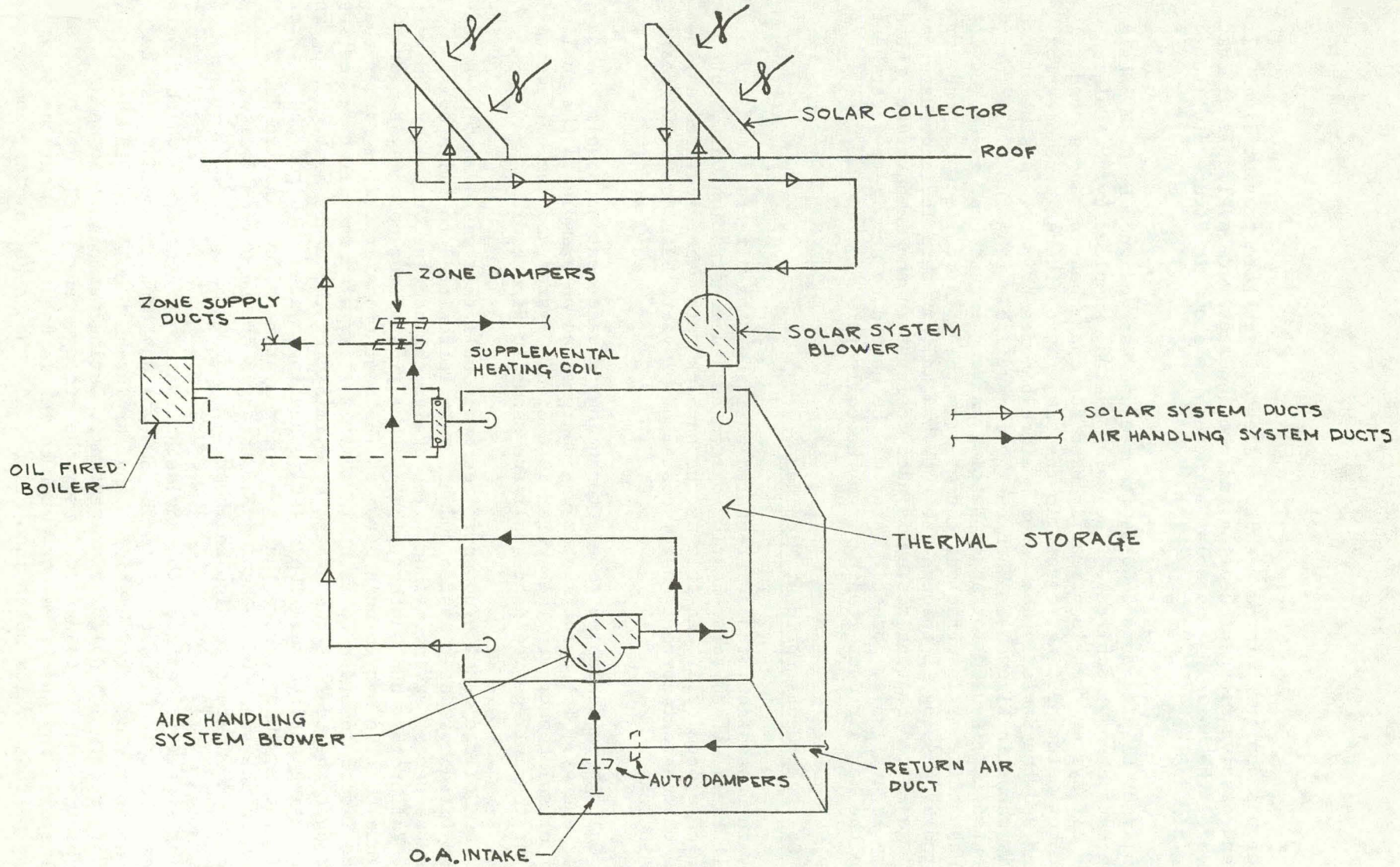


FIGURE 1 : SOLAR PANELS ON ROOF OF NORTHVIEW SCHOOL, HOWARDS GROVE, WISCONSIN



NORTHVIEW SCHOOL
SOLAR SYSTEM SCHEMATIC

FIGURE 2

building that was designed around a solar collector structure that utilized all the active and passive means of heating and cooling that were available at that time. A view of the building and solar structure is shown in Figure 3. The system is an air system.

The Esslinger Clinic has a 2600 sq ft area and was designed by G. M. Design, Inc., George Matsoutson, architect. The solar system, supplied by the Solaron Corp., is an air system that is primarily used for space heating and secondarily for domestic hot water heating, except in the summer when there is no need for space heating and the domestic hot water heating becomes primary. A schematic of the system is shown in Figure 4. When energy is available from the collectors, the solar heated air is used for space heating and any excess heat is stored in a rock bed. When there is insufficient energy from the solar collectors, the air will be heated by passing it through the rock bed and, if this is inadequate, a conventional gas-fired heating system is used to maintain the temperature. When excess energy is available, domestic water may be heated by an air-to-water heat exchanger in the hot air duct leading from the collectors.

Jordan College, Cedar Springs, Michigan

Already in possession of a solar-heated building, the directors of Jordan College built their second solar heating system as a demonstration only, not intending to be economically feasible as the payback rate was calculated as 150 years, based on constant current energy costs, or 31 years based on a 10%/year energy cost increase.

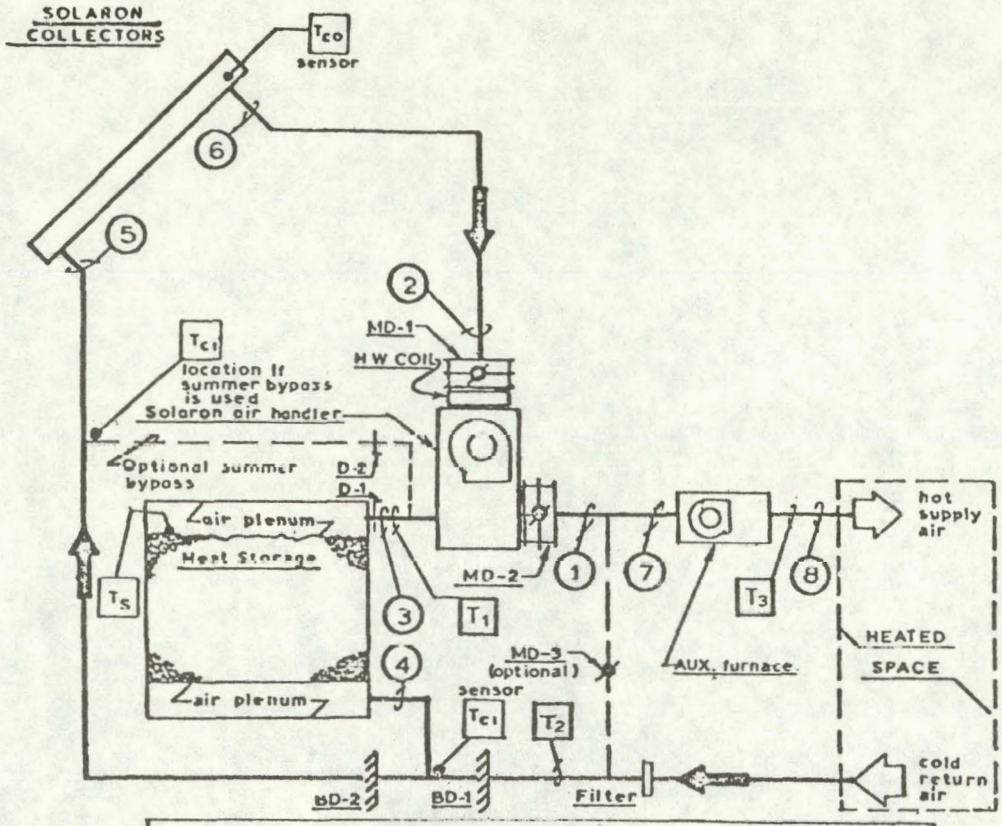
Jordan College is dedicated to the technology advancement and public education of solar energy. The solar system was designed as an example to the public of the power of solar energy. The system is a liquid system and the collectors on the roof of the college residence hall are shown in Figure 5.

The Jordan College has a 6700 sq ft residence hall that was heated by a conventional gas-fired hot water system and has been retrofitted to add a solar energy system as a cost saving method. The design engineering on the system was performed by Fairbrother and Gunther, Inc. Schematics of the solar system are shown in Figure 6. The system uses water as the heat transfer medium rather than an antifreeze liquid in order to maintain compatibility with the existing heating system and reduce the cost of the system by eliminating the extra heat exchangers required when using antifreeze. The existing heating system requires 180°F water and a glycol system would require that the solar system produce heat at 200°F which was not in the state of technology at the time of the system design, according to Mr. K. Gunther, design engineer.

The solar system is designed to provide hot water to a day tank which floats in the system. Heat is extracted from the 300-gal day tank and used for space heating and domestic hot water heating. Any surplus heat collected in the day tank is transferred to a 5000-gal storage tank. During periods of no solar insolation, heat energy is transferred from the storage tank to the day tank, as required. The existing gas-fired hot water boiler is used to augment the solar system during periods of low solar insolation. All the tanks, piping, and solar



FIGURE 3 : SOLAR COLLECTORS
ON ROOF OF ESSLINGER CLINIC,
TRAVERSE CITY, MICHIGAN



SOLAR HEATING FLOW SCHEMATIC

O = open
C = closed

SEQUENCE OF OPERATION

P.O. = partial open

MODE	MD-1	MD-2	BD-1	BD-2	MD-3	D-1 / D-2	pump	solaron air handler	aux. furnace fan	aux. furnace heater
HEATING FROM COLLECTOR	O	O	O	O	P.O.	O / C	ON	ON	ON	OFF
HEATING FROM STORAGE	C	O	O	C	P.O.	O / C	OFF	OFF	ON	OFF
STORING HEAT	O	C	C	O	O	O / C	ON	ON	OFF	OFF
HEATING WITH AUX. FURNACE	C	O	O	C	P.O	O / C	OFF	OFF	ON	ON
WATER HEATING (SUMMER)	O	C	C	O	O	C / O	ON	ON	OFF	OFF

FIGURE 4

ESSLINGER CLINIC

278-755 O - 78 - 12

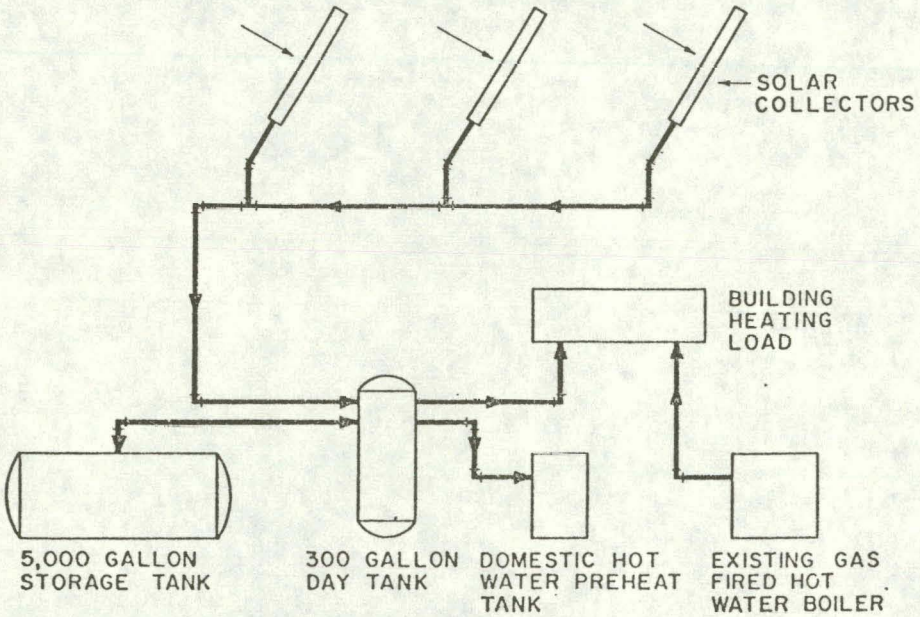


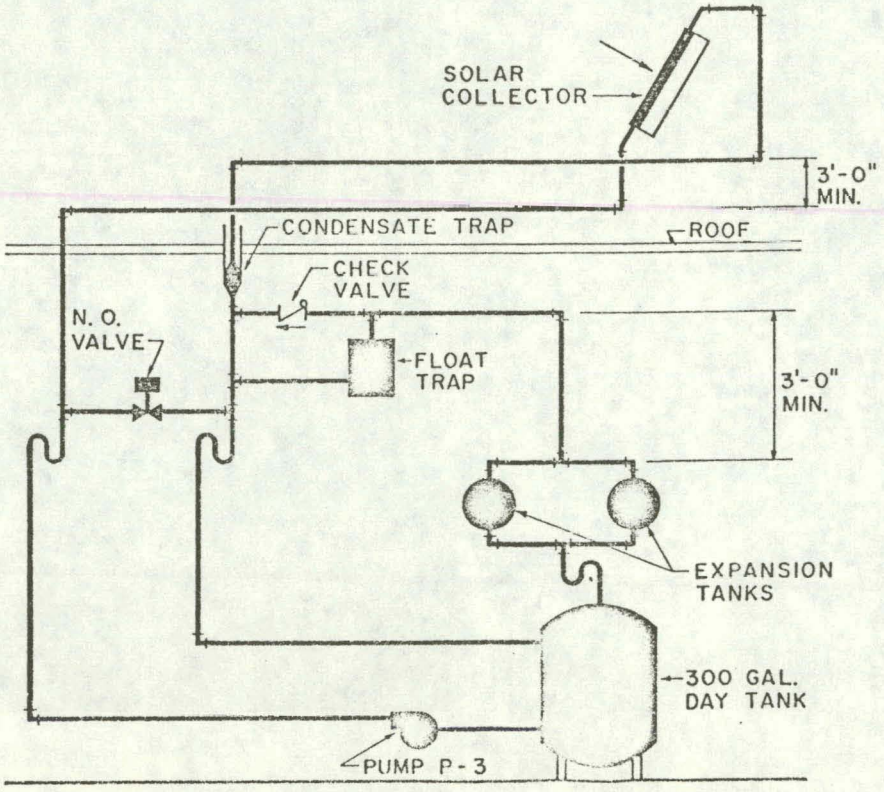
FIGURE 5 : SOLAR COLLECTORS ON ROOF OF JORDAN COLLEGE RESIDENCE HALL, CEDAR SPRINGS, MICHIGAN

FIGURE 6

JORDAN COLLEGE

SCHEMATIC OF SOLAR SPACE HEATING SYSTEM





system controls are located in an addition to the residence hall as shown in Figure 7.

The system is designed as a drain-down system so that when there is low solar insolation and the differential temperature of the water entering and leaving the day tank reaches 1°F, the circulation pumps shut down and the water in the solar collectors is automatically drained by siphon action into the day tank and expansion tanks.

CONSTRUCTION AND OPERATIONAL PROBLEMS

Northview School, Howards Grove, Wisconsin

There were very few construction problems of any magnitude that occurred during the construction phase. The sealing compound on some of the glass covers was not installed properly and resulted in air-leakage from the collector. Resealing the glass covers eliminated this problem. This site was selected for full instrumentation and data acquisition. There were several problems associated with the proposed location of instruments but these were handled during construction.

Operating problems associated with the conventional auxiliary oil-fired heating system are still prevalent. The oil-fired furnace is not operating properly and one backfire caused a considerable amount of soot to be blown over all the fans, ducts, and equipment in the utility room. The architect is still working with the contractor to get this situation rectified. Another operating problem is an inordinate amount of air leakage from the system, some of which can be isolated and the location of others is yet to be determined. The air leakage from the duct penetrations for the damper shafts can be eliminated by fitting small collars around the shafts. There is an unknown source of leakage which may be coming from the rock storage and is evidenced by a large amount of air leakage around lavatory drains that enter a pipe chase adjacent to the rock storage. Other leakage is evidenced by insulation dust being blown onto the floor near the baseboard in a room adjacent to the rock storage. Such leakage can materially affect the overall efficiency of the system.

The operating efficiency of the entire system has yet to be shown. The system has been operational early in 1978 and the solar unit provided all the heat for the classroom addition during April and May. This somewhat indicates that the solar installation is providing a portion of the heating load but the exact quantification of this information can only be established after the installation of the instrumentation.

Esslinger Clinic, Traverse City, Michigan

Other than minor items, there were few problems during the construction and installation of the solar system. Two collectors were vandalized by someone throwing stones that broke the glass covers and these units had to be replaced.

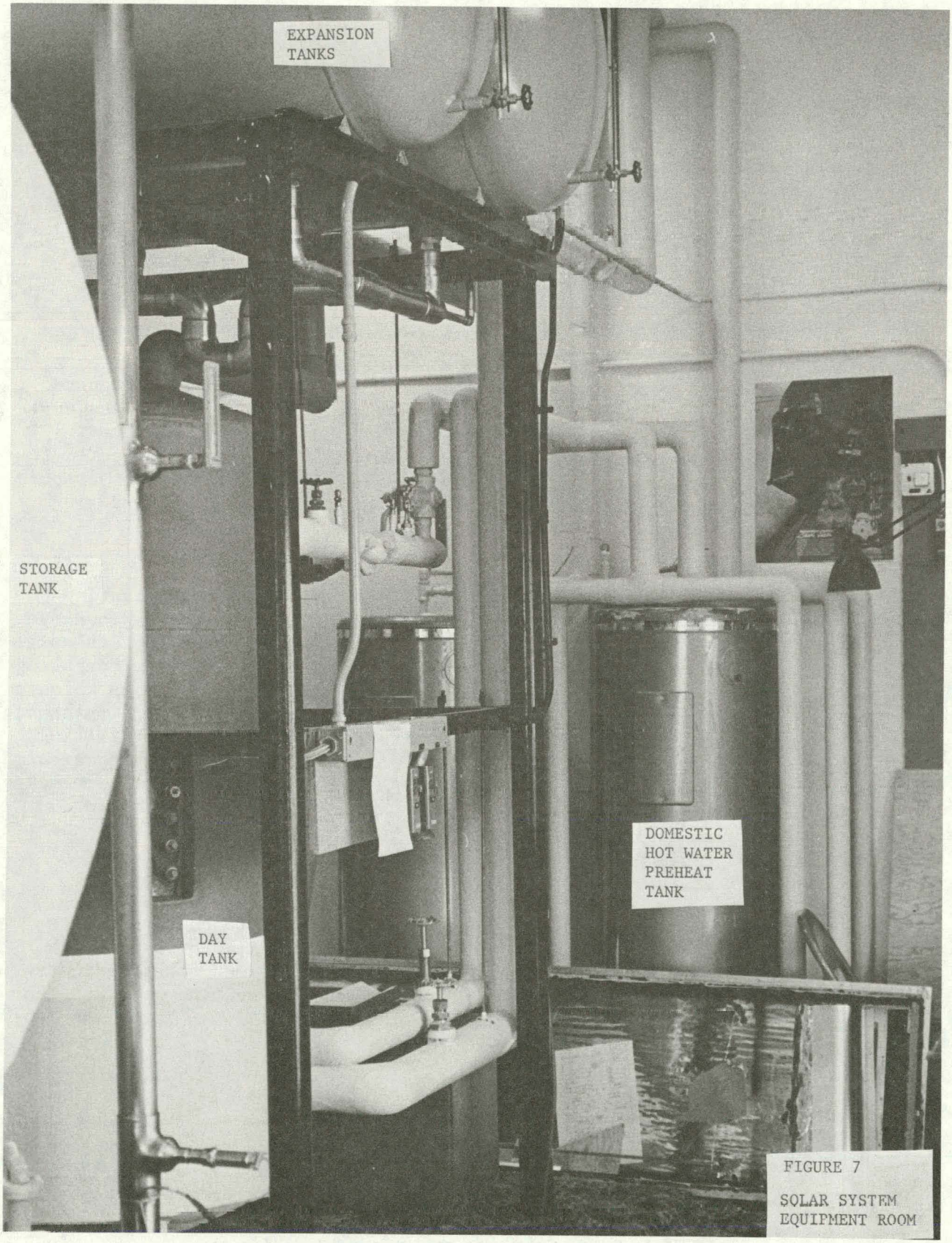


FIGURE 7

SOLAR SYSTEM EQUIPMENT ROOM

The system has been operational since January 6, 1978 and has functioned without any problems or difficulty. The only operational concern is that although the solar unit has operated quite well, the costs for auxiliary gas heat are higher than expected. This problem is still being investigated and the actual magnitude of the cost problems has not been determined or the analysis of the system itself been performed. Several potential reasons for this problem are being investigated such as inefficiencies or maladjustments in the auxiliary heating system, or maladjustments of the system dampers that may permit the backflow of air into the collectors.

Only two glass covers on the solar collectors have been broken since their installation. As the collector cover is a sealed, double-glazed unit, much like a thermopane window, the entire double-glazed unit must be replaced when one cover is broken. The only other problem with the collectors was that in some cases the glass expansion broke the neoprene seal and water leaked into the unit. These cases have been repaired and no such incidents have occurred since that time.

Jordan College, Cedar Springs, Michigan

The Jordan College solar energy system has had numerous construction and operating problems in almost every part of the system. The domestic preheat storage tank arrived with a large dent but was accepted in that condition as the dent would not affect its operation. There is some loss of collector efficiency because the 12 ft bank-to-bank distance is not sufficient to prevent one collector bank from shading the collector bank behind it.

During initial system operation, there was a problem with air continuously circulating between the expansion tanks and the day tank. Apparently the back-pressure on a check valve was not sufficient to keep the valve closed and air would be drawn from the expansion tank into the 2-1/2-in. collector return line and then back to the day tank. This flow problem was corrected by inserting a 3/4-in. beveled pipe into the return line to create the backpressure needed to keep the check valve closed and prevent air from entering the return line.

The greatest problem with the system was freezing of several collector panels. As water is the fluid used in the collector system, rather than a gylcol solution as used in other liquid system designs, the water must be drained from the collector system when there is insufficient solar insolation to prevent freezing of the water. When the system is shutdown, the water drains from the collectors into the day tank and causes the air in the expansion tank to be expelled into the collector return line and thereby into the collectors. On December 13, 1977, the system was shutdown but apparently a number of collector tubes and lower flexible connectors did not drain properly, remained filled with water, and subsequently froze. The freezing burst the collector tubes and the system could not be pressurized. The defective panels were replaced but the problem still remains of determining whether the entire system has drained properly. An attempt to determine proper draining by using infrared techniques was not successful. Other approaches are being investigated. It has been suggested that capillary action may be sufficient to retain the water in the tubes. The

problem must be solved before next winter if effective utilization of the system is to be realized.

Another problem with the collectors is the fogging of the collector's glass cover plates by some substance whose nature and source has yet to be determined. The fogging is thought to be caused by the outgassing of some material and its condensation on the cold glass plate. One suspect is the paint on the absorption panel and another is the insulation. The manufacturer of the collector panels is investigating the problem.

Several other minor problems that occurred during construction and initial operation have been rectified. An audible alarm that was to enunciate upon low system pressure was sounding in the unoccupied solar equipment room and this has been changed to sound in a remote location. Several of the replacement solar panels had been installed but not fastened in place when a violent storm came up and blew them over causing them to be damaged. The missing panels are still visible in Figure 5.

COMMENTS ON SOLAR COLLECTORS

There is a great diversity in solar collectors and their stage of design can be likened to the design of nuclear fuel elements in the 1950s. At that time there were a variety of flatplate and rod-type designs and it took a number of years before the state-of-the-art was optimized to the present state of design. I suspect that it will take a number of years before the solar technology is optimized to some standardized design.

The collector design varies in the design and configuration of the absorber plate, the cover plate, the supporting structure, materials, and surrounding factors. The absorber plate may be flat, cusped, finned or otherwise configured with each vendor vouching for the optimality and efficiency of their design. The type of coating for the absorber plate is usually propriety information.

The cover plates vary in number and material. Some units are single-glazed while others are sealed, double-glazed units. Sometimes Fiberglas or other plastic materials are used instead of glass. The type of material used in the cover is a factor in both the cost of the unit and the efficiency of solar collection. A considerable amount of research is being performed in the transmission of solar energy through various materials.

One vendor of double-glazed units uses a Lexan top plate to minimize breakage and vandalism. One designer claims that single-glazed units are preferable in northern climates because the heat loss through the single plate will cause snow to melt or slide off the unit more quickly than a double-glazed unit and thereby make the entire unit available for solar collection a greater fraction of the time. Designers of double-glazed units say this is a negligible factor and that snow buildup is not a problem. In either case the snow will have to be shoveled from the collectors after heavy snow or prolonged accumulation. (See Figure 8.)

Other factors in collector design may be the structure and roofing materials. One designer claims that reflective material on the roof adds 20% to the radiation

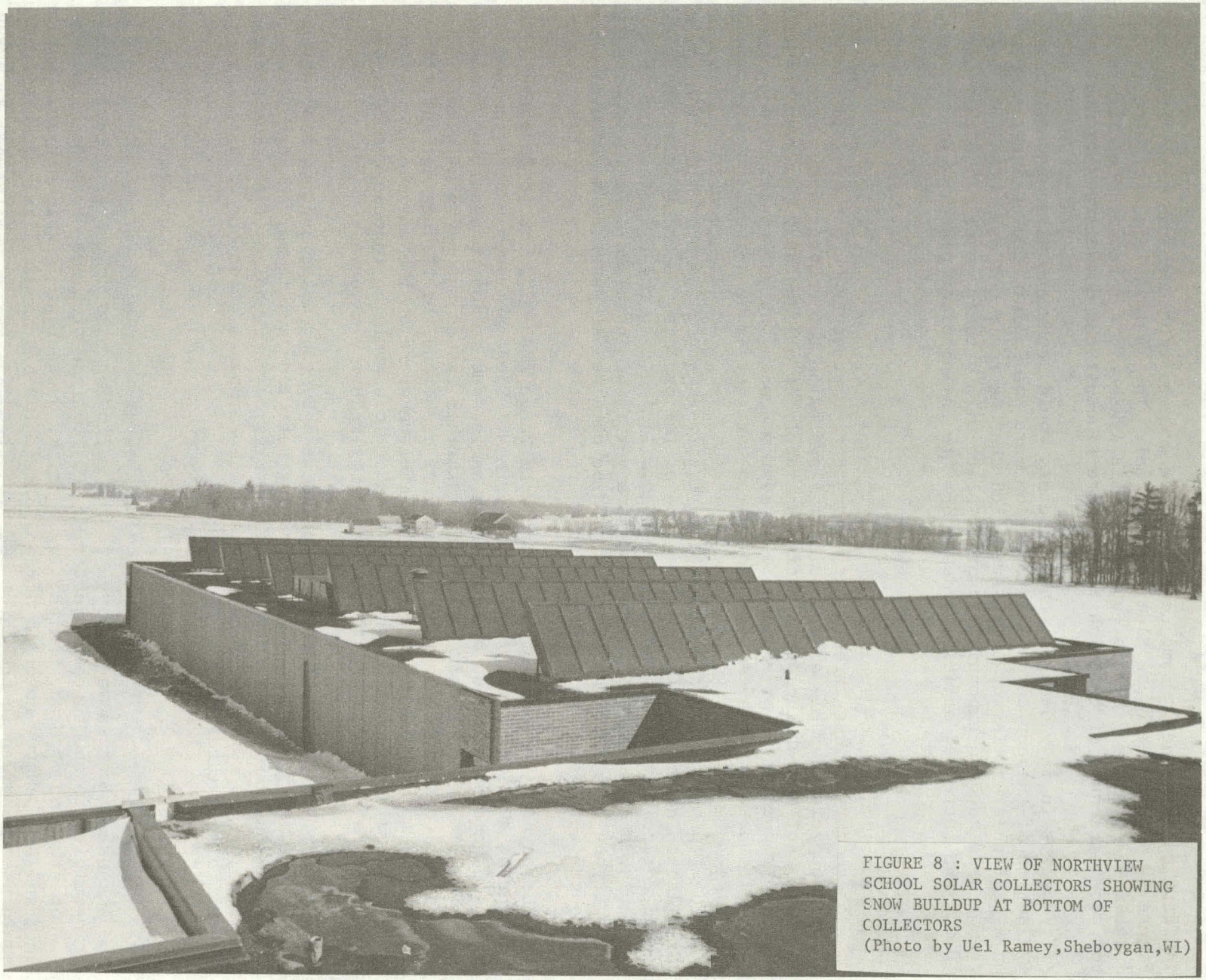


FIGURE 8 : VIEW OF NORTHVIEW SCHOOL SOLAR COLLECTORS SHOWING SNOW BUILDUP AT BOTTOM OF COLLECTORS
(Photo by Uel Ramey,Sheboygan,WI)

incident on the panel. Some designers use wooden structures, such as shown in Figure 9, while others use aluminum or steel. The latter claim that wood is less durable and prone to failure, and particularly should not be used for the collector panels because of the high temperature fluctuations during operations.

Such as in many designs, these factors could lend themselves to economic evaluation if the appropriate information were available. One engineer commented on a particular collector being evaluated that he could not understand why the vendor used such an expensive absorber plate with a cheap cover plate that may affect the increased efficiency designed into the absorber plate.

SUMMARY

In summary, these three solar demonstration projects have exhibited that solar energy is a viable alternate energy system to the conventional systems of today and for conserving our diminishing supply of oil and gas. However, as with any new product, type of equipment, or system design, all of these projects have had their share of problems, some of which have yet to be solved.

These projects are all in northern latitudes where the economics of a solar installation have yet to be proven. One of the projects is to be fully instrumented for collection of system data that will indicate the efficiency of the particular system and the instruments are yet to be installed. It is important for everyone concerned that as much data be obtained as possible to assure public knowledge of the economics of a solar energy system.

The payback periods for these projects range from 12 years to 31 years considering a 10% per year rise in oil prices. These analyses usually do not take into account the cost of money such as is used in most present worth analyses. The inclusion of this factor would further extend the payback period. This payback period is not acceptable because it is beyond the replacement lifetime of some of the major components and the capitol recovery on the unit would be inadequate. I would expect that these payback periods would be reduced considerably as experience is gained and the solar energy industry matures.

Finally, as stated by the Better Business Bureau, solar systems are part of a new and rapidly changing means of saving petroleum and it may be some time before any conclusive data are available to guide your choice of a solar system. However, just as sure as the sun rises in the morning, solar energy has a bright and promising future.

ACKNOWLEDGMENTS

Acknowledgment is to be given to the following persons who gave their time during visits to the three projects; Mr. R. P. Linde of Linde-Groth Architecture, Mr. Robert Grant of G. M. Design, Inc., Mr. K. Gunther of Fairbrother and Gunther, Inc.; and Dr. DeWayne Coxon of Jordan College for his hospitality. Acknowledgment should also be given to the three DOE project engineers, J. Zamirowski, F. Gorup and J. Hooper for their information and counsel they have given; and Ms. Kate Busch for her participation in the writing of this paper.

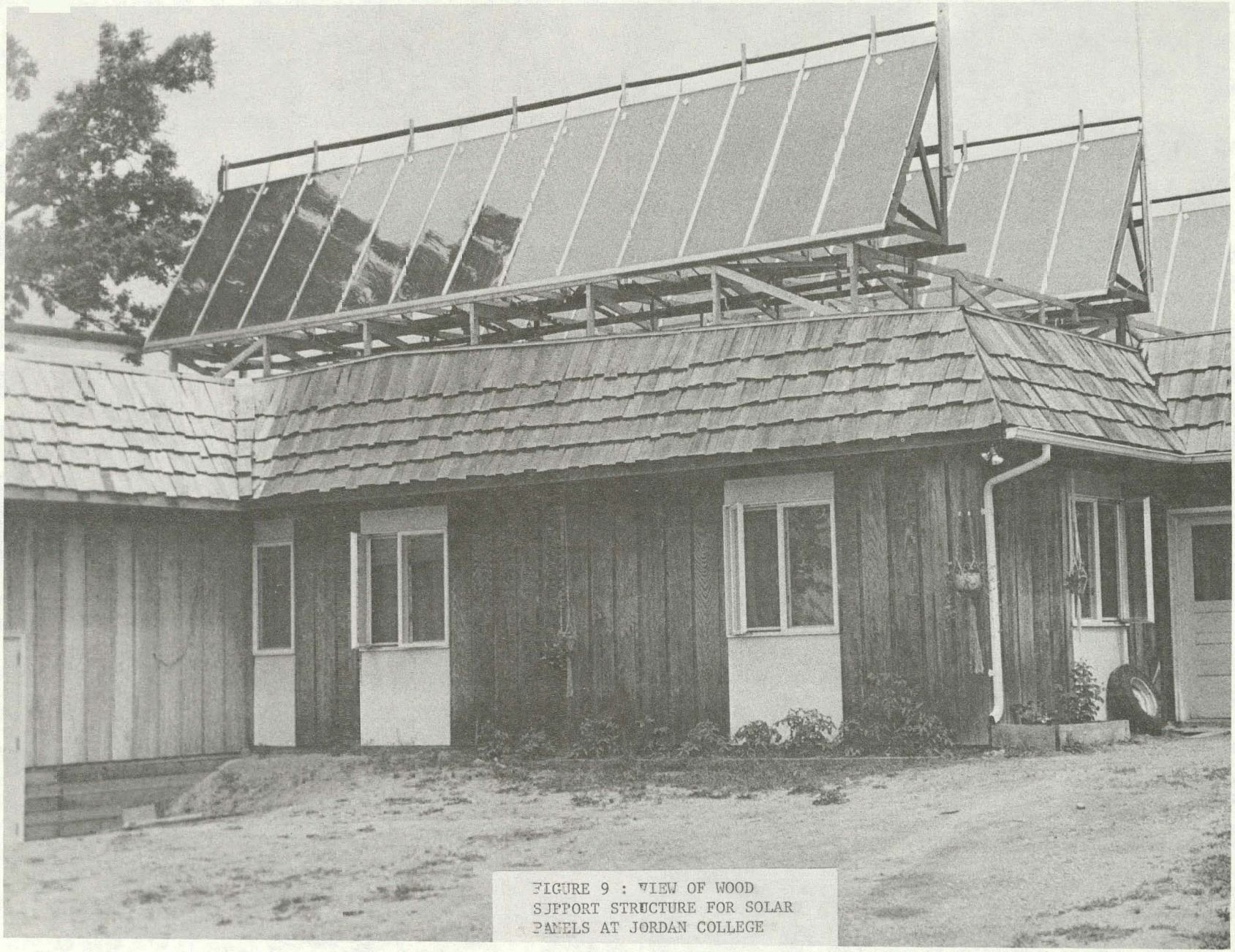


FIGURE 9 : VIEW OF WOOD SUPPORT STRUCTURE FOR SOLAR PANELS AT JORDAN COLLEGE

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Navy Pier Solar Demonstration Project

Bill Fagan

INTRODUCTION

A Solar Heating System is being retrofitted into a 60 year old building complex located on Chicago's downtown lakefront. The complex, Navy Pier, is a man-made peninsula extending over 3/5 mile into Lake Michigan and affording the joint advantages of public visibility and unobstructed solar access.

Lacking a permanent mechanical system, the East End complex has been available for use only during the non-heating season; the solar system, in conjunction with a conventional mechanical system under construction, enhances the opportunity for year round utilization of the Pier.

An information center located on the ground level Pedestrian Promenade will provide visitors with a close-up view of interface hardware and static collector displays. The information generated by the data collection activity in this center will be used in evaluating the feasibility of retrofitting existing buildings for solar energy harvest.

SYSTEM DESCRIPTION

Thermal energy collected by approximately 8000 square feet of solar panels is expected to furnish 33 percent of the space heating load and 100 percent of the domestic hot water load for the Terminal Building, a 36,000 square foot, three story masonry structure serving as the gateway to the East Complex. The solar panels themselves constitute a static display: the exterior of the array is exposed for its 500 foot length to the South Pedestrian Promenade and lake traffic and the panel underside is fully visible to building occupants.

SYSTEM COMPONENTS

The solar energy system at Navy Pier consists of a thermal energy collection loop, a heat exchange component, a thermal storage system and a conventional HVAC system. The scope of the contract includes all but the last component.

The Collector Loop consists of 300 solar panels arranged in two tiers of 150 panels each and subdivided into twenty-five equal groups or banks of twelve panels. The loop is a closed, pressurized system with relief valves located in the return main and air vents located in each return header. A thermal switch activates the circulating pumps (1 active, 1 standby) when absorber plate temperature exceeds 120°F during the heating season and 180°F during the cooling season.

The Working Fluid is a 50% concentration ethelene glycol solution with a nitrate-based corrosion inhibitor. This solution is subject to degradation at high temperatures and in the presence of oxygen; degradation creates a corrosion hazard in the case of the material used in this particular absorber plate. (Reference 1)

In an effort to eliminate the venting requirements altogether, the Department of Public Works in cooperation with fluid engineers from Doe's Chicago Operation Office investigated a silicone-based solution as an alternative working fluid. The low vapor pressure of this fluid precludes the need for vents.

On the basis of their findings (Reference 2), ethylene glycol is being retained as the heat transfer medium on this particular project. The major obstacles were: 1. Equipment and plumbing changes necessary to maintain design pressure. 2. Performance profiles and 3. Cost.

Manual Vents, which though they don't have to be located at the system high point and present a more stringent maintenance requirement, were installed with provision (knock out caps and plugged tees) for installation of automatic vents if required after start up in October, 1978.

The Thermal Energy Exchange System interfaces directly with, and hydraulically separates the collector loop and the storage loop. System hardware consists of a shell and tube heat exchanger. The solar domestic hot water system interfaces with the conventional domestic hot water system through a solar heat exchanger.

The Thermal Energy Storage System consists of two-7500 gallon above-ground storage tanks. A differential thermostat comparator energizes the storage loop pump when the collector loop outlet temperature exceeds the tank termperature by $12^{o}F$ and shuts off the pump when a temperature differential of $3^{o}F$ is reached.

INSTRUMENTATION

I.B.M. Corporation will install the three basic data collection elements: 1. Sensors 2. A SITE Data Acquisition Subsystem and 3. A Central Data Processing System.

Preliminary instrumentation of this system was defined by I.B.M. and revised as a result of a field meeting with the following modifications: 1. Two pyranometers, for the measurement of solar insolation will be installed because of the extreme length (500 feet) of the solar array. Partial cloud shading of a single instrument would give an erroneous determination of the actual energy available to the unshaded part of the array.

2. Inlet and outlet temperature measurements will be provided on the collector side of the excess heat rejection loop (solar system to lake water heat exchanger) to permit energy balance calculations when the system is in the warm weather operational mode. 3. Outlet temperatures will be monitored at four points along the array instead of the conventional single point because of the unusual array length and significant temperature gradients along the outlet manifold piping. This data will be used in connection with pyranometer data to identify collector sector energy contribution. 4. Temperature probes in the storage tanks have been modified to take readings at the top, middle and bottom to ascertain any layering affect. The original design called for a probe only at the mid-level.

CONSTRUCTION PHASE EXPERIENCE - SUMMARY

1. The decision to incorporate the solar collectors as an integral part of the building enclosure system was a distinct advantage in terms of ease of construction during severe weather, temperature stabilization in long piping runs, and protected maintenance. No problems were encountered in any of these areas.

2. Heat transfer medium evaluation or alternative solutions was a vaulable experience in determining which medium worked best in relation to performance, cost and equipment.

3. Panels must be protected by careful design of pressure relief vents. Panel manufacturer consultation and coordination is essential.

4. SITE meetings with the instrumentation supplier engineers were important in modifying and finalizing the data collection elements to insure an efficient and successful monitoring system.

5. No major problems were encountered during the installation due to the close co-ordination and cooperation of the Department of Public Works and its consultant, the construction sub-contractor, panel manufacturer and the Department of Energy. All have contributed substantially with their experience and expertise to a common solution to a difficult problem.

The conventional HVAC System is being installed and will be completed by October, 1978 at which time the solar system will be interfaced to it. We are anticipating a successful completion with the hope that this demonstration will contribute to the widespread use of solar energy at the earliest possible time.

REFERENCES

1. Design for a Solar Heating System, Navy Pier, Chicago, Illinois General Electric Company, G.E. Document 76 SDS 4236, June 1976.

2. Proposal to Substitute a Silicone Fluid for the Planned Water/ Ethylene Glycol Solution in the Solar Heating System at Navy Pier, Chicago, Illinois, City of Chicago, Department of Public Works, November 18, 1977.

Design Philosophy and Solar Configuration for Headquarters of Contemporary Systems, Inc.

John C. Christopher

INTRODUCTION

Contemporary Systems is a small, privately-owned New Hampshire corporation active in the design and development of solar thermal devices for space heating application. The scope of our company's work includes residential and commercial applications in both active and hybrid systems. Past projects have included installations in new residential construction, a bank, and a residential solar laboratory on the Manchester campus of the New Hampshire Vocational-Technical College.

Contemporary Systems is currently working on one of its most extensive projects to date. This is a combined solar heating and night-air cooling system to be integrated into the new CSI engineering and production facilities. This building is to be constructed in Peterborough, New Hampshire, and will incorporate many new concepts in solar design and materials application. The 7000-square-foot structure will consist of a two-level office section with extensive hybrid systems utilization and a production section with a large air-type active array comprising the south wall of the structure.

DESIGN PHILOSOPHY

The CSI organization is involved both in the development of component hardware on an experimental level and the production and installation of commercial hardware. The close ties that the developmental personnel have with applications personnel permit a constant flow of positive information from the field regarding refinements in design or application which will facilitate easier installation, enhanced performance or lower cost. It is apparent that increasing materials and labor costs are becoming a significant factor in the economic viability of solar space heating applications. The real costs of manufacturing and installing operational systems are becoming more fully recognized. Because of these constraints it is imperative that manufacturers, designers and installers use good design judgement in the configuration of their components and systems. The functionality of materials and components must become a prime design criterion.

The use of high performance materials which exceed the functional requirements of the system may insure results but may also destroy any economic viability the system may possess. The conditioning of living or working space in the temperate northern latitudes does not require sophisticated high-temperature, high-performance systems. Moderate performance in a low temperature range from 85°-125°F. provides a comfortable environment and allows the use of less sophisticated and far less expensive equipment. It also eliminates potential dangers to the structure and occupants that high temperature systems present.

The major advantage of low temperature operation is the significantly lower level of material degradation. This factor allows the usage of component materials that would not be considered in high performance systems. New glazings are possible other than glass.

Alternate absorber surfaces may be utilized, as well as less expensive insulation. The overall effect is a lower delivered cost per BTU and a longer system life. This whole concept can be expressed simply as "Don't catch all the heat -- just catch it cheaply."

A second aspect of functionality is multiple usage of materials. This requires that the materials or components perform two or more individual functions and thereby reduce the effective cost of accommodating each of the functions. A good example of this concept put into practice is the CSI integrated roof/wall collector system. In this case the collector performs its primary function of energy conversion and at the same time serves as a structural component of the roof. The collector has replaced roof sheathing, felt paper, nails and shingles, plus the associated labor required for the conventional roof. The collector has in effect become the roof rather than an addition over the existing roof.

Also possible is the creation of a definitive architectural effect or texture. If well integrated into the structure, the array can be an enhancing feature of the building rather than something which is just tolerated.

DEMONSTRATION PROJECT

The CSI headquarters that is now in the design stage is a commercial demonstration project funded under PON DSE 76-2. The structure is to be divided into several distinct functional areas, each utilizing various techniques for both active and semi-passive solar collection. The structure will be located on U.S. Rt. #202 in Peterborough, N.H. The site was selected to take advantage of good solar exposure with an orientation that would afford good public visibility. Specific attention was given to the overall visual effect of the solar array. The building had to be visually pleasing if it was to serve as a positive demonstration vehicle and encourage further commercial applications.

ACTIVE SYSTEM

The CSI Series V collector unit was selected for the active array on the south wall of the structure. This array is 1200 sq. ft. in area and is an integral and structural element of the sloped south wall. It is externally manifolded in a parallel configuration on the inside collector face. The common input ports are on the bottom and common output ports are on the top. Conventional rigid fiberglass duct board is used for this purpose. Individual balancing dampers are used on each collector to insure uniform air distribution. The collector forms a weathertight external skin. The array is operated at negative pressure to control losses of heated air from the collectors and to give better overall thermal performance. The output air at temperatures ranging from 85° to 125°F. moves from the array and then through the fan and valving unit which directs the flow to its required function. To facilitate efficient air transport a backward curve fan is utilized and driven by a high efficiency motor.

The use of an aerodynamically

designed fan with efficient air moving characteristics over a wide range of delivery is essential to low-temperature air systems. It is equally important that a high efficiency electric drive motor be selected which will match the requirements of the system. The CSI project will be using Buffalo Forge BL type fans with a 16 1/2-inch rotor. This is a single inlet fan which is integrated directly into the air valving unit. The valving device or "Universal Switching Unit" forms a one-piece assembly which contains all required valving and air moving equipment for a simple three-mode system. The incorporation of all of these elements into one package greatly reduces design and installation time as well as providing a pre-engineered flow path that assures uniform results. The office area storage vault is segmented into two units to allow the concurrent functioning of both heat storage/discharge and night-air cooling storage. This dual functioning will occur in late spring and fall when both heating and cooling may be required. It will allow the use of night air cooling of the primary cooling vault while the primary heating vault is being used

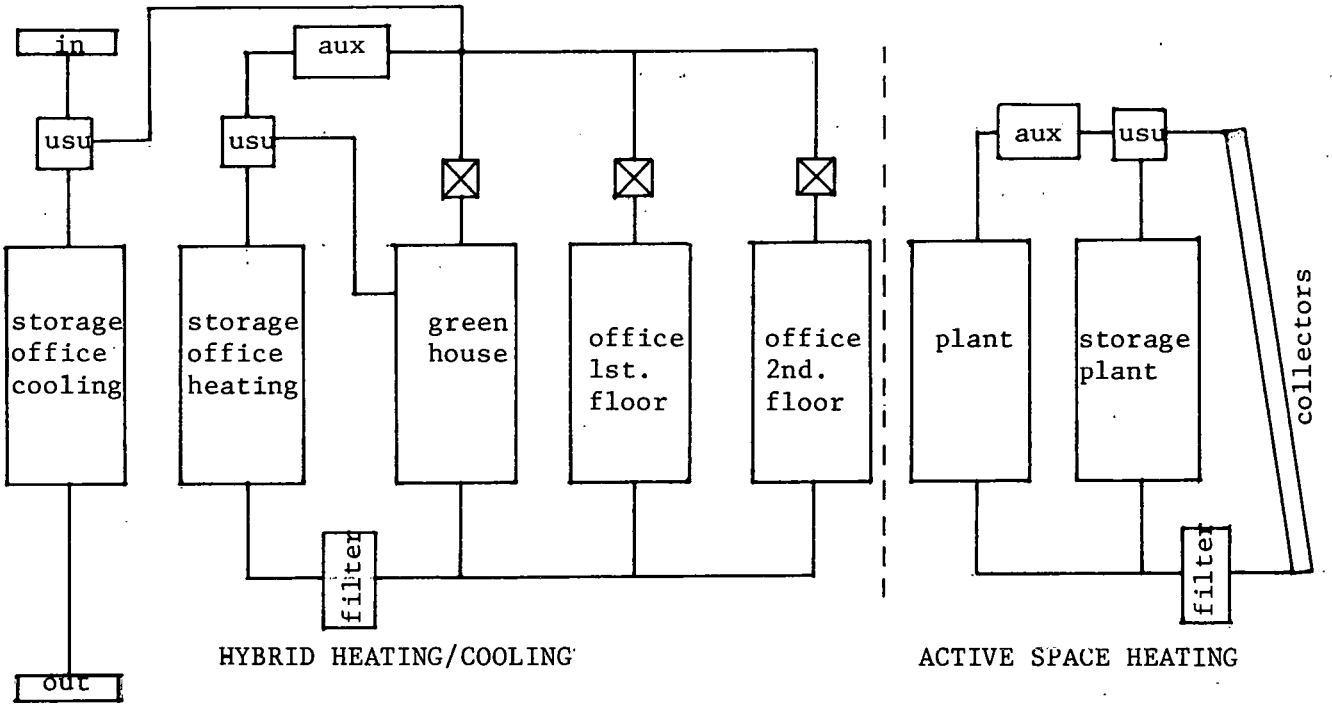


Figure 1. Schematic Diagram of Solar Energy System

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for heat storage.

PASSIVE SYSTEM

The passive components of the office wing have four distinct segments. Upon entering the building there is a glazed foyer which is separated from both the office and production sections. This area performs in a manner similar to a greenhouse, except that rather than glass as a glazing material, a double wall acrylic sheet material is used. The sloped top section can be closed off by means of a mechanical reflective shutter to control night losses and summer gain. This design allows the foyer to receive the total benefit of passive solar gain during the heating season and to exclude this radiation in the non-heating months. The thermal output of this section is removed from the second floor level and transported to storage.

The second segment of the passive system is simply the use of several window elements located in rooms on the southern side of the building. There is no storage associated with these elements; however they are small enough to just provide localized lighting and space heating.

The third element of the passive system is the clerestory lighting elements located in the second level above the engineering and computer center. These window elements are glazed with an optical material that will provide a high degree of dispersion. Control of radiation from the clerestory is of great importance so as not to adversely affect working conditions below. The clerestory will provide general lighting and controllable space heating. The window will control beam radiation so as to avoid glare in the work space below.

The fourth segment of the passive system is the high performance

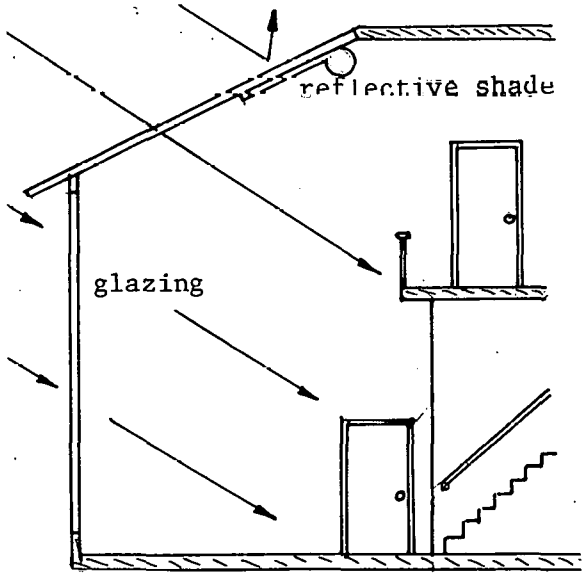


Figure 2. Foyer/Greenhouse

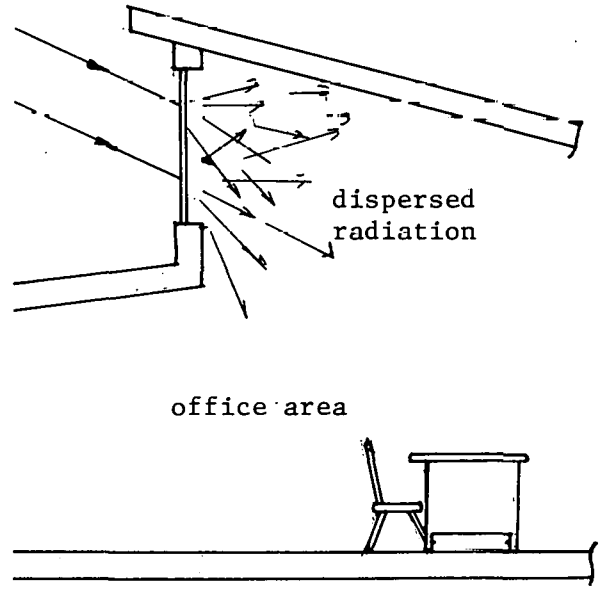


Figure 3. Clerestory Lighting

solar skylights in the production area. These devices provide a high level of solar gain in winter months, thus providing needed general lighting and space heating. Their thermal loss is significantly reduced due to a high aperture to roof penetration ratio.

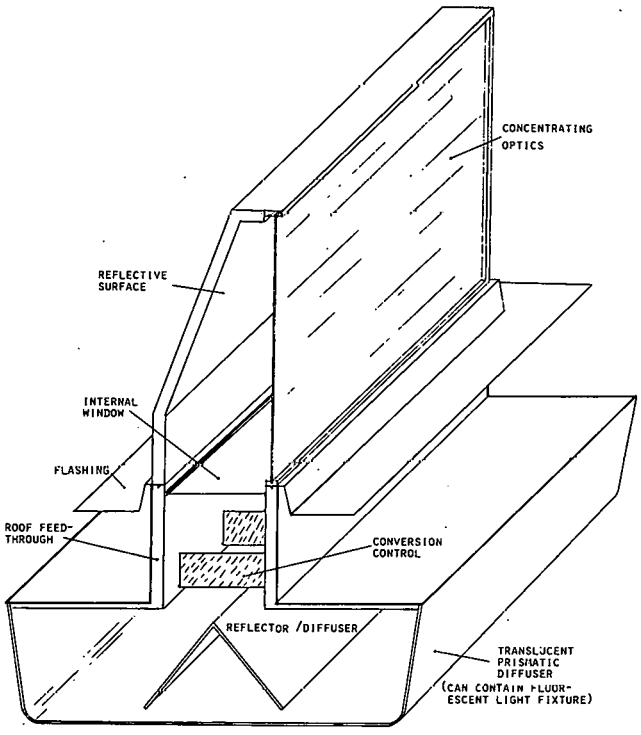
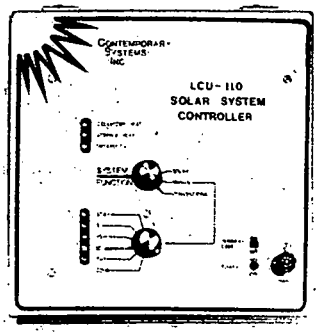


Figure 4. Solar Skylight

CONTROL SYSTEM

Control of the active and hybrid systems will be implemented by the use of two standard Contemporary Systems LCU-110 solar control units. The logic requirements of both systems are very similar and the programmable capability of the LCU-110 will accommodate the specific requirements of each system. The control outputs of the LCU-110 are plug compatible with the USU-A and B air moving systems.

The SOLAR CONTROLLER Logic Control Unit LCU-110



Designed For Optimum Control Capability In Air-Type Solar Space Heating Systems. Advanced Computer-Style Construction Techniques Provide Reliable Operation And Easily Accessible Board Replacement Servicing.

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PROJECT OBJECTIVES

The total effort in this project is to produce a commercial system that will have the potential for reproducibility. It is not intended as a one-time engineering exercise. Each component will have the potential for re-application in similar projects. The clerestory lighting and skylight system will have broad application in any commercial building that needs controllable lighting and/or space heating. It provides comfortable lighting levels without the use of mechanical devices. The foyer/greenhouse will provide a working model for the mechanical configuration of a solar foyer. This could easily be a simple addition to any commercial building and converts a decorative aspect of the structure into a functional system. The active array is an application of an already

proven technology to larger commercial installation. It is unique, however, in that it will evaluate the suitability of night-air cooling to our northern New England climate.

It is hoped that the thoughtful integration of solar devices into this project will provide a functional, effective and visually pleasing project which will serve to promote the further acceptance of solar utilization in commercial structures.

Cary Arboretum Solar Project Update: Design, Submittal, Construction and Operational Problems

Daniel F. Brown, Project Director

INTRODUCTION

The Cary Arboretum's Plant Science Building is a new 27,400 sq. ft. branch education and research facility of the New York Botanical Garden, located in Millbrook, New York, between Albany and New York City. The Cary project was conceived by staff ecologist, Dr. Robert Goodland, in 1972, before the recent rise in foreign oil costs. The idea was embraced by its parent organization and by the Mary Flagler Cary Charitable Trust, which supported its construction. The building design was approached as an opportunity to demonstrate responsible conservation methods and energy use alternatives as part of a holistic concern for world ecological issues. The design goal was to reduce the use of non-renewable energy resources in the built environment and thus, by demonstration, serve as an example to others who would follow. Passive energy collection storage and distribution, extensive energy conservation, and appropriate use of natural resources were integrated at the conceptual design level with active solar collectors, supplemented by a solar assisted heat pump, to meet all the building's heating needs.

Architect Malcolm Wells and engineer Fred Dubin were commissioned in April 1973 to perform energy use studies and prepare an energy program for the building. Dubin's preliminary decisions and Wells' preliminary plans were approved in April 1974. The writer joined the project in May 1974 to coordinate and supervise the project for the owner. The project was bid in October 1975, and, after negotiation, John Lowry, Inc., of New York City was selected as General Contractor. with C. B. Strain of Poughkeepsie, New York, mechanical sub-contractor. Construction began in April 1976, and the owner took beneficial occupancy in April 1978.

Cost sharing for the solar system was provided by the U.S. Dept. of Energy and the N.Y.S. Energy Research and Development Authority. The project is heavily instrumented by the owner with a computer-driven Robertshaw digital monitoring system. The owner is presently seeking funds to analyze the performance of the buildings's energy systems and to disseminate the resulting information.

The lessons the owner has learned from the design, construction, start-up and initial opeartion of the Cary project are the subject of this paper. While the final results are not yet in, indications are that, on balance, the project will perform as required to meet its original purpose. We are grateful to the Dept. of Energy and the NYSERDA for their support in helping us to meet the contingencies which have arisen. We are happy to share with others information and solutions for problems encountered so that they might be avoided in the future.

BUILDING DESCRIPTION

The two story building is "U" shaped and is mostly below ground. The open part of the "U" faces east and uses stepped-down planted terraces to introduce light to the lower floor library areas. The north, east and west sides of the building are heavily bermed with earth to reduce the area of the building's skin exposed to wind, as well as increase the area of perimeter wall subject only to ground temperature (50°F) outside conditions. A hemlock forest close to the north and west side of the building further acts to reduce wind chill losses.

Circulation in the primary and secondary loops is started-up by a signal from an inclined pyronometer (to reduce cycling of the pumps). Heat is dumped into one or both of the lined concrete storage tanks (5000 gal. and 10,000 gal.) when the circulating liquid exceeds the temperature at the top of one or both tanks. The primary and secondary pumps are interlocked for two speed operation to maximize efficiency in the collector panels.

The solar system is designed to furnish 85% of the annual BTU requirement, putting 105°F liquid directly into the storage tanks (through tube and shell heat exchangers). When the collection temperature drops below 105°F, it is stored in one of the tanks and is used as the heat sources for the water-to-water heat pump (chiller). When solar assisted, the heat pump will produce a COP of approximately 5. The back-up heat source for the heat pump is well water at 49°F, producing a COP of about 3.

PROBLEMS AND SOLUTION APPROACHES

The project has had a varied set of problems related to design, submittals, construction, start-up and initial operation of the heating system. Some of the problems delayed completion and start-up of the system and were costly to remedy.

Design Problems

The degree days listed by the Naitonal Oceanographic and Atmospheric Administration (NOAA) for Poughkeepsie, New York, is 5824. Millbrook, 17 miles to the northeast, is listed at 6738, a 16% difference. During design, the figure for Poughkeepsie was used because 1) the Millbrook listing was overlooked and 2) it was assumed there would not be a significant difference. (The difference is due to Poughkeepsie's urban location, adjacent to the Hudson River, and to the higher elevation and rural location of Millbrook. Fortunately, the difference will be overcome because the owner (before the discrepancy was known) opted to add a seventh row of collectors (a 17% increase) "as an insurance factor", even though it would have adversely affected payback in the original design.

The design assumption of well water temperature 57°F. No actual temperature readings were taken when the wells were drilled. Since well water is the back-up heating source to the solar assisted heat pump (chiller), it is essential that the hat pump operate with well water. During start-up the chiller shut down on freeze protection and the well water was actually measured at 49°F, one degree lower than the minimum operating temperature of the chiller. After a period of anguished investigation, it was discovered that since the chiller was sized for the cooling load, it would be possible to operate the chiller with 49°F well water on two cylinders, and still provide the required heating. A simple selector switch was installed to prevent the chiller from stepping up to four cylinders during the winter heating mode.

The structural supports which carry the collectors free of the roof were originally designed as 3"x8" common lumber, supported on 11 foot centers. The wood deflected unevenly and in some cases warped. To avoid undesirable stresses on the collector panels and unsightly waves in the arrays which could have caused drainage problems in the piping, the supports were changed to 10" steel channel sections. This was an expensive and time consuming change.

The thermal storage tank insulation originally selected by the architect

was styrofoam. It was discovered during submissions that styrofoam would degrade if subjected to the high temperatures anticipated in the storage tank. Other insulation materials reviewed were discovered to be partly hygroscopic. Foam glass was finally selected for below grade and bearing locations, as well as the tank tops. Side walls above grade were insulated with a combination of urethane board (nearest the tank wall) and styrofoam.

Due to the small cross-sectional area within the Chamberlain absorber plates, Chamberlain recommended the primary solar piping be cleaned with a special cleaning solution to remove debris before hook-up to their collectors. While the piping was flushed with water, no provision had been made in the specifications for special cleaning and one was done. When a sample was taken after the system was charged, a relatively high degree of turbidity was noted. The feedwater consultant recommended an electrostatic water treatment column be added to the closed, primary loop.

Propylene glycol was specified for the heat transfer solution for both the space heating and hot water systems, using a combined storage tank and charging pump. While this substance may be suitable (due to its much lower toxicity) for domestic hot water systems, we were advised it has lower "reserve alkalinity" than ethylene glycol and is more difficult to inhibit and control breakdown into glycolic acid. Consideration should be given to using the less expensive and more easily inhibited ethylene glycol in space heating systems, and to providing separate drain-back tank and charging pump.

A solar preheat system was designed to be used to preheat demineralized water for laboratory use on this project. PVC thermoplastic pipe was specified to prevent destruction of the pipe and contamination of the lab water. The pipe and glues used failed when subjected to high temperatures (180°F) in the demineralized water piping between the preheat tank and a mixing valve on the discharge side of electric hot water back-up heater.

Submittals

The solar collector specifications stated that the primary system would be drained-back during the summer and permitted to withstand dry stagnation. No exception was taken to this condition by the successful bidders and no problem was recognized during the review of bids. After the Chamberlain panels were erected on the roof, it was noted (by label on the collectors) that they were for use in a "closed" system only. Oxygen, admitted to the collectors through the vents during drain-back, will permit the steel abosorber plates to rest. It will be necessary, therefore, to keep the system charged in summer and to 1) shade the collectors, or 2) collect and dissipate energy collected, or 3) both.

The variable speed motors and SCR controllers for the air handling units required coordination by the contractor during submittal phase to permit the motors to operate over a range from 0% to 100%. The motor manufacturer now maintains their motors will heat-up and eventually burn-out if operated below 75% of full rated speed. We are presently attempting to identify this problem and assign responsiblity.

The emergency generator, designed as a back-up heating system by recovering jacket heat from the engine, presently overheats when this heat is pumped to an air-cooled radiator during summer operation. The contract drawings showed the air-cooled radiator remotely located at a higher elevation, but the specifications (worked out with the manufacturer) did not make provision for the necessary acessories, neither did the bidder. In addition, a day tank was

necessary for the diesel fuel tank, also located well above the center line of the engine.

Our combination of collectors contains copper as well as steel components. The corrosion inhibitor originally submitted adequately treated only the copper components. This condition was belatedly recognized by the mechanical sub-contractor's feedwater supplier, who furnished additioanl, supplemental inhibitors for the system. The engineers felt the responsiblity for feedwater treatment was the owner's, since mechanical engineers are not water chemistry specialists. The owner disagreed and required the engineer to review and approve the feed-water company's supplementary recommendations.

Construction Problems

Specifications required that the solar collectors be shipped crated and on pallets. The KTA collectors, which are 8'0" high, would not fit on pallets in an enclosed truck and so were shipped by the manufacturer strapped in groups to the side of the truck. In shipment, some of the straps broke, causing breakage in 26 of 63 collectors. Not all of the damage was discovered until the protective paper was removed from the plexiglass cover plates after the collectors were erected and bolted in place on the roof. The manufacturer repaired and returned the collectors to the site without delay.

Cold weather during final piping of the collectors on the roof made it difficult to properly flush the piping of debris prior to hook-up to the collectors. The problem required waiting for favorable weather conditions and special attention to assure complete drainage.

Temperatures below 50°F in the control room over a winter weekend resulted in the computer memory being "dropped". The control sub-contractor repaired the damaged memory but refused to return the unit to the site until he could be assured the temperature would not drop below 55°F in the control room.

Start-Up and Initial Operation

Many of the problems of start-up and initial operation were due to design, submittal and construction problems and are mentioned in their respective areas above. Other problems were as follows:

Corrosion monitoring devices were not specified in the construction documents and have not been installed to date. Conductivity meters and coupon testing devices are highly desirable and should be specified as part of the construction documents so that they will be operational during the critical period immediately following charging and start-up.

The plexiglass KTA cover plates have failed to keep dust and organic litter from entering and collecting on the tube assemblies. This is due to the open edge top and bottom (and inadequate closure on the sides) and subsequent expansion and buckling of the cover plate along the top and bottom edges. In addition, many plates have split where fastened with self-tapping screws on the face of the collector.

On one occasion, circulation in the primary loop was started when the collectors were in a "wet stagnation" condition. Thermal shock caused two silicon connecting tubes to split and approximately 30 (out of 2520) outer glass tubes to crack on the KTA collectors.

Window area on all sides except the south are minimized by design to reduce heat loss. South facing windoews are protected from summer heat gain with overhangs. All windows and skylights are double-glazed and are covered at night with interior insulating shutters to further reduce heat loss. Natural light from windows and 28 skylights provide most of the indirect lighting in work areas in the daytime. Task lights on individual work stations in the open-landscape office plan are turned on only when needed. The connected lighting load for the building, when all task lights and nighttime indirect lighting are energized, is only 1.75 watts/square foot. Borrowed light from light wells, glazed partitions above 8'2", and glass walls in certain office and conference room spaces, further reduce dependence on electric lights.

Thermal mass designed in exterior walls, and elsewhere within the structure, stores heat to return to the interior spaces when the 10°F night set-back is in effect. Exterior walls are heavily insulated on the outside to permit these walls to act as a "heat sink". This feature conserves actively collected solar heated storage water as well as dampens the effect of diurnal swings in outside temperatures. Through conservation and the passive energy systems described, the building heat loss has been reduced to 43,000 BTU's/sq. ft./yr. The design heating load on the building (0°F outside ari, 15 MPH wind) is only 140,000 BTU/hr.

Mechanical System Description

Low temperature hot water (105°F utilization) is piped from storage to air handling units with oversized heat exchangers (coils). Constant temperature supply air (90°F) is maintained (when storage water is hotter than 105°F) with variable speed motors and SCR controllers. Cooling is supplied using well water (49°F) directly or, on very hot days, with a 30 ton chiller and evaporative cooler. Well water, discharged from the air handlers, is cooled by gravity overflow from the building's cistern and natural percolation in a gravel basin through 100 feet of loose glacial outwash.

Air distribution is through a dual duct mixing box system, with variable air volume regulation within each building zone. A 10°F "dead-band" (between 68°F and 78°F) permits ventilation only (no heating or cooling) within this range. Fresh outside air can be modulated down from 100% (atmospheric cooling) to 10% during cooling and ventilation modes and to building code minimum during heating modes. No cooling is permitted during unoccupied hours.

Heat recovery systems are employed (except in summer) on the laboratory fume hood exhaust system, as well as on the emergency generator, which doubles as the back-up heating ysstem for the building. (When producing 63% of the 40 KW connected load, the generator will deliver 140,000 BTU/hr., which is the design condition heat loss of the building.

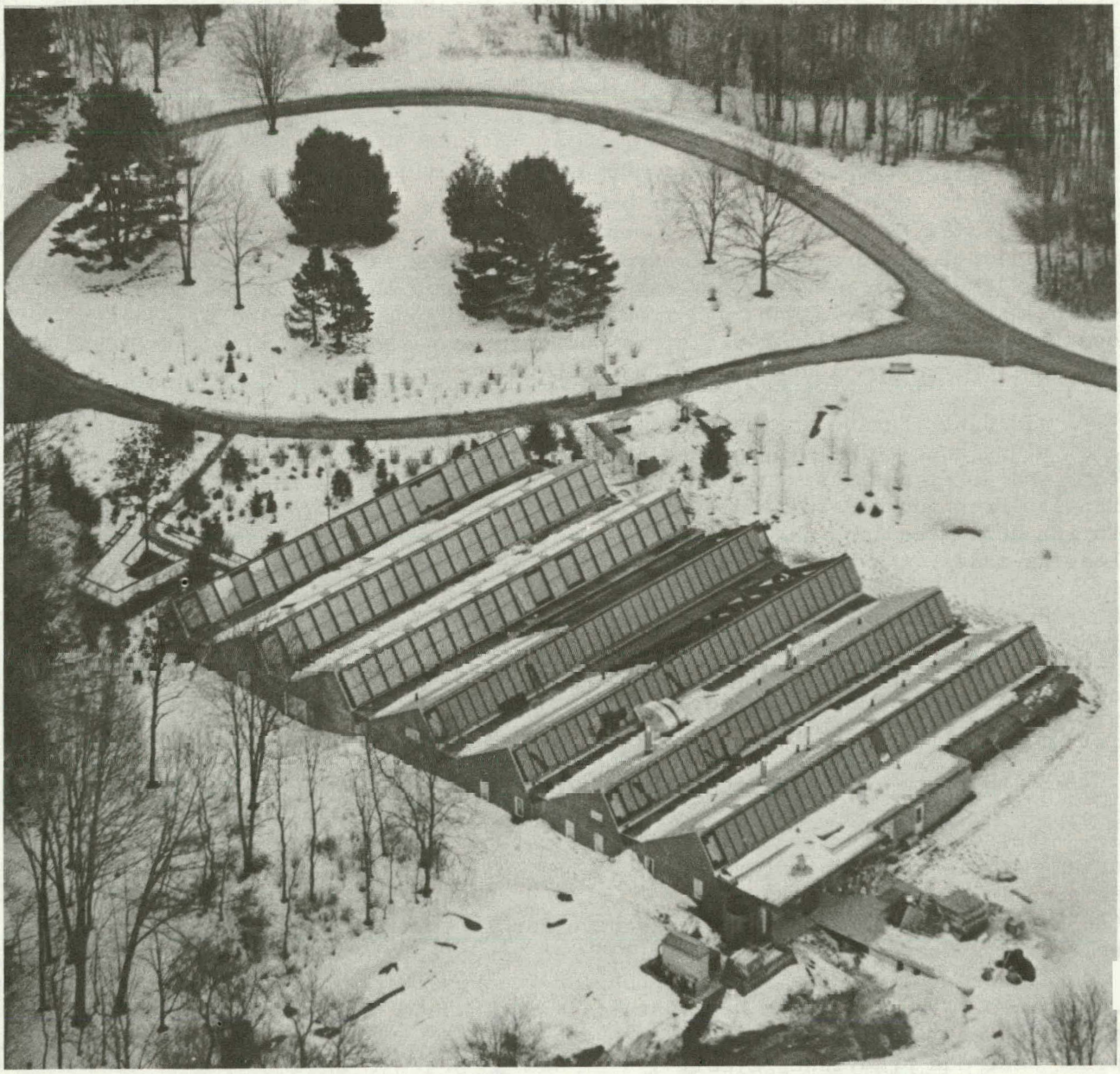
Solar System Description

The solar system consists of 5650 square feet of liquid-filled collectors arranged in seven saw-toothed arrays. The collectors in each row are connected in parallel, with reverse return. Four rows (144 3'x 7' collectors) are made by Chamberlain Manufacturing Corp. and have double tempered glass covers and selectively coated steel absorbers. Three rows (63 4'5"x8' collectors) are manufactured by KTA Corp. and are tubular (non-evacuated), semi-concentrating collectors. The Arboretum has installed instruments to compare the performance of equal sections of each type. The heat transfer liquid is a 50% solution of well water and propylene glycol.

Condensation under the outer glass on the Chamberlain collectors appears to be persistent problem, affecting a large area of the glass on a majority of the collectors. The condensation remains during the entire day and, in some instances, appears to be due to separation of the rubber gasketing from the corners of the collectors.

CONCLUSION

Since the system was started-up in early March, solar energy has provided all of the heating requirements of the building. Well water alone (without the chiller) has kept the building cool and comfortable throughout the summer. When the remaining design and construction problems are resolved, we look forward to a full test of the system, with data collection and monitoring, during the coming heating season. We welcome your comments and encourage you to visit one of the largest operating solar heating systems in a privately constructed building in the world.



Solar Heating and Hot Water System for the Technology Properties Trust Building Burlington, Massachusetts

John Zvara, P.E.

INTRODUCTION

The Technology Properties Trust (TPT) office building is a new, energy-efficient, multi-tenant office building located in the northwest suburbs of Boston. Construction of the three-story structure containing a gross area of 20,350 sq. ft. was completed in November 1977. The design incorporated energy conservation techniques throughout, exceeding the guidelines of ASHRAE Standard 90-75 in every respect. Provision for incorporation of a solar heating and hot water system was made in the initial design. A solar energy system for heating and domestic hot water is currently being installed with partial funding by DOE under its commercial demonstration program. Completion of the system installation, checkout and acceptance tests is scheduled for the late summer of 1978, with the system ready for full operational use in the winter of 1978.

SOLAR ENERGY SYSTEM

Collector and Reflector Design

The solar system selected for the TPT building consists of ninety (90) Daystar type liquid flat plate collectors (active area 90 x 20.8 = 1,872 sq. ft.) augmented by flat reflectors 8 feet in length inclined 10° to the horizontal. This collector/reflector combination increases the effective collection area by an average of over 40 percent during the winter months, assuming a reflectivity of 75 percent. This results in a total effective collection area of 2,600 sq. ft. that is estimated to provide 79 percent of the heating load of the building. The Daystar type flat plate collector with an integral overtemperature protection system was chosen following careful consideration of a number of possible collector types.

The collectors and reflectors are supported on a steel structure which is anchored to the steel framing of the building structure. The reflectors are hinged to permit lifting them and using them as protective covers for the solar collectors. Manual shuttering of the collector array will be accomplished at the beginning of the summer (May) except for two units piped separately and used to supply the limited hot water needs of the building. At the beginning of the fall heating season (September) the reflectors will be manually lowered and locked in the 10° reflecting position.

Storage System

The system includes a storage capacity of 6,000 gallons in two steel tanks containing 50,000 lbs. of water which has a heat storage capacity of 5 x 10^6 BTU for a temperature rise of 100°F to an estimated temperature of 170°F. The maximum input to the tank on a sunny day is of the order of 2.2 x 10^6 BTU resulting in a temperature rise of 45°F with the average temperature rise of the order of 20° to 25°F per day. This will provide the average January heat load of 1.8 x 10^6 BTU/day for nearly three days.

Heating

The primary heating mode for the building is circulating solar heated water ranging in temperature from 140°F to 90°F through fan-coil units. Hence, whenever the solar storage

tank temperature or the heater water supplied directly from the solar heat exchanger is above 90°F, the building heat will be supplied 100 percent by solar energy.

If the tank temperature is above 140°F, it can be reduced to 140°F by mixing it with return water from the fan-coil loop. If the solar tank water is below 90°F, solar tank water (or well water, if warmer) will be heated to 105°F using the water-to-water heat pump and the heated water circulated through the fan-coil loop of the building.

Conventional Auxiliary and Backup Systems

The building cooling system and the auxiliary backup heating system use another renewable source of energy, constant or near constant temperature groundwater. Test borings made at the site indicated that there is an ample supply of groundwater with temperatures of 54°F in summer and 56°F in winter (small groundwater temperature variations are four to six months out of phase with average ambient air temperatures). This cool groundwater is expected to provide 80 percent of the cooling requirement by circulation through heat exchangers and the fan-coil distribution system. The fan-coil units are designed to provide heating from low temperature heat sources such as heat pump condensers and solar energy devices and are sized to provide heating from water down to a temperature of 95°F. The deep coil feature also permits the use of cooling water at the temperature it comes from the ground through the heat exchanger.

Control System

The control system will consist of a control panel with temperature and pressure indicators mounted on the front panel selector switches for the cooling and heating modes. "Hands-Off Automatic" switches for circulating pumps, time clock for night set back, differential temperature controller for solar collector panel and storage tank temperature control and monitoring points.

Storage Tanks

A differential adjustable temperature controller with a sensor located at one of the solar collector panels and a second sensor located in the storage tank will control the operation of the solar collector fluid circulating pump as the solar energy input to the collectors dictates, to maintain the transfer of thermal energy from the collectors to the tank. The heat exchanger to thermal storage tank circulating pump will be operated whenever the solar loop circulating pump is operating.

Storage tank temperature can vary from a high of 200°F to a low of 40°F. The two storage tanks will be piped in such a manner as to provide maximum thermal stratification. It is expected that a total stratification from input to output of between 30°F to 45°F will be achieved, which will benefit collector operating efficiency.

Solar Water Heating Mode with Heat Pump

The building heat circulating pump will be under the control of an outdoor ambient controller to start the pump at an ambient temperature of 65°F. Storage heated water above 90°F will be supplied to building fan-coil units. During the periods of unavailable tank storage heat, the diverting valve port to the hot water storage tank will be in a closed position, the valve port to the condenser will be in an opened position with heated water from the condenser supplied to the fan-coil units. Well water and chiller water circulating pumps will be in operation during the heat pump mode. Building, chilled and well water pumps will be in the automatic operation position during the heating mode.

Well Water Cooling Mode with Solar Water Reheat

The building chilled water, well water and building heat circulating pump will be in the automatic operating position. Well water at 54°F to 56°F will be supplied to the building fan-coil units through the heat exchangers. Building heat circulating water from the thermal storage tanks will be supplied to the fan-coil units for zone reheat requirements.

Mechanical Cooling Mode with Solar Water Reheat

The building heat, chilled water and condenser water circulating pumps will be in the automatic position. The mechanical cooling mode will be under the control of a room humidistat in the event the well water temperature cannot maintain room humidity. The building heat circulating water from the thermal storage tank will be supplied to the fan-coil units for zone reheat.

Fan-Coil Units

Perimeter fan-coil unit control valves are under the control of a unit self-contained thermostat. Interior zone fan-coil unit control valves are under the control of remote zone thermostats.

Monitoring Points

Temperature monitoring points to be indicated on the central control panel will include the following:

1. Collector solar panels - water in and out of the heat exchanger.
2. Storage tanks and associated circulating pump - water in and out of heat exchanger and storage tank water temperature.
3. Building heat circulating - water temperature out and return from fan-coil system.
4. Domestic hot water - storage water in and out.
5. Well water temperature - in and out of the heat exchanger.
6. Chilled water - in and out of the heat exchanger to fan-coil units.
7. Chilled water - in and out of the water-to-water heat pump chiller unit evaporator.
8. Water temperature - in and out of the water-to-water heat pump chiller unit condenser.

Night Set-Back Control

Exhaust fans and fan-coil units are under the control of a time-clock for exhaust fan control and night set-back. During the night cycle and weekends, fan-coil units are turned off. The time clock will be provided with an override switch to permit manual operation.

Instrumentation

The system has been selected by DOE as an instrumented site tied into the National Solar Data Network by commercial telephone lines. A total of 63 sensors are being installed. The instrumentation includes 28 pipe temperature sensors, 6 tank temperature sensors (3 in each tank), internal and external air temperature sensors, 7 flow meters, 12 wattmeters, total and diffuse radiation sensors, wind speed and direction, and internal and external relative humidity sensors.

A schematic flow diagram of the solar heating and hot water system is shown in Figure 1. The location of the sensors is indicated on the diagram with temperature sensors indicated by T, flow meters indicated by W and electric power meters designated by EP.

Acknowledgment is given to Mr. Eric Wormser and Mr. John Bays of Wormser Scientific Corporation, Stamford, Connecticut and Mr. Fred Broberg, Hill and Harrigan Consulting Engineers, New Haven, Connecticut, for their contribution to the design of the solar energy system.

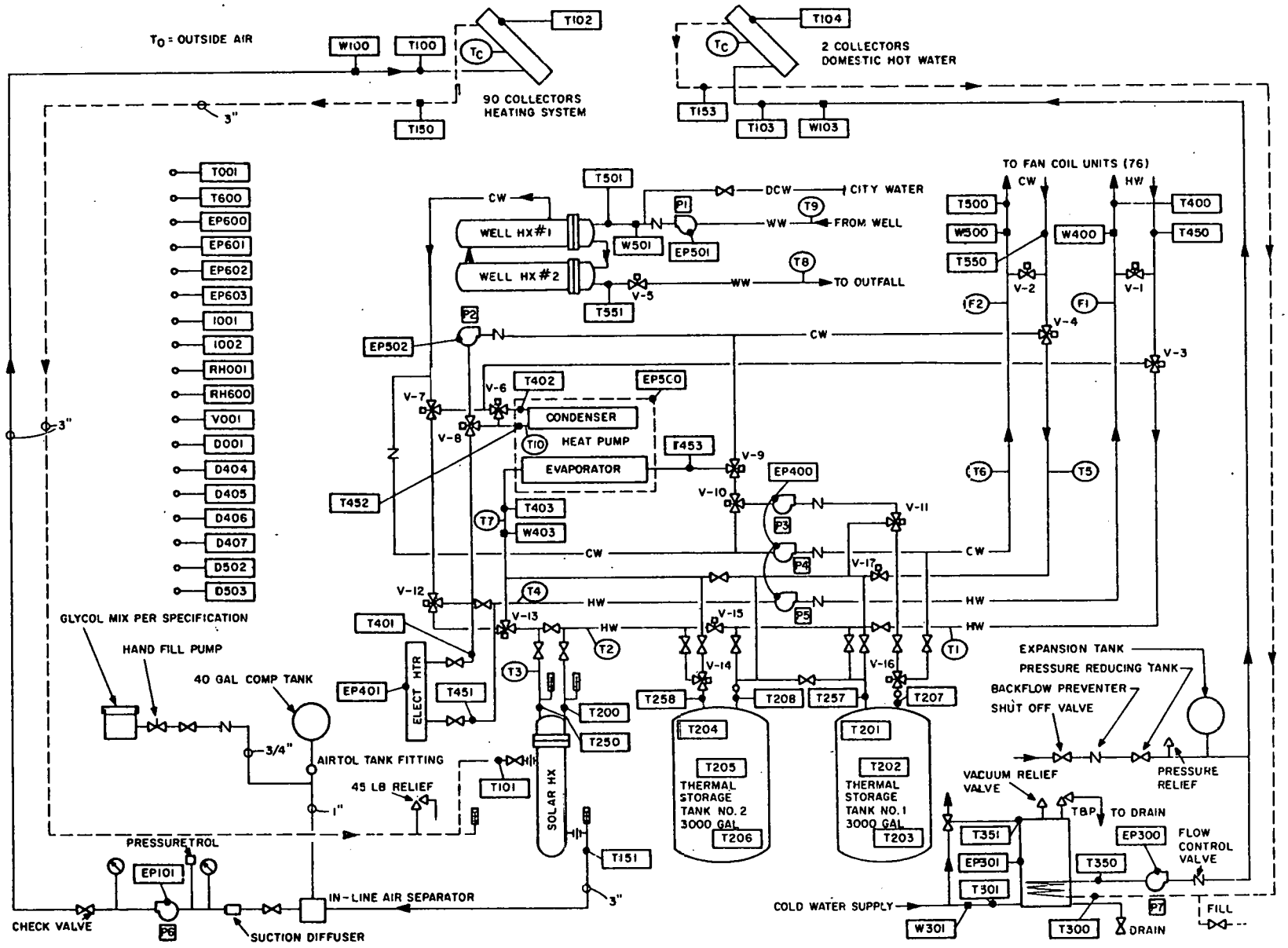


Figure 1. Schematic Flow Diagram for Technology Properties Trust Solar Heating and Hot Water System.

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The Design/Construction Approach to the Solar Demonstration Project at the Children's Hospital Medical Center

Vince Gisone

PURPOSE

My purpose today is (1) to describe the Design-Build Method for construction projects, and (2) to show by reference to some specific experiences in the construction of the solar heating demonstration project for the Children's Hospital Medical Center in Boston, how this Method benefits the project and Owner.

It is my belief that if the combination of rising energy costs and technological/manufacturing break-throughs makes solar energy systems more economically feasible for large scale commercial and industrial applications, the Design-Build Method will be extensively used. It is therefore, important that those involved be familiar with the concept and its attendant forms of contractual agreements.

DISCUSSION

The Design-Build Method of contracting is becoming increasingly popular with Owners as a replacement for the "traditional" method of awarding separate contracts for design and construction. There are a number of reasons for this:

1) In times of double-digit inflation, cognizant Owners are acutely aware of the increased opportunity costs which are lost in direct relationship to increases in length of time of the design/construction process. Design-Build offers a Method to reduce these costs, by reducing the design/construction process time. Construction of the project can be initiated on a phased basis while design is still underway. This "fast tracking" reduces the Owner's interim financing costs and permits him to occupy the project at an earlier date. It can also reduce the Contractor's time-dependent job costs.

2) With fuel shortages and rising energy costs, many Owners of large facilities have hired energy conservation managers and engineers to evaluate and recommend way(s) to improve older inefficient systems. The person performing this function often turns to the contractor servicing and maintaining his building equipment for advice, recommendations, and estimates of cost. To respond to this need, many service contractors with design/construction capability offer technical solutions and recommendations for system improvement. Their thorough knowledge of the Owner's building and systems often results in practical solutions with attractive economic paybacks. This gives further impetus to Design-Build, since the Owner would now also realize the benefit of having his energy savings system retrofit on line sooner.

3) Under the Design-Build concept the Owner is provided with a single point of accountability. The Owner need no longer act as adjudicator for any disputes between the Designer and the construction firm. The lines of communication are, therefore, simplified in comparison with those of the "traditional" method. Chances for misunderstandings are reduced, and the coordination between the Owner and the Contractor is improved. Of course, under the Design-Build concept, the successful construction firm must

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consistently perform at high standards, giving the Owner value and guaranteeing, in writing, the expected performance of the installation.

A recent survey of mechanical construction firms on the growing utilization of the design/construction concept (Ref 1.) resulted in the following responses.

a) 77.3% found design/construction more profitable than the traditional plan and specification approach.

b) 90.2% said that schedules are speeded up with over 90% reporting an acceleration of at least 10%, and 40% reporting a speed-up of more than 25%.

c) 70% stated that duplication of effort is less than in the traditional approaches.

Other trends cited were that manufacturing competition to service firms was increasing due to design/construction capability. From the preceeding it be seen that the concept yields benefits for all parties involved

Design-Build construction contracts are negotiated in different forms, although the reputation and capability of the construction firm is often the most important factor to the awarding agency regardless of the form of agreement. As with traditional contracts the "stipulated sum" form of agreement, in which the design/construction firm undertakes the project in accordance with the Owner's requirements, has a defined stated price. Included in the price are all the Contractor's costs plus overhead and profit. Usually this form of agreement outlines the Owner's requirements and the proposed solution in substantial detail, with the Owner often paying for the preliminary engineering and estimating costs under a separate agreement. Design time and costs are less than the "traditional" method however, since a lengthy specification is in most cases not required. Construction financing costs are saved by the shortening of the process since the ordering of long-lead time items which often delay the schedule can proceed before the final design is approved. The contractors bid preparation and review time, unlike than the "traditional" method, is eliminated.

The Design/Construction process can be further shortened if the Owner agrees to a "cost reimbursement" type of contract in which the Contractor's direct engineering and construction costs and overhead are paid. The Contractor is paid an additional fee to provide for profits. This fee can be expressed as a lump sum or as a percentage of the agreed upon reimbursable costs. The final price paid the Contractor, which is the sum of the reimbursable costs plus the fee, is determined at the completion of the project. This type of agreement results in the fastest schedule, and provides for the most flexibility to the Owner in determining his project requirements. The Contractor is often willing to negotiate a lower fee, because of the reduced risk associated with not being required to submit a guaranteed maximum price.

This leads to a third form of agreement which is a variation of the reimbursable cost type. It includes a provision in the contract for a guaranteed maximum price. This type of contract is for the Owner who has to forego flexibility and must set an upper price level for the project. The Contractor must now assume some added risk and must spend more time defining, detailing, and estimating the project, although much less than the time spent for "stipulated sum" agreements. Provisions are often negotiated in which the Contractor is given incentive to perform value engineering and give recommendations to the Owner on ways in which the project's costs can be reduced. This incentive is usually in the form of a payment to the Contractor a percentage of the costs saved below the total estimated cost value. The fee which is negotiated is paid regardless of the actual costs, and the Owner has the knowledge and protection that as long as the agreed upon project scope remains unchanged the total project price will not exceed the estimated cost plus the fee, regardless of the actual project costs.

It can be seen therefore, that the major criticism of the Design-Build Method (ie., lack of competitive price) can be overcome through the type of agreement negotiated or through the Owner's solicitating a number of Design-Build proposals on a competitive basis.

We will now examine the solar energy heating project installed in the John Enders Pediatric Research Building of the Children's Hospital Medical Center in Boston, Massachusetts, in some detail and begin with a summary description of the system. Please refer to the packet of sheets which were distributed.

The Enders Building has fourteen stories with 180,000 gross square feet of space, and is devoted to pediatric research. There are two penthouses, one at either end of the building housing elevator machinery, and directly above this machinery a multiplicity of exhaust fans that serve the animal rooms in the basement and the laboratory exhaust hoods located throughout the building.

The building is constructed of concrete pan and reinforced concrete frame. Exterior walls are poured concrete with precast concrete panels between the windows.

Steam is used in the Enders Research Building for heating, domestic hot water, distilled water production, sterilization, and miscellaneous other laboratory uses. The building is air conditioned and ventilated by nine air handling units with a total capacity of 216,000 cubic feet per minute, all operating on 100% outside air. Seven units are located in the sub-basement and two on the fourteenth floor. Four steam heated domestic hot water units, two located in the sub-basement and two on the fourteenth floor, provide 775,000 gallons of hot water monthly.

The nature of the research conducted in this building imposes an unusually heavy ventilation/air conditioning and hot water load. During fiscal 1976 (September 15, 1975 through September 14, 1976) a total of 46.8 billion BTU's

in the form of steam was purchased to meet the heat energy needs of the building.

The solar heating system located on the building's roof (Fig 1.) contains one hundred fifty-five (155) General Electric TC-100 Solar Collectors and has a total active area of 2,294 square feet. Total installed cost of the system is $192,182.00.

The TC-100 panel as shown in Figure 2 was chosen because of the expected high temperatures and efficienceies achieved by the use of a vacuum between the absorbing surface and the window and with non-imaging concentration. Figure 3 is a typical cross section of the functioning collector components and can be used to describe the panel's features.

As shown in Figure 3, the principle component in the collector is the evacuated glass shroud. The shroud consists of two glass cylinders joined to form a large "thermos bottle". The outer cylinder serves as the "window". The inner tube is coated on the outer diameter and serves as the absorber. The space between the two cylinders is evacuated to minimize front losses as well as back losses from the "absorber".

The shroud is nestled within a simple Vee-trough reflector. The reflector reduces the material content of the collector, and according to the manufacturer improves performance at low insolation rates by concentrating the available energy on the shroud.

The energy absorbed by the outer surface of the inner cylinder is conducted through the inner glass tube, and into a fin that conforms to the inside diameter of the inner glass tube. Thermal energy is conducted through the fin and to the working fluid flowing through a U tube flow passage. The U-tube has one leg attached to the fin and the other leg floats free. The working fluid circuit is not affected by breakage of glass shrouds. Only a slight drop in thermal performance will be realized in the event of shroud breakage.

The overall collector module consists of ten glass shrouds mounted parallel to each other in the appropriate reflector assembly. Each of the finned loops contained within the shrouds is connected to form a serpentine structure of ten loops in series.

The solar system as schematically shown in Figure 4 will provide preheat capability to one ventilation/air conditioning unit which handles 36,230 cubic feet per minute of 100% outside air, conditioned for space comfort five days a week from 6 A. M. to 6 P. M., and two parallel domestic hot water heaters supplying a 15,000 gallon per day demand. All this existing equipment is located on the fourteenth floor mechanical area. Of the buildings 180,000 square feet, the solar energy assisted areas involve 24,000 square feet for space heating and 96,000 square feet for domestic hot water. To get a rough idea of how the system works, please refer to the schematic diagram as the slides are shown.

The solar energy system depicted in schematic form in Figure 4 consists of three sub-systems:

- Collector Loop
- Space Air Preheat Loop
- Thermal Energy Storage/DHW Loop

The collector field modules transmit the absorbed solar energy to an ethylene glycol water mixture being pumped through the collectors. The heated mixture is distributed to a liquid to air heat exchanger installed in the air intake duct of an existing ventilation/air conditioning unit (Space Air Preheat Loop) or through a liquid to liquid exchanger (TES/DHW Loop). During the heating season, the liquid to air exchanger (HX2) preheats incoming outside air to a maximum of 55° F in support of the existing steam preheat coil of the air conditioning unit. The existing steam preheat coil will continue to operate in its present mode to insure meeting the 55° F preheat requirement when the solar exchanger cannot raise the outside air to the prescribed limit. When outside air can be raised to the 55° F preheat level and excess solar energy is available, a portion of the ethylene glycol/water mixture is by-passed by a modulating valve, to a liquid to liquid heat exchanger (HX1). Water is circulated from the storage tank through this liquid to liquid heat exchanger when the differential temperature between the tank and collector loop exceeds 20° F, storing the excess solar energy for use in preheating domestic hot water. Cold potable water passes through a coil in the storage tank and is preheated before passage to two existing domestic hot water water heaters operated in parallel. The existing hot water heaters raise the solar preheated cold water to the prescribed 140° F, as necessary. The thermal energy storage tank is primarily needed to store weekend solar energy, since the building is unoccupied and no outside air preheat or domestic hot water requirements exist. The TES/DHW tank temperature is limited to 250° F. If the temperature in the tank rises above 250° F, an over temperature control (OTC) system is activated. The OTC system consists of a roof mounted liquid to air exchanger in a parallel piping loop off the collector array main header. When the temperature exceeds 250° F, a motorized three-way valve is positioned so that the collector loop glycol mixture passes through the liquid to air exchanger where energy is dissipated to the surrounding atmosphere. The TES/DHW tank also contains a pressure relief valve set at 50 psig as an additional back-up should the OTC system fail to operate.

Now that we've reviewed the essentials of Design-Build concept and of the system operation, let me briefly relate to you how being in control of the design and construction for the project expediated solutions to problems and how value analysis and engineering judgments resulted in the project's completion within the allocated budget.

1) We were able to pre-purchase long lead items such as solar collectors, heat exchangers, etc., before the final design review was complete, thereby condensing the construction schedule and possibly avoiding price increases on equipment which lately seems to be relentless.

2) Our original structural layout which was dimensioned, detailed, and approved according to budget, had to be greatly modified because of field conditions.

a) Review meetings with D. O. E. lead to the conclusion that the shadowing caused by the north and south mechanical room towers at different seasons and times would have an adverse affect on a single tier panel layout. To minimize this problem we were able to redesign and construct a two-tier array toward the west end of each panel row, within the allocated budgeted cost.

b) Also existing on the roof is a louvred fresh-air intake penthouse and evaporative condenser cooling tower for constant temperature rooms which should have been relocated to accommodate optimum collector panel location. Because of the high costs of this plan and the reluctance of the hospital to relocate the tower and disturb research projects in the constant temperature rooms, we redesigned the array to minimum cost to us and no additional cost to the project. We were able to do this by co-ordinating the changes on-site with our structural sub-contractor with minimum design detail.

3) A problem was encountered in the rigging of the storage tank into the location which was allocated and desired by the Owner. Since the system has low pressures, codes allow for field welding and testing, so we had the tank shipped to the field in three sections and then completed construction and testing on site.

4) There were two areas in which cost over-runs were experienced, one in the temperature control system and the other in the fact that we added an automatic feature to the system which was not included in the original proposal or estimate. The control budget was exceeded due to the unanticipated cost of the recording instrumentation, although we felt it necessary to have high quality recorders and sensor inputs for research information purposes.

The automatic fill system was an added feature to make-up for system leakage should it occur. The fifty gallon storage tank/pump assembly, filled with glycol solution at all times, is activated as a function of reduced pressure in the collector loop to refill the system.

5) One of the ways in which costs were reduced while maintaining high quality levels was in the area of out-door piping insulation. Our original plan was to use fiberglass insulating as used inside covered with a metal jacket. Our Engineering Department researched alternatives and specified urethane insulation with a factory applied P. V. C. jacketing. Urethane is a rigid foam and appears to be very suitable for this application. The installation costs were less than that of jacketed fiberglass.

CONCLUSION

From the preceeding discussion it can be seen that the Design/Construction Method where one organization is responsible for a system from concept to check-out, as in this project, offers many advantages. Opportunity cost savings from inflationary equipment price and labor cost increases, are possible through condensed construction schedules. Communications are simplified and are more effective. If the project involves an energy saving retrofit, further savings are realized from fast-tracking. Various forms of contractual agreements are possible where the building owner has flexibility and is insured of obtaining value for the price he pays. It is important however, that for large size projects the firm involved has a proven history of successful experience and that it preferably maintains a traditional contracting discipline in its organization to develop cost histories for budgeting.

ACKNOWLEDGEMENT

I would like to acknowledge and recognize the efforts of Mr. John Williams of Balco's Project Engineering Section for taking the slides in this presentation and Miss Susan Lofgren for diligently working on the text.

REFERENCES

Reference (No. 1) Statistics from survey in CONTRACTOR MAGAZINE, January, 1976.

CHILDRENS HOSPITAL MEDICAL CENTER----------Sponsor
BALCO INC---------- Design Build Project Manager
THE ARCHITECTS COLLABORATIVE---------- Architect
GENERAL ELECTRIC COMPANY---------- Solar Systems

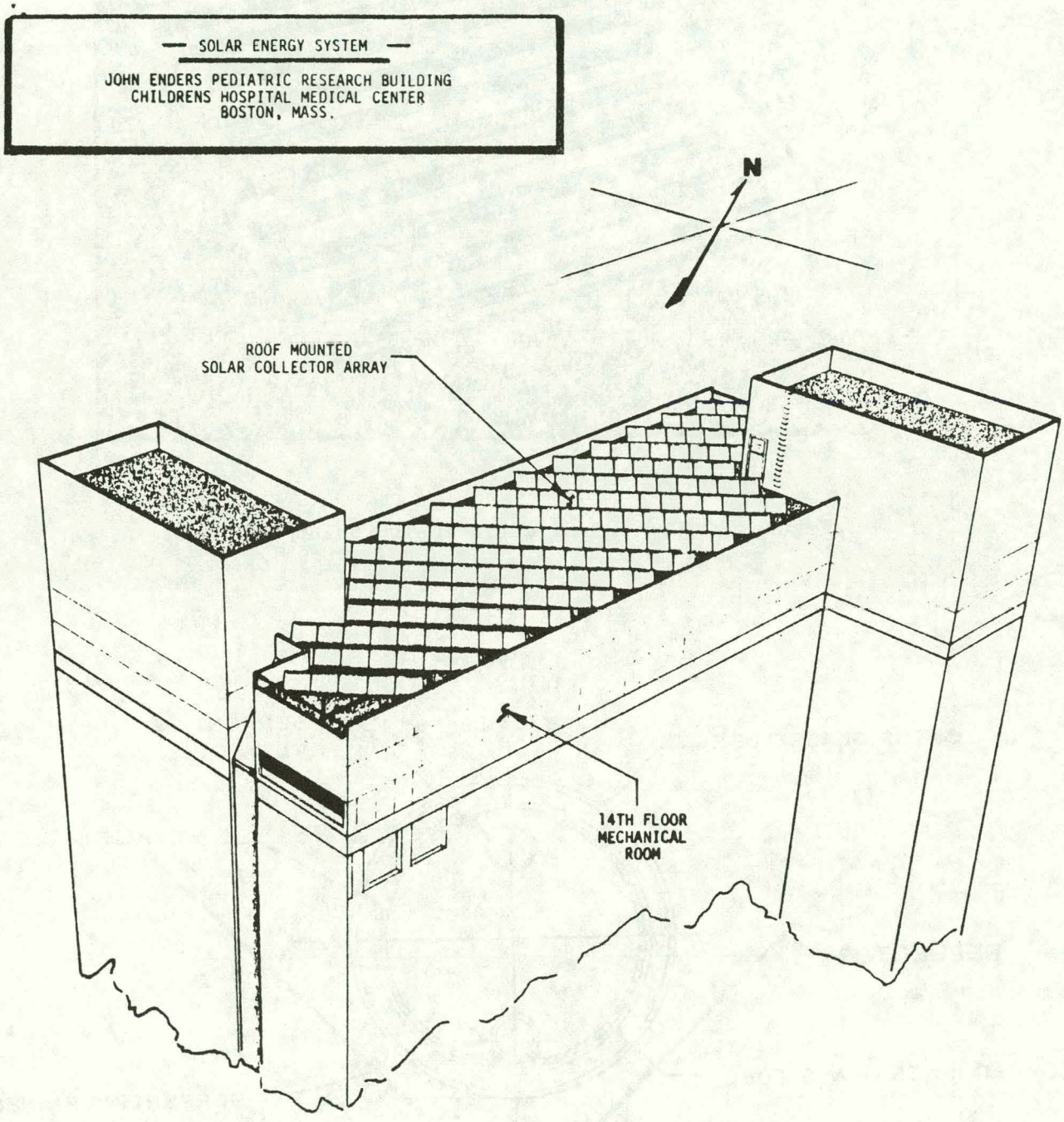


Figure 1

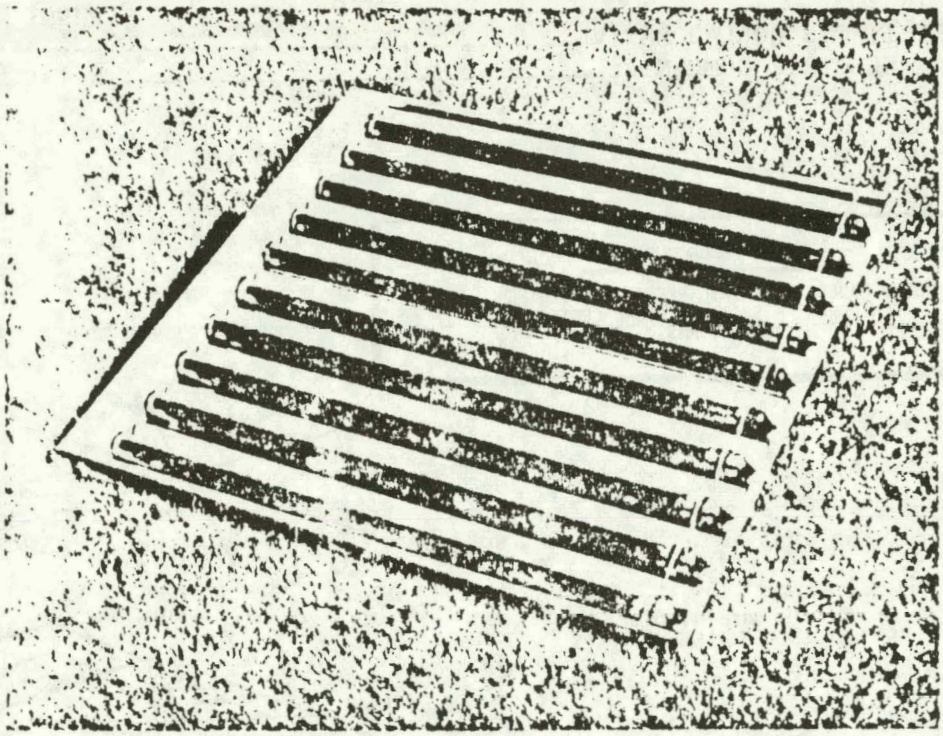


Figure 2 General Electric TC-100 Solar Collector

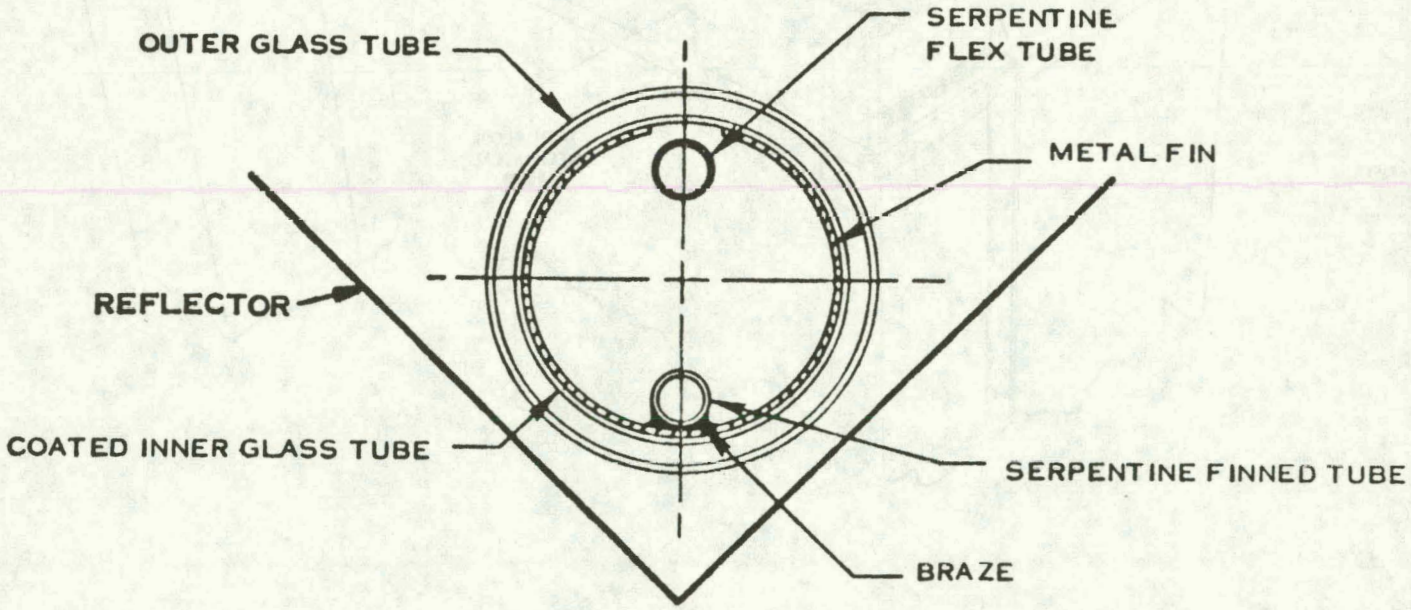


Figure 3 Typical Cross Section of TC-100 Active Elements

SOLAR ENERGY - SPACE AIR AND DWH PREHEATING SCHEMATIC

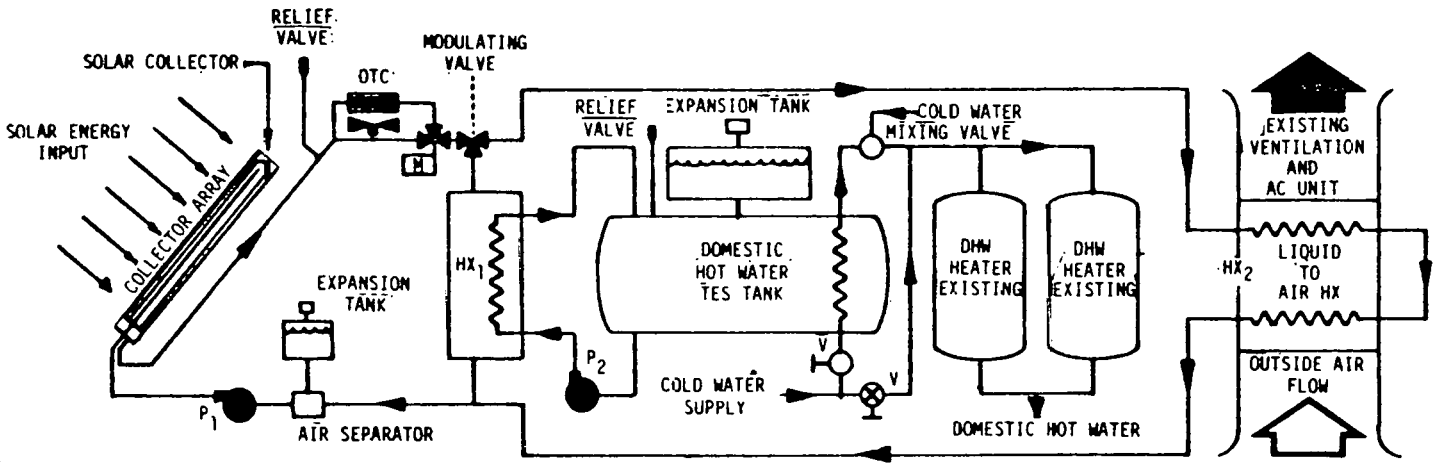


Figure 4

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The National Solar Data Program

H. Jackson Hale

I would like to give a brief overview of the National Solar Data Program.

The objectives of the National Solar Data Program are listed in Figure 1. The first is to evaluate and publish thermal performance of representative solar demonstration systems located throughout the U. S. The second objective is to evaluate and publish operational performance and cost/benefit analysis reports from these same solar demonstration sites. Finally, we plan to publish comparative analysis reports that will lead to improvements in future solar systems.

I have identified the areas that are currently receiving the most significant attention in the National Solar Data Program in Figure 2. These areas are identified by the ovals in the upper part of the figure. We are concentrating on solar system performance, system descriptive information, operational performance history, design and construction information, solar system cost, and reliability and maintainability information. All of these activities are essential in attaining the principal objective which is to determine the benefits of solar systems. In the lower portion of the figure, I have identified the National Solar Data Network as an element of the National Data Program. This is the network that has been implemented by IBM and is currently in use to gather the solar system performance data, as well as information on the climatic conditions that affect the performance of the solar systems. As indicated, that work is performed for us under contract by IBM-Federal Systems Division. Their activities are managed by Larry Murphy, program manager.

The PRC Energy Analysis Company is functioning as a support contractor to the DOE Solar Heating and Cooling Office; all of their activity related to the data program is managed by Ron Kirkpatrick. PRC/EAC is working actively now in acquiring data that will allow us to completely describe each of the solar systems in the as-built condition. The Ehrenkrantz Group is involved in the collection of design and construction information. This effort is presently managed by Steve Weinstein. Mueller Associates, Inc., under the direction of Andy Parker, also participates in the evaluation of design and construction information. However, their prime responsibility is in the collection of solar system cost information. Here, we have found a group who is very familiar with the construction industry, so that the cost information gathered and presented by Mueller Associates should be meaningful throughout the industry.

Another area of activity under the National Solar Data Program is reliability and maintainability. This activity is being performed by the Argonne National Laboratory under the management of Dr. Prem Chopra. This organization has had considerable experience in reliability and maintainability in other systems. We are now trying to apply those techniques in the field of solar energy. In the reliability and maintainability activity, as in all elements of the data program, we have made a deliberate attempt to find organizations that have special expertise that can be directly applied to solar systems so that we can obtain and publish the most meaningful results.

I would now like to briefly summarize the achievements of the National Solar Data Program, shown in Figure 3. As I stated earlier, the National Solar Data Network is operational. This is surely an understatement, to represent the vast amount of complex work that has been done over the past couple of years as such,

NATIONAL SOLAR DATA PROGRAM

OBJECTIVES

- Evaluate and publish thermal performance of representative solar demonstration systems
- Evaluate and publish operational performance and cost/benefits
- Publish comparative analysis reports leading to improved future solar systems

Figure 1

NATIONAL SOLAR DATA PROGRAM

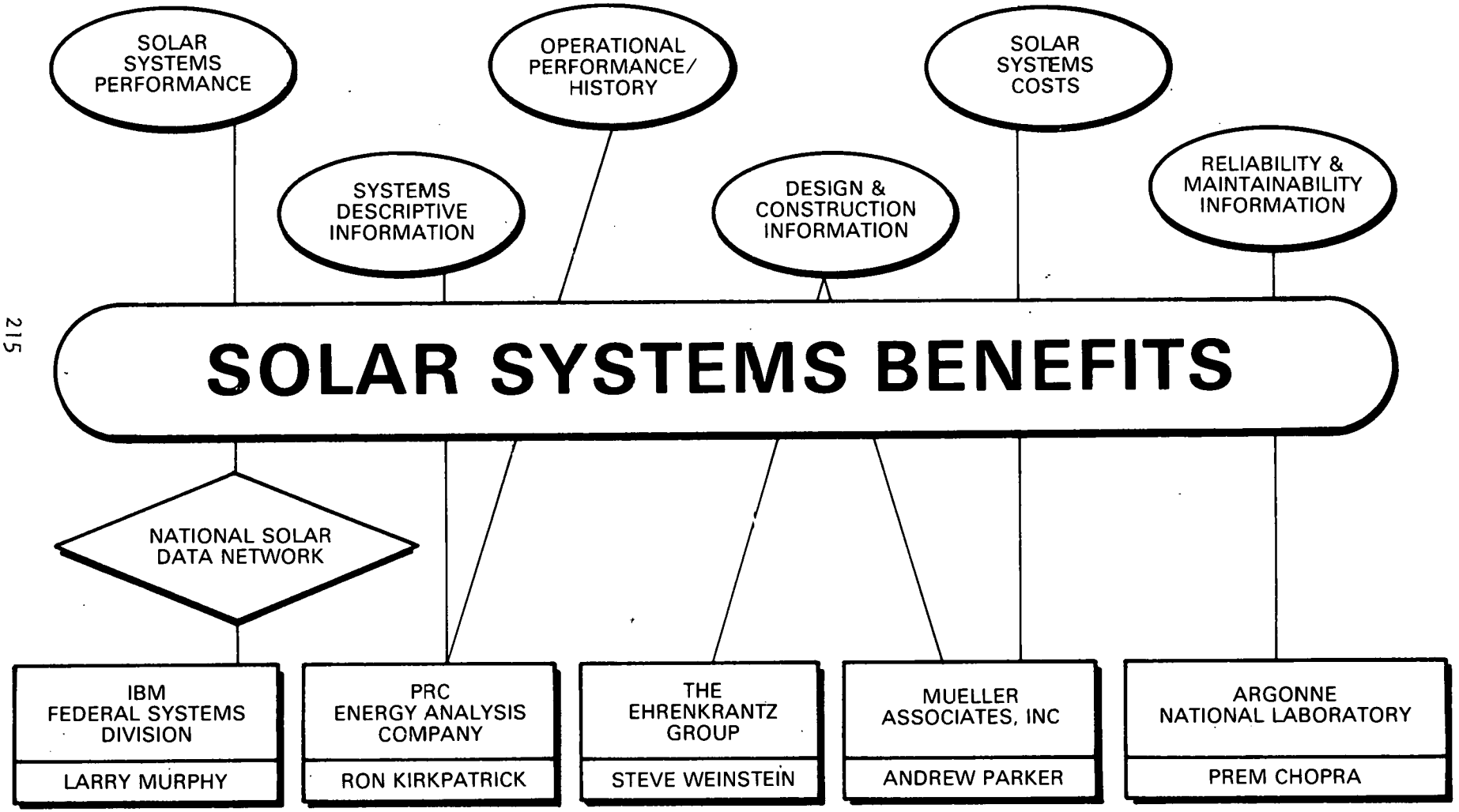


Figure 2

ACHIEVEMENTS

- National Solar Data Network — Operational
- Non-instrumented data collection & analysis operations — Operational
- Reliability and Maintainability Program — Operational
- Uniform analysis and reporting techniques — Developed
- Solar publications — Being disseminated through DOE-Technical Information Center
  - Solar project descriptions
  - Solar energy systems — Monthly performance reports
  - Solar energy systems performance evaluation
  - Solar project cost reports

Figure 3

but we are pleased to report that this system is operational. Most of the reports that have been presented at the Solar Update Conferences include information that is the direct result of the system being in operation. We also have the non-instrumented data collection analysis operation in place and functioning with the work being performed by PRC-Energy Analysis Company, Mueller Associates, Inc., The Ehrenkrantz Group, and the Argonne National Laboratory.

If you have had an opportunity to look at very many of the reports that we have published, you will note that there has been a considerable amount of emphasis placed on uniform analysis and reporting techniques. This is a very deliberate attempt on our part to get some uniformity in these reports so that when you see a report from one site and compare it with another site, you can make a ready comparison. We think that this is worthwhile and will continue to do so.

There have been a number of publications prepared to date and they are being principally disseminated for us through the DOE Technical Information Center. For example, there have been a number of Solar Project Description Reports available at these conferences. In addition, many of you have seen the Monthly Performance Reports. We have also just prepared a number of Solar Energy Systems Performance Evaluation Reports. These reports take the monthly performance reports over an entire season and analyze them more comprehensively, from a seasonal perspective, since most groups recognize that you cannot fully evaluate any solar system with only one month of performance data. We have also prepared a number of Solar Project Cost Reports which are now available.

I would now like to make a couple of comments on the areas that are currently receiving emphasis as shown in Figure 4. At the New Orleans Conference last December, there were a number of people who indicated that they had a desperate need for the ability to read out data from the data acquisition system with an on-site readout unit. In the early part of the program, we did not anticipate that an on-site readout would get that much use. We had procured 20 on-site readout units early in the program and they were placed throughout the demonstration program on an as-needed basis. Based on numerous comments, we have increased the number of on-site monitors to a total of fifty. The first four of the additional 30 units have just been delivered. All units will be available very shortly and they will be disseminated throughout the program as needed.

The National Solar Data Program has also been considerably active in support to the sites during the start-up period. We had not anticipated this. We had thought that the installer of the solar system would spend a few weeks checking it out, turn it on, and that would be it. We found that that wasn't quite the case. We have had the IBM analyst spending a considerable amount of time working directly with the site people, feeding data back to them, and working in the resolution of the problems that occur in the early stages.

We also have tried to be responsive to the solar data user requirements. We have periodic reviews of the kinds of reports that we are publishing and call n people from various disciplines to review these publications. We have talked to architects, solar engineers, site owners, and a number of other people. They have given us insight into the kinds of information that they would like to have and I think we have been responsive to that need.

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CURRENT AREAS OF EMPHASIS

- On-site data readout units — Increased deliveries
- Support to sites during solar system start-up — Increased support
- Response to solar data users requirements — Periodic reviews and increased site interactions
- Comparative analysis of solar systems — In process
- Determination of solar systems benefits — In process

Figure 4

We have also had our data program people increase their interactions with the site people. This has proved to be very valuable in the early days of operation. Again, I think we were overly optimistic in thinking that the solar system and data systems would work smoothly shortly after completion of their installation. This hasn't been the case. We find that our data analyst and data collection personnel must interact with the site people and let them know that our data collection and evaluation process is not a one-way exchange. We are gathering information that they can use and we would like to share it with them. We have had a very cooperative attitude on the part of site people and I am sure we will continue these interactions.

We are now getting to a point where we can do comparative analysis of solar systems. We are beginning to get performance and cost data that we can use to develop a comparative analysis process. Work is underway in this area and reports on this comparative analysis activity should be published during the latter part of this year.

We are also at the point that we can begin to assess the benefits of solar systems. We now know how much some of these projects cost in terms of equipment costs, installation cost, etc. We also know how much useful energy we can get out of these systems in terms of BTU per given time period. This data can now be analyzed to determine the cost and the value of solar energy that we are deriving from these systems.

I would like to make one final point, and that is that the National Solar Data Program emphasizes the collection and analysis of real data under real operating conditions. All the data that is presented here, and in the reports that we publish, is based on actual solar systems operating under realistic field conditions.

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THE NATIONAL SOLAR DATA NETWORK

L. J. Murphy

As part of the National Solar Heating and Cooling Demonstration Program, the daily operation of a wide variety of solar energy systems located at various sites throughout the country (Figure 1) is being monitored. The data collected is analyzed and the results are published in support of the overall Program goals of (1) improving the general knowledge and understanding of the performance and operating characteristics of solar energy systems, (2) providing a performance data base for improving solar energy systems and their components, and (3) estimating the economic importance of solar energy systems in reducing the consumption of conventional fuels.

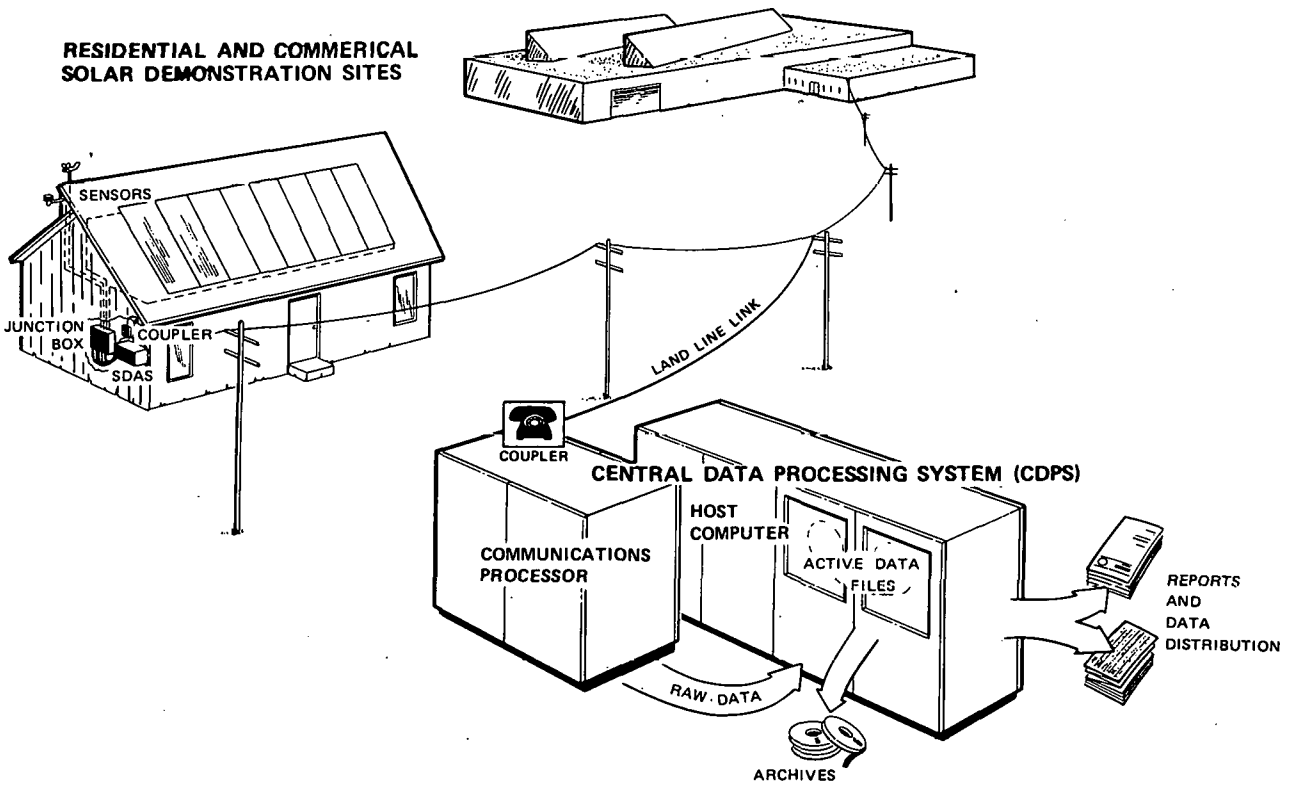


Figure 1. National Solar Heating and Cooling Demonstration Sites

The National Solar Data Network (Figure 2) is being employed in this collection and analysis activity. Numerous schemes of data gathering had been considered, but studies showed remote automatic data collection by a central facility to be the most cost-effective approach. Thus the National Solar Data Network featuring a Central Data Processing System (CDPS) was developed for the Department of Energy by the Federal Systems Division of International Business Machines Corporation. Through this network, accurate, consistent, and orderly data is gathered, converted, transferred, and analyzed. The CDPS organizes and maintains the data to ensure consistent performance evaluation and system nalysis.

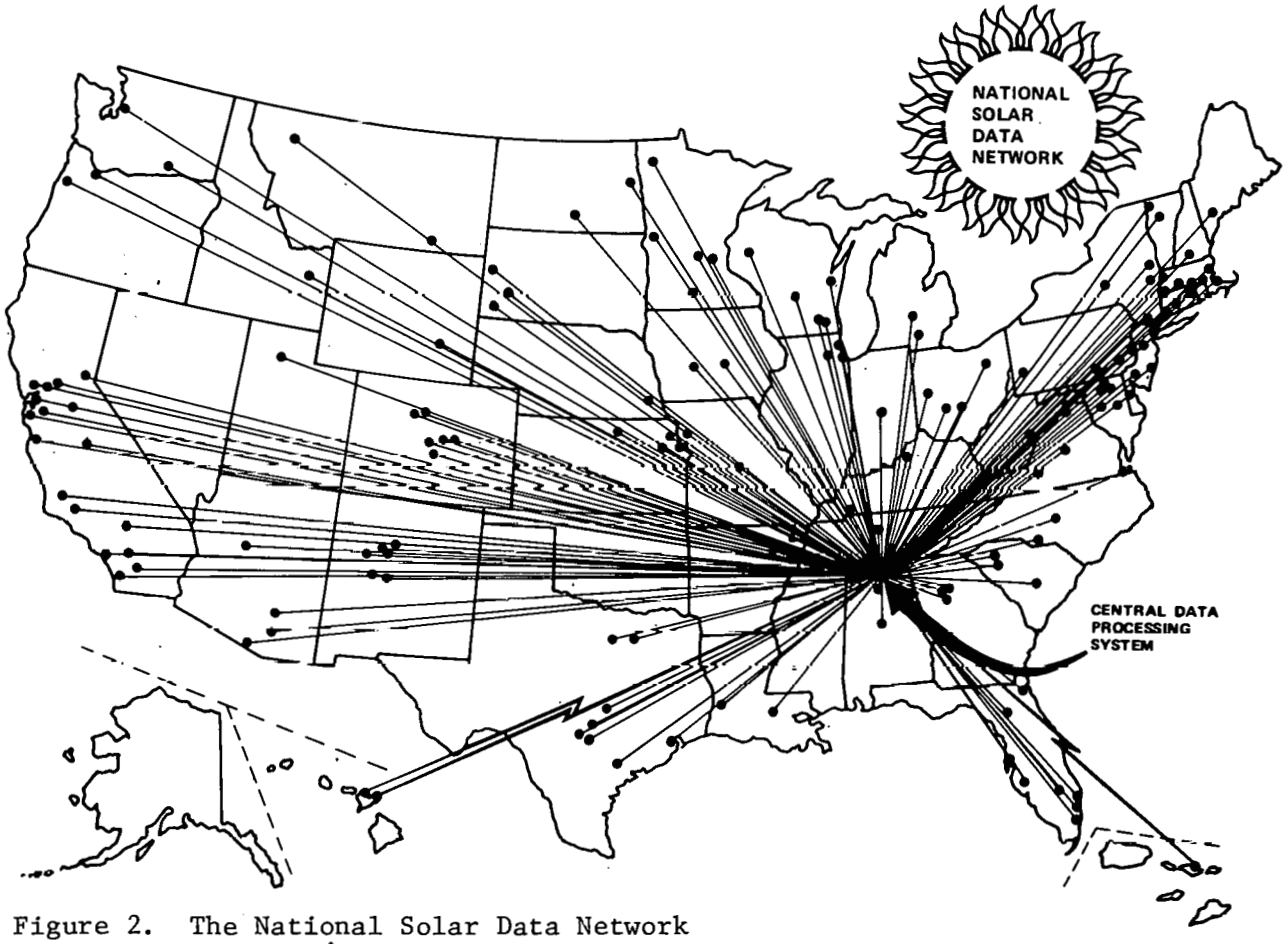


Figure 2. The National Solar Data Network

To prepare each site for connection to the network, there are three basic steps:

1. Analyze each site and its instrumentation requirements.

2. Select sensors and personalize standard data acquisition equipment to meet specific site requirements.

3. Install and checkout site instrumentation.

In the first step, using information supplied by the site contractor, both the system and its environment are investigated to establish instrumentation requirements and performance evaluation techniques. The information from the site contractor is provided formally in the Instrumentation System Planning Information (ISPI) document which describes the solar energy system and the site in sufficient detail to allow either the site contractor or IBM to make the initial selection of instrumentation for system monitoring. Working together, with IBM having program responsibility, they arrive at a final set of instrumentation requirements that are formalized in the Instrumentation Installation Guidelines (IIG) document for the particular system-site. After the appropriate government approvals, the sensors and other monitoring instrumentation are purchased. The site contractor then installs the instrumentation according to the system-site schematic, or the as-built drawings when available, contained in the IIG document.

The performance evaluation techniques follow general guidelines which were established by a governmental inter-agency committee for use in evaluating solar energy systems. Performance evaluation factors and equations are defined using the energy balance concept. Simply stated, the energy entering a system (or subsystem) is equal to the sum of (1) the energy leaving the system, (2) the energy accumulated in the system, and (3) the energy lost through thermal leakage and conversion inefficiency. The sensors selected and the factors and equations defined are those necessary to accurately and economically determine this energy balance.

The overall results of the site study are documented in an Instrumentation Plan which describes in detail all elements of the instrumented system. In addition, a Solar Energy Project description is published that documents the solar energy system and its instrumentation.

The second step in site preparation is the selection of sensors and the personalization of standard data acquisition equipment to meet the requirements specified in the Instrumentation Plan. Sensors are selected from a standard set which has been established to insure compatability with the Site Data Acquisition Subsystem (SDAS) and to optimize software development. Typical sensors are:

- Pyranometers
- Flowmeters
- Temperature Probes
- Electrical Power Meters
- Wind Speed and Direction Indicators

These sensors are connected to the SDAS. The SDAS is a microprocessor-controlled electronic unit developed by IBM which collects and stores data from the sensors several times an hour and transmits it to the central facility once a day. The collection process, data treatment procedure, and other functions of the SDAS are directed by a microprogram which is custom developed for each SDAS during site preparation according to the Instrumentation Plan for a particular site. The microcode is "burned into" the programmable read-only memory of the SDAS before it is shipped to the site.

The third step is installation and checkout of the SDAS and the sensors. The site contractor installs the supplied sensors in accordance with installation procedures (Reference: Instrumentation Installation Guidelines, DOE Report No. SOLAR/0001-77/15) and verifies that the wiring is correct before the SDAS is connected. Sensors are connected to the SDAS through a junction box which is wired according to the site Instrumentation Plan wire list and attached to the SDAS by a standard interface cable. The SDAS is connected to the National Solar Data Network through a data coupler installed by the local telephone company.

After the SDAS has been installed, checkout procedures are initiated to verify correct local operation of the sensors and data acquisition equipment as well as correct transmission of data to the central facility. An on-site monitoring unit is provided to allow a direct readout of the system measurements and thereby verify that the solar energy system and the SDAS are performing correctly.

Site preparation is followed by the on-going daily activity of data collection and analysis. The first phase is the once-a-day transferral of data from the on-site SDAS to the Central Data Processing System (CDPS) located at the IBM facility in Huntsville, Alabama, using the standard commercial telephone network. This data was collected during the previous 24 hours by the SDAS which scans sensor inputs several times an hour and stores the raw data on a cassette tape. The Communications Processor (an IBM System/7) at the CDPS calls each SDAS daily. The SDAS then rewinds the cassette tape and plays back the data.

In the second phase of data collection and analysis, the Communications Processor receives the data, performs error checking and formatting operations, and passes the data to the CDPS Host Computer (an IBM System/370 Model 145) for further processing. The Host Computer prepares the data for analysis by further checking for errors, preparing error reports, and updating data files. This data is then used to compute performance evaluation factors which are made available to the site analysts who review system performance on a weekly basis. In this third and final phase of activity at the central facility, the performance evaluation factors will be used to:

- Determine the savings in fossil fuel and electrical energy resulting from the use of solar energy for space heating, space cooling, and/or, hot water.
- Determine the total heating, cooling, and/or hot water thermal energy loads, and the fraction of each load supplied by solar energy.
- Measure the efficiency of the solar energy system in converting solar radiation into useful thermal energy.
- Measure the thermal performance of major subsystems or components and the thermal interactions among collector array, storage, and energy conversion components.
- Measure the occupant's use of the system by means of parameters such as the temperature level maintained and the demand for hot water.

- Determine the major system operational characteristics and degradation over the life of the demonstration.

- Obtain records of the incident solar radiation and other pertinent site environmental parameters that could affect the performance of the system over the life of the demonstration.

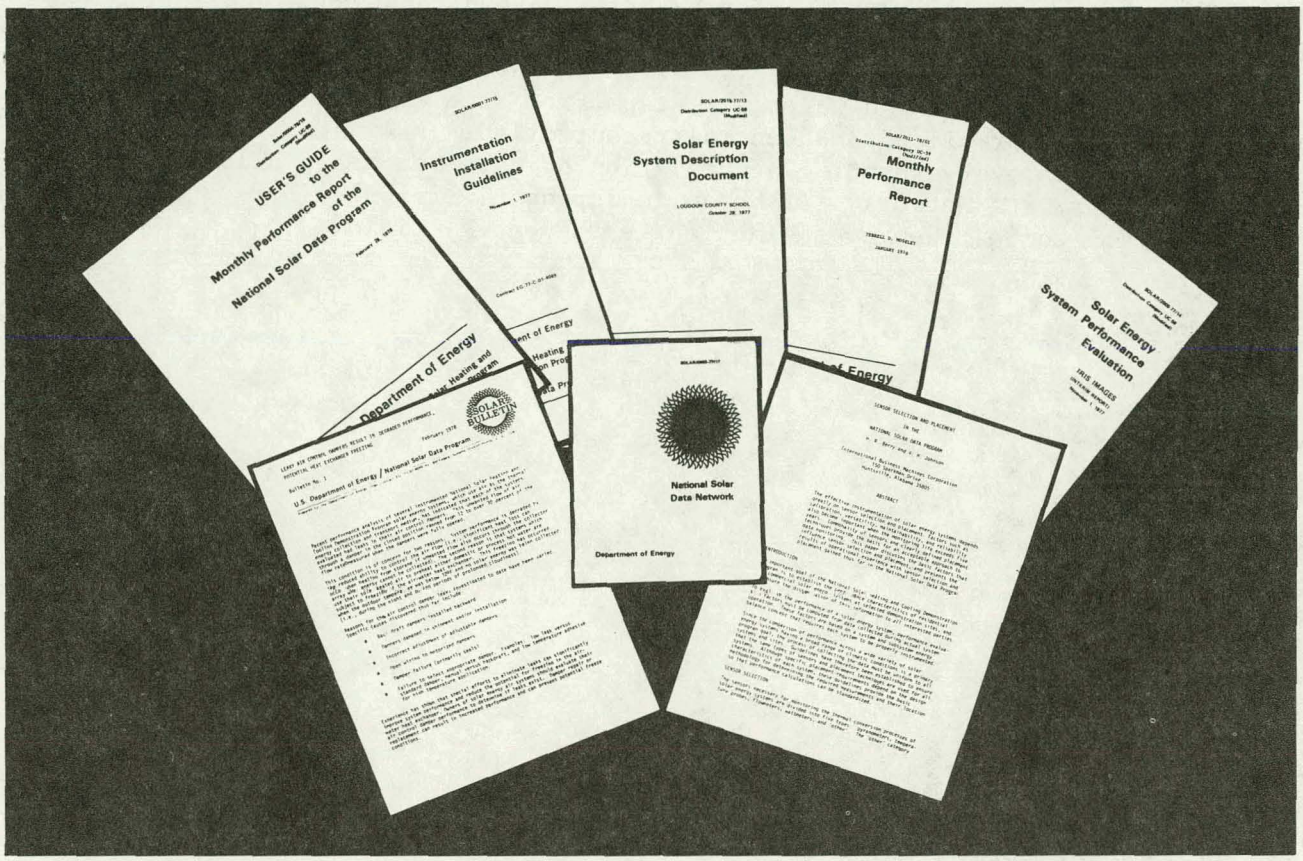


Figure 3. Examples of Solar Data Publications

The systematic analysis and evaluation of the data from the National Solar Data Network is reflected in the publications that result (Figure 3.). The Solar Energy Project Description is based on careful study of the solar energy system and its site. This document describes the system, the site, and the required instrumentation, and also predicts system performance. A Monthly Performance Report for each site contains system status and a monthly performance tabulation generated by the CDPS Host Computer. A Solar Energy System Evaluation Report containing a more comprehensive analysis of system performance is published periodically for each site. Comparisons of data from the various sites along with multiple site evaluations are presented in Program Wide Analysis reports. Solar Bulletins are generated in a timely manner when information of use to the newly developing solar industry becomes evident. Reports are also issued which pertain to special studies defined for the Demonstration Program. The above reports are distributed primarily through

DOE's Technical Information Center, P. O. Box 62, Oak Ridge, Tennessee, 37830. In addition, Solar Bulletins containing timely items of general interest to the solar energy community are widely distributed.

In summary, a systematic approach has been taken for the development of instrumentation requirements, performance evaluation techniques, collection procedures, and analysis methods. The program to establish a large body of data on the performance of diverse solar energy systems has been implemented using a systems approach in which all steps from site study to report generation have been formalized and centrally controlled. As installations are completed and an ever-expanding accumulation of data becomes available, the National Solar Data Network will be an indispensable resource for establishing the direction to be taken by the nation in the energy field.

Solar Energy Control System Evaluation

J. C. Bartlett

INTRODUCTION

The National Solar Heating and Cooling Demonstration Program, administered by the Department of Energy, includes solar-energy systems located at various sites throughout the United States, the Virgin Islands, and Puerto Rico. System design and climatic conditions vary widely among these systems, and some have been selected for performance monitoring under the National Solar Data Program. The monitoring, evaluating, and reporting of the thermal performance of these selected solar-energy systems is being done by the International Business Machines Corporation. In the performance monitoring process, numerous systems have been observed in which the control system has caused abnormal operation of the solar-energy system. The purpose of this paper is to discuss these observed anomalies to aid the designers of solar-energy systems in avoiding such problems in the future. For discussion purposes, the problems which caused the anomalies have been classified as problems with control sensors, problems with individual controllers, and problems with multiple controllers. Several examples are given which characterize each of these classes of problems. If the cause of the problem is obvious, it is briefly mentioned. But if the cause of the problem is not obvious, a detailed discussion is presented to ensure that the problem is well understood and can be avoided in the future.

CONTROL-SENSOR PROBLEMS

A control-sensor problem is characterized by an invalid input to the controller. In this class of problems, the controller performs as it should, but the system operates abnormally because the inputs to the controller are invalid. An obvious example of an invalid input is one based on a faulty or inaccurate sensor. Another example is an input from a sensor which is physically mislocated.

An example of a control-sensor problem which is not as obvious as those identified previously, but which has been observed on several systems, is the effect of an extraneous heat flow on a temperature-control sensor. In each case the extraneous heat flow caused either heating or cooling in the immediate vicinity of the temperature-controller sensor. The result of the control-sensor problem was either degraded performance or system failure.

Extraneous heat flows have resulted from solar radiation, wind, and ambient temperature. They have also been associated with a storage tank, a boiler, or a hot or cold pipe near the temperature-control sensor. In some cases they have been caused by thermal gradients between two points along a pipe or duct under normal no-flow conditions. These thermal gradients have resulted in either heat transfer along the pipe or duct, or free convection cells being set up within the piping loop wherein fluid is transported by buoyant thermal forces from the hotter to the cooler region. Invalid inputs from temperature-control sensors located between these regions have resulted in abnormal system operation.

There are two types of abnormal system operation caused by invalid inputs to the system controller resulting from extraneous heat flow on temperature-control sensors. The first is degraded system performance as typified by the

case where the collector-inlet temperature is artificially high. Under this condition the solar energy collected over an extended period may be significantly reduced because the collector circulation pump is not always operated when useful energy could be collected. This effect, even when significant, might go unnoticed.

The second type of abnormal operation is outright system failure. An observed case involved a solar-energy system where liquid from storage was recirculated to prevent freezing in the collectors. The temperature-control sensor which was used to initiate the freeze protection mode was appropriately located adjacent to the collector, but it was inadvertently heated by thermosiphon effects from the hot liquid within the storage tank. With recirculation thus disabled, freezing occurred within the collector manifold causing the piping to rupture.

In light of these observations, all temperature-control sensors for solar-energy systems should be reviewed with respect to their location and susceptibility to extraneous heat flows. Special attention should be given to their insulation. If these sensors are properly insulated, their susceptibility to the influence of ambient temperature fluctuations will be greatly reduced. When heat flows are internal to the heat-transfer fluid, such as those associated with thermosiphon cells, their influence can be reduced by proper placement of the sensors or by use of check valves or backdraft dampers. In addition, the designer or installer of a solar-energy system should ensure that all control sensors are neither faulty, inaccurate, or mislocated.

INDIVIDUAL CONTROLLER PROBLEMS

An individual controller problem is characterized by either the controller not functioning as designed or the controller functioning as designed but the design being incompatible with the solar-energy system. The first example is obvious and thus not discussed. However, problems of the latter type are not as obvious and a few typical examples are presented.

Numerous solar-energy systems have been observed in which the operation of the pump which circulates the heat-transfer fluid through the collector is repeatedly cycled on and off. This abnormally high rate of on-off operation degrades system performance and could cause premature failure of the pump. It most often occurs during periods of low solar radiation such as early morning or late afternoon when the collection of solar energy is being initiated or terminated. The cause has been found most often in either the collector controller or the control sensors, and sometimes in the system dynamics.

The typical collector controller turns the circulation pump on or off based on the difference in temperature between the collector outlet and the bottom of storage. If the pump is off and this temperature difference rises above some present value, ΔT_{ON}, the circulation pump will be turned on. If the pump is on and this temperature difference falls below some present value, ΔT_{OFF}, the circulation pump will be turned off. The temperature difference required to turn the pump on must be significantly greater than

that required to turn it off. Otherwise cycling will result. For example, when the pump is turned on, energy will be removed from the collector and the fluid outlet temperature will decrease. If, ΔT_{OFF} is too close to ΔT_{ON} and the incident solar-energy does not increase sufficiently, the pump will quickly be turned off. With no flow through the collector, the fluid-outlet temperature will increase, and the pump will quickly be turned back on, starting another cycle. This will continue until the incident energy either increases or decreases enough to keep the pump either on or off. The ratio of ΔT_{ON} to ΔT_{OFF} that will prevent this instability is determined by the characteristics of the collector and the environmental conditions. This ratio has been found to be typically between 5 and 7 for liquid collectors and between 1.5 and 3 for those using air. Setting it too low will result in cycling, as described, and setting it too high will result in inefficient operation by not maximizing the solar energy collected. For maximum efficiency, this ratio should be set during system operation in the field to a value slightly above that required to prevent cycling.

System dynamics in both start up and no-flow conditions have also been observed to cause unstable operation of the collector fluid circulation pump. If, at collector start-up in the morning, the line from the storage tank to the collector contains a significant quantity of fluid which has reached ambient temperature during the night, cycling might result due to the cooler fluid passing through the collector ahead of the warmer fluid from storage. The cooler fluid will quickly lower the collector-outlet temperature below that at the bottom of storage thus turning the pump off. This problem has been eliminated in some solar-energy systems by using a time delay in the controller to allow passage of the cooler fluid through the collector without the pump being turned off. During no-flow conditions at night, it is also possible for enough thermosiphon of the fluid between the cooler collector and the warmer storage to heat the temperature-control sensor enough to turn the pump on. This condition has also resulted in instability since once flow is initiated, the sensors will be cooled quickly and the pump therefore turned off. This condition has been avoided in many systems by the use of check valves to prevent thermosiphoning.

Because of the numerous observed cases of instable operation of the collector fluid circulation pump, the designers of solar-energy systems should give particular attention to the collector-pump controller. If, however, the operation of the pump is unstable after the system is operational, the cause of this instability should be determined. If the cause is found to be one of those previously mentioned, it is recommended that the solutions discussed be considered. In addition, the designer or installer should ensure that the controller is functioning as designed.

MULTIPLE CONTROLLER PROBLEMS

A multiple controller problem is characterized by a solar-energy system having two or more controllers which are incompatible. This class of problem is more complex than those previously discussed since rarely have two systems been observed which have the identical problem. Because of this complexity it is easier to discuss this class of problems in general terms instead of with specific examples as was done previously.

A few solar-energy systems have been observed where the incompatibility that caused abnormal operation was between one control system functioning within another control system. An example is a system in which a major component, such as an absorption chiller, has its own control system, which is incompatible with the solar-energy system controller. To illustrate the problem, an absorption chiller could have an internal controller which turns the chiller off based on certain chiller requirements such as maximum condenser water temperature. If the solar-energy system controller was not designed with this in mind, it could continue to circulate water to the generator when the chiller was off.

Other systems have been observed where the incompatibility is between the collector controller and the load controller. In several systems using air as the transport fluid, the collector controller collected and stored energy late in the afternoon at a temperature lower than that which the load controller had defined as useful. The energy at a lower temperature was stored at the top of the rock bed, forcing the higher-temperature energy, collected in the middle of the day, to the middle of storage. At night, when a demand for space heating existed, the temperature at the top of the rock bed was less than the useful temperature for heating; and the heating demand was met completely with the auxiliary unit even though the temperature of the middle of storage was useful.

Because of the number of systems that have been observed to operate abnormally for reasons of incompatibility of multiple control systems, it is recommended that the designers of solar-energy systems give particular attention to the compatibility of the various control systems. The cause of the various observed problems have varied greatly; therefore, it is difficult to present any specific recommendations. However, if an overall systems approach is used in designing the various control systems, it may be possible to avoid some of the problems in the future.

SUMMARY AND RECOMMENDATIONS

Control system anomalies observed during the monitoring of instrumented solar-energy systems by IBM as part of the National Solar Data Program have been discussed using examples of abnormal operation. The problems are classified as control-sensor problems, individual controller problems, and multiple controller problems. In many cases, the performance of the system was significantly degraded. In other cases, the abnormal operation resulted in system failure. All existing systems should be reviewed in the light of their susceptibility to these problems, and they should be kept in mind during the design of future solar-energy systems. Solutions which have proven to be effective were presented for specific examples of control-system anomalies. If during the operation of a solar-energy system the specific problems presented here are found then these solutions should prove helpful.

Analysis of Collector Array Performance from Field Derived Measurements

W. H. McCumber Jr.
and
M. W. Weston

INTRODUCTION

The National Solar Energy Demonstration Program is collecting and archiving data measured at operating solar-energy systems. These systems represent heating, cooling and hot-water applications to residential, commercial, and industrial facilities.

The availability of these data provides an opportunity to verify the practicality of design concepts and tools which, prior to now, were the province of laboratory scientists. One such tool is the industry standard collector model, the Hottel-Whillier-Bliss (HWB) equation.

This paper presents a technique by which the field performance of collector arrays is related to the HWB equation via ASHRAE Standard 93-77, which established technical criteria for collector evaluation. An example array, located in the north central, Great-Plains Area, is used to illustrate the technique. Preliminary results of the analysis of three collector designs are presented.

COLLECTOR ARRAY EFFICIENCY

The steady-state thermal performance of a single flat-plate collector is well understood, and has been the subject of a number of technical papers over the past four decades (Refs. 1-6). Rigorous thermal performance calculations involve the iterative solution of nonlinear matrix equations of rank 5 or higher. To avoid this complexity, the industry has adopted the HWB equation (Ref. 2) as its standard tool for steady-state collector evaluation.

$$Q_u = F_R A \left[I (\tau\alpha)_e - U_L (t_{f,i} - t_a) \right] \qquad (1)$$

The elements of the HWB equation are the absorber plate area, A; the insolation level, I; the effective product of the cover transmissivity and the plate absorptivity, $(\tau\alpha)_e$; the collector loss coefficient, U_L; the fluid in-

let temperature, $t_{f,i}$; ambient temperature, t_a; and a collector heat removal factor, F_R. The principal inaccuracy of the HWB equation lies in the assumption that U_L is constant; whereas, in reality, U_L is a strong function of wind and temperature. The usual method of collector evaluation is to set up steady-state laboratory test conditions and measure energy gain from the equation:

$$Q_u = \dot{m} C_p (t_{f,e} - t_{f,i}) \tag{2}$$

where $\dot{m}$ is the mass flow rate, C_p is the working fluid specific heat, and $t_{f,e}$ is the fluid exit temperature. Setting Eq. 1 equal to Eq. 2 and solving for the ratio of actual energy collected to the incident energy leads to

$$\eta = Q_u/IA = F_R (\tau \alpha)_e - F_R U_L (t_{f,i} - t_a)/I \tag{3}$$

Q_u is calculated from the available measurements and material properties by Eq. 2, and the expression $(t_{f,i} - t_a)/I$ is formed from measured quantities, leaving $F_R (\tau\alpha)_e$ and $F_R U_L$ as unknowns.

An expression of the form of Eq. 3 can be graphed as a straight line having the intercept, $F_R (\tau \alpha)_e$, and the slope, $F_R U_L$, on a coordinate system that has $(t_{f,i} - t_a)I$ as the abscissa and η as the ordinate. This provides a convenient basis for comparison of various collector configurations. Toward that objective and for reasons of consistency, ASHRAE Standard 97-77, "Methods of testing to Determine the Thermal Performance of Solar Collectors", was released in 1977 (Ref. 7).

Briefly described, the collector testing guidelines of ASHRAE 93-77 require testing to be accomplished under the following conditions: (1) a steady state collector temperature environment; (2) insolation greater than 200 Btu/ft^{2}hr; (3) wind speed less than 10 mph; and (4) a range of ambient temperature of less than 55 degrees during the testing. A minimum of 16 efficiency points are required.

The test method of ASHRAE 93-77 is to establish steady-state conditions of flow, irradiation, exit temperature, and ambient temperature for several values

of inlet temperature (the controlled variable); then, calculate efficiency, η , from equation (3) and plot the resulting points. A line is then drawn through the points, using a first-order, least-square curve fit. A typical test result is illustrated in Figure 1.

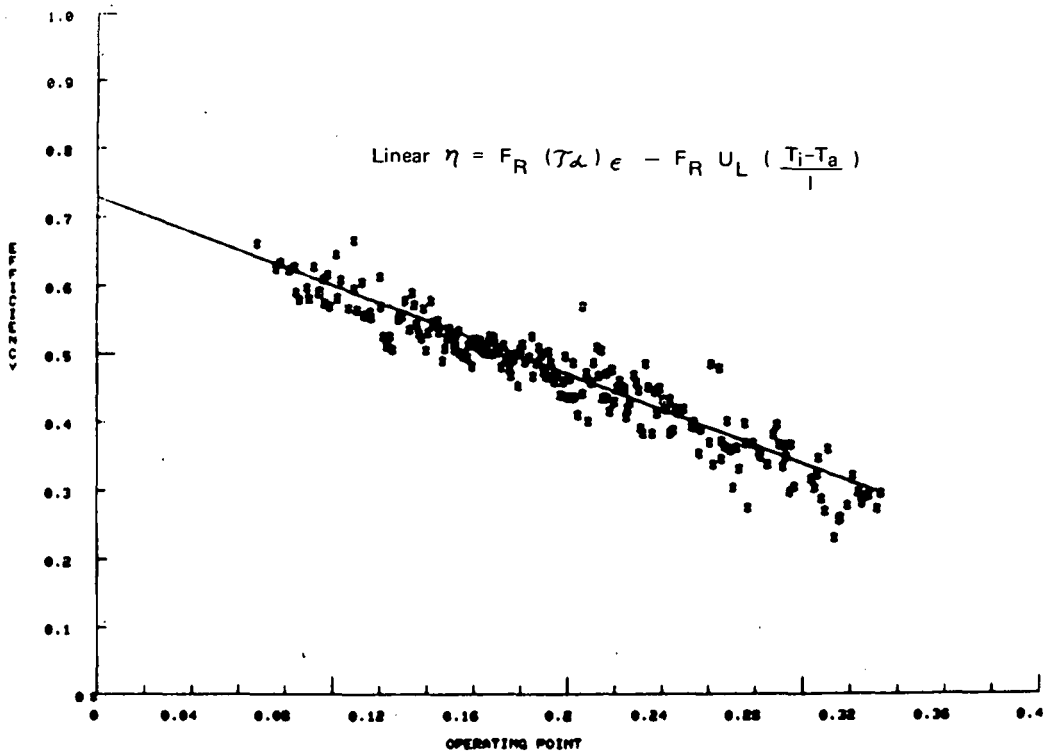


Figure 1. Typical Test Result

The extension of single-collector performance expectations to an array expectation requires assumptions, since the single collector analysis does not take into account the working fluid held in the external manifolding and risers. For an array of more than one, or two collectors, the working fluid held external to the collector panels becomes significant. Also, it is noted that the ASHRAE "steady-state" requirement is equivalent to requiring a zero propagation time between a change in fluid-inlet conditions and the effect on the fluid-outlet conditions. Since collector arrays in the field are exposed to a variety of dynamic forcing functions, (clouds, wind, diurnal variations in sunlight, shading, etc.), the expectation is that steady-state conditions will never be observed.

The effect of the fluid mass between inlet and outlet temperature sensors is to delay the propagation of transient effects, resulting in a large degree

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of scatter in the derived information points. To partially compensate for this effect, the energy-gain equation is modified to include stored, internal energy.

Consider implementation of the ASHRAE collector thermal analysis procedure in a system which acquires time-coherent data points at equally spaced intervals. A time-coherent group of measurements is called a "scan". The measured parameters are $\dot{W}$, the fluid volumetric flowrate; $t_{f,e}$, fluid exit temperature, $t_{f,i}$, fluid inlet temperature, t_a, ambient temperature; and I, insolation level. The fluid specific heat, C_p, may be calculated from its material properties. The fluid mass, M, between inlet and outlet temperature sensors is a measured constant. Volumetric flow rate, $\dot{W}$, is converted to mass flowrate, $\dot{m}$, through multiplication by the fluid density, ρ, and a flow-correction factor, f_c[1]. Then, for computation of the abscissa, we write

$$X = (t_{f,i} - t_a)/I \tag{4}$$

and for computation of the ordinate, we write

$$\eta = \dot{m}C_p\,(t_{f,e} - t_{f,i})/IA + MC_p\,(\Delta t_{avg})/T \tag{5}$$

where Δt_{avg} is the change in the average fluid temperature over the scan period, T.

It was assumed in the derivation of Eqs. 4, 5 that the input measurement data is representative of steady-state thermal operation. However, field derived measurements are dynamic and include transient thermal effects. In order to meet the "steady-state" requirements of ASHRAE 93-77 and to utilize the HWB equation, constraints must be placed on the field-derived data. These constraints typically take the form of limitations on magnitude, and limitations an allowable variation with time. In the process of evaluating field performance of collector arrays, the application of constraints is referred to as "filtering".

[1] C_p, ρ, and f_c are calculated functions of the fluid temperature at the point of flow measurement.

FILTERING

The filtering process attempts, as closely as practical, to adhere to the philosophy and procedures outlined in ASHRAE Standard 93-77. To accomplish this, eight filters were designed to effectively impose and implement the restrictions associated with quasi-steady-state operating conditions. These filters are:

- Sun angle maximum
- Insolation floor
- Insolation variation between scans
- Wind velocity ceiling
- Inlet temperature variation between scans
- Temperature gain variation between scans
- Ambient temperature variation between scans
- Flowrate variation between scans.

where a scan is one time-coherent group of measurements.

The capability has been provided to choose the number of scans (5-min., 20-sec. periods) over which variation constraints are imposed. A brief description of the use of the filters is given below.

The isolation floor filter establishes a variable lower limit on the insolation. It is nominally set for 200 Btu/hr-ft^2, may be adjusted as required for the collector array design.

The sun-angle constraint is required in order to exclude reflection effects at low angles of incidence and to compensate for collector array orientations which do not face due south. When flat-plate collectors are evaluated, it is desirable to exclude all data points beyond 30 degrees of the collector normal. However, tracking collectors and tubular collectors operate well at higher angles, and the sun-angle filter limit is increased correspondingly.

A ceiling is placed on the wind velocity. The principal error source of the HWB equation lies in the variation of U_L with wind and temperature. Since the wind filter is adjustable in the software, the exact effect on U_L may be characterized for a given array. Control of the wind effects, through filtering, reduces point scatter considerably.

After the raw scan data has passed the limiting filters, the search begins for steady-state conditions. Examination of Eqs. 4, 5 reveals that flow, fluid-inlet temperature, fluid-exit temperature, ambient temperature, and insolation level enter into the determination of a point on the $X-\eta$ coordinate system. These are the measurements which must be held nearly constant for a period of time greater than the time constant of the collector in order to establish steady-state.

EXAMPLE RESULTS

The performance analysis of collectors from field derived measurements is an experimental technique now under development and evaluation. The following results must, therefore, be considered preliminary.

Figure 2 is the initial scatter diagram derived by applying Eqs. 4, 5 to raw, unfiltered data from an aluminum absorber - copper tube collector array. Application of a 10 mph ceiling on the wind velocity reduces the scatter to a much narrower band, as shown in Figure 3. Figure 4 is the scatter diagram of the points remaining after setting the sun-angle filter to 30 degrees and variation filters to 5 percent over one scan (320 seconds). A regression line has been plotted through the points, from which the slope and intercept are found to be -0.303 and 0.815, respectively.

Figure 5 is the initial scatter diagram for a lexan glazed - steel/aluminum absorber collector array. Figure 6 is the efficiency curve derived from raw data by the filtering process and curve-fit. Note the coefficients deviated less than 5 percent between filtered and unfiltered data.

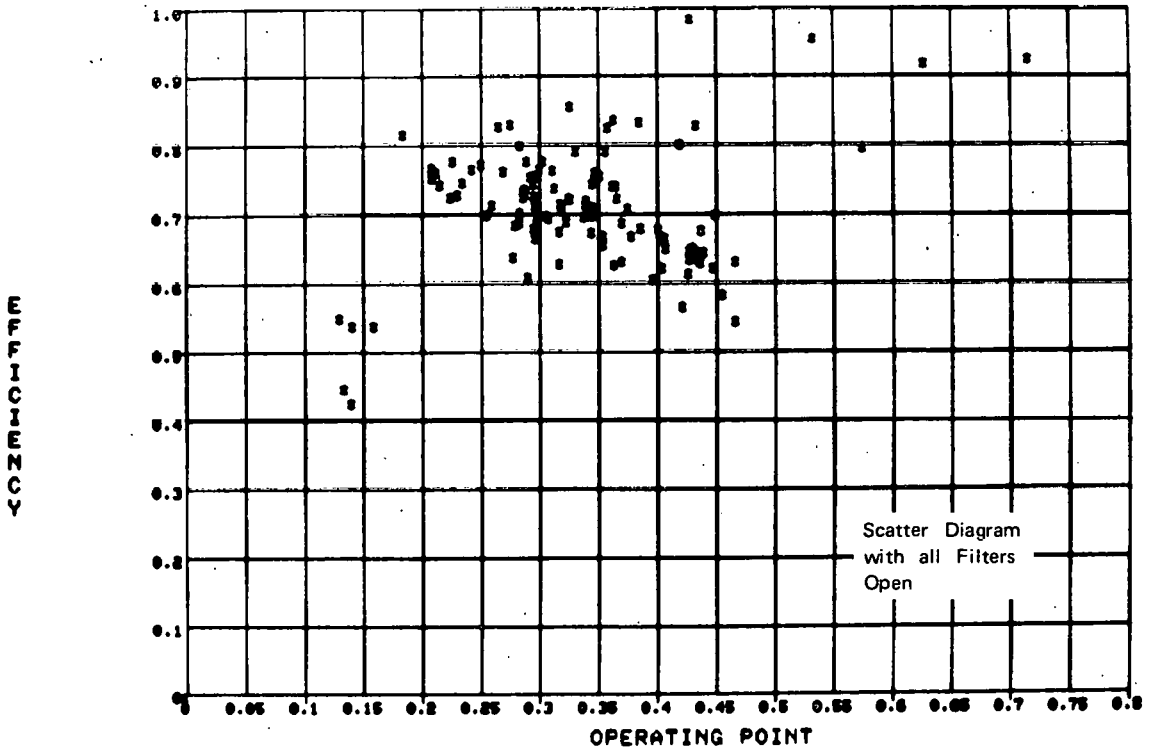


Figure 2. Scatter in Data Points for Aluminum Absorber Copper Tube Collector

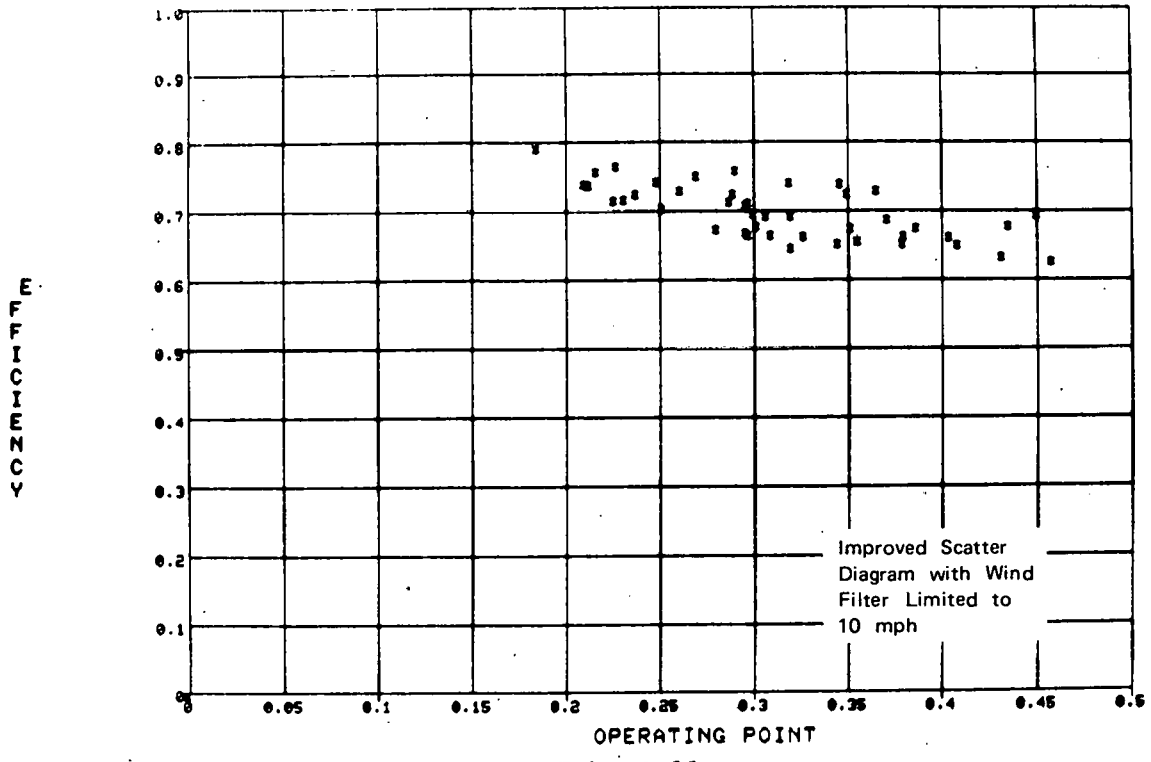


Figure 3. Aluminum Absorber Copper Tube Collector

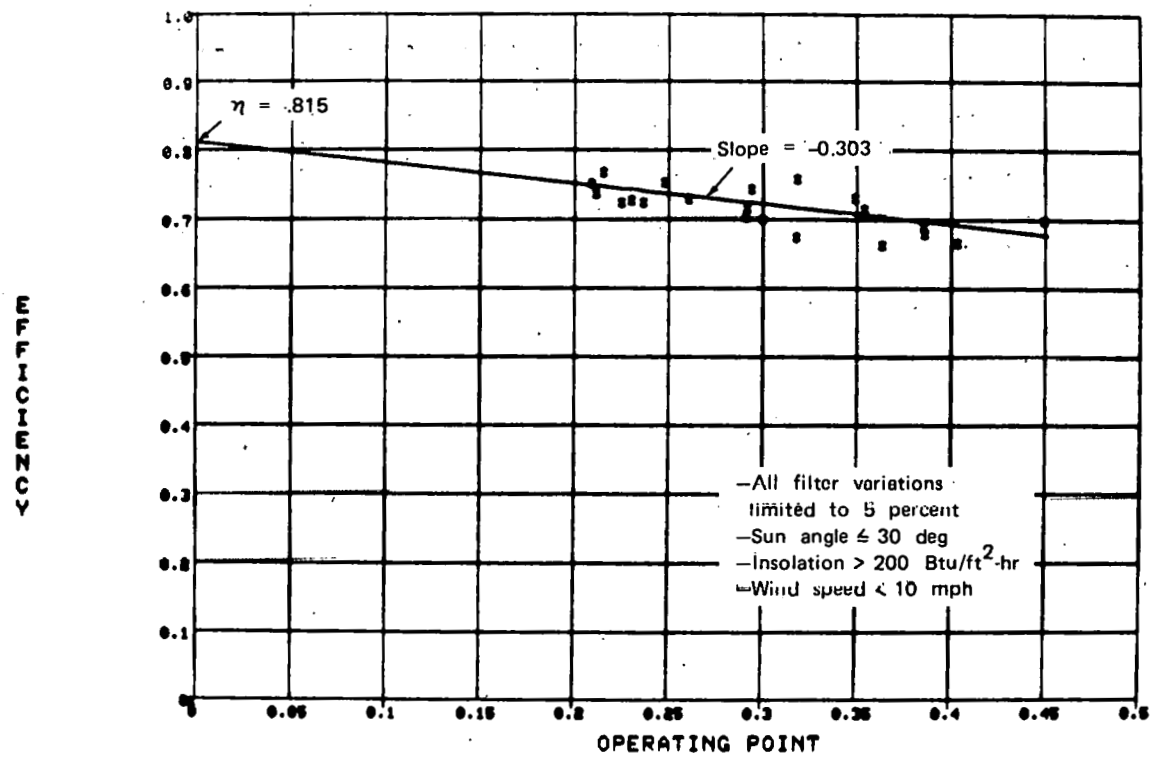


Figure 4. Aluminum Absorber Copper Tube Collector

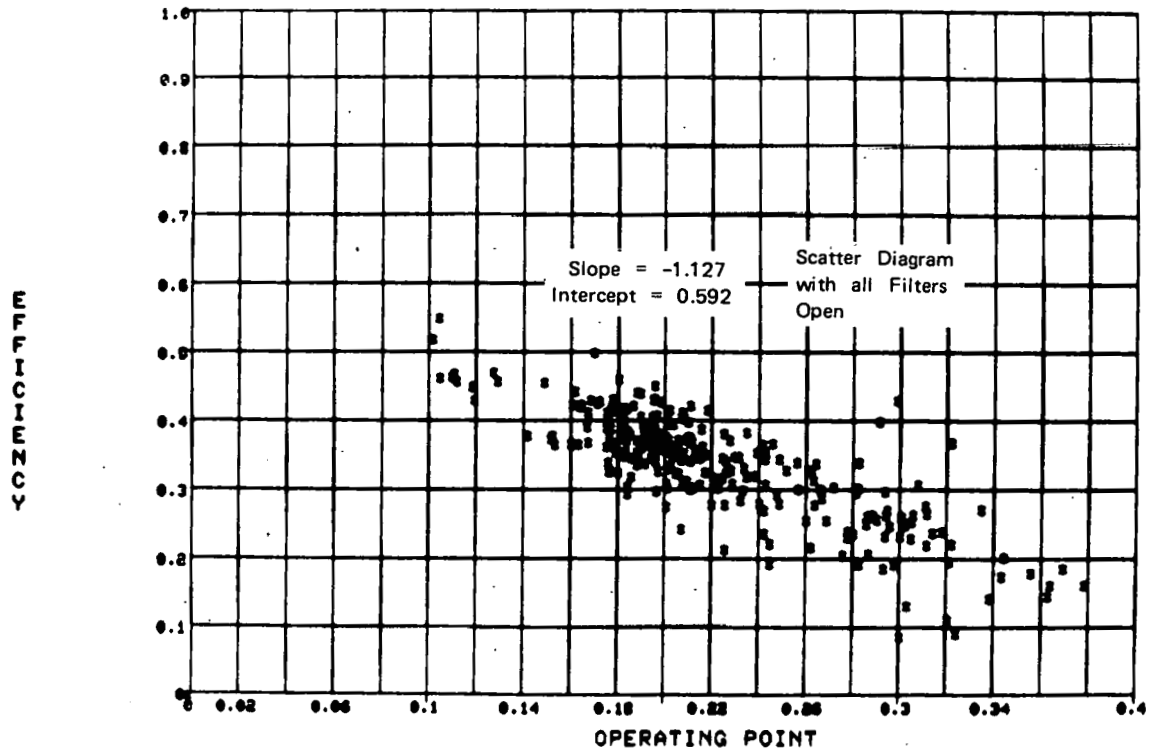


Figure 5. Aluminum Absorber Steel Tube Lexan Glazed Collector

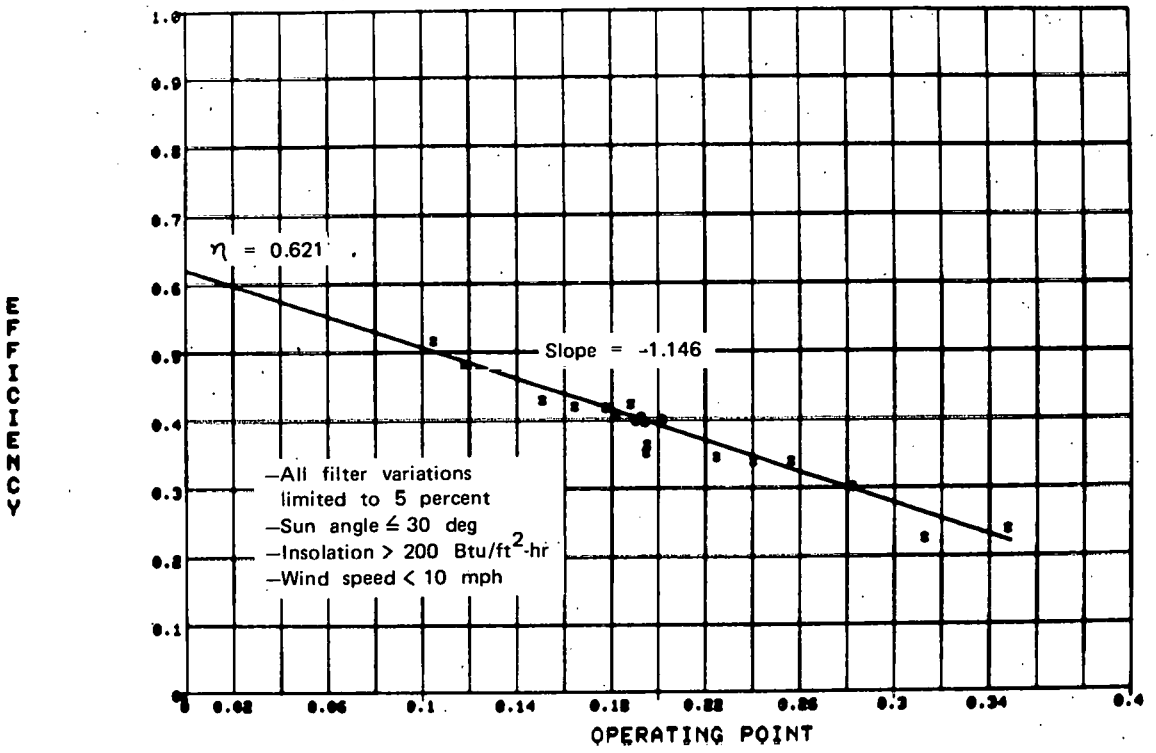


Figure 6. Aluminum Absorber Steel Tube Lexan Glazed Collector

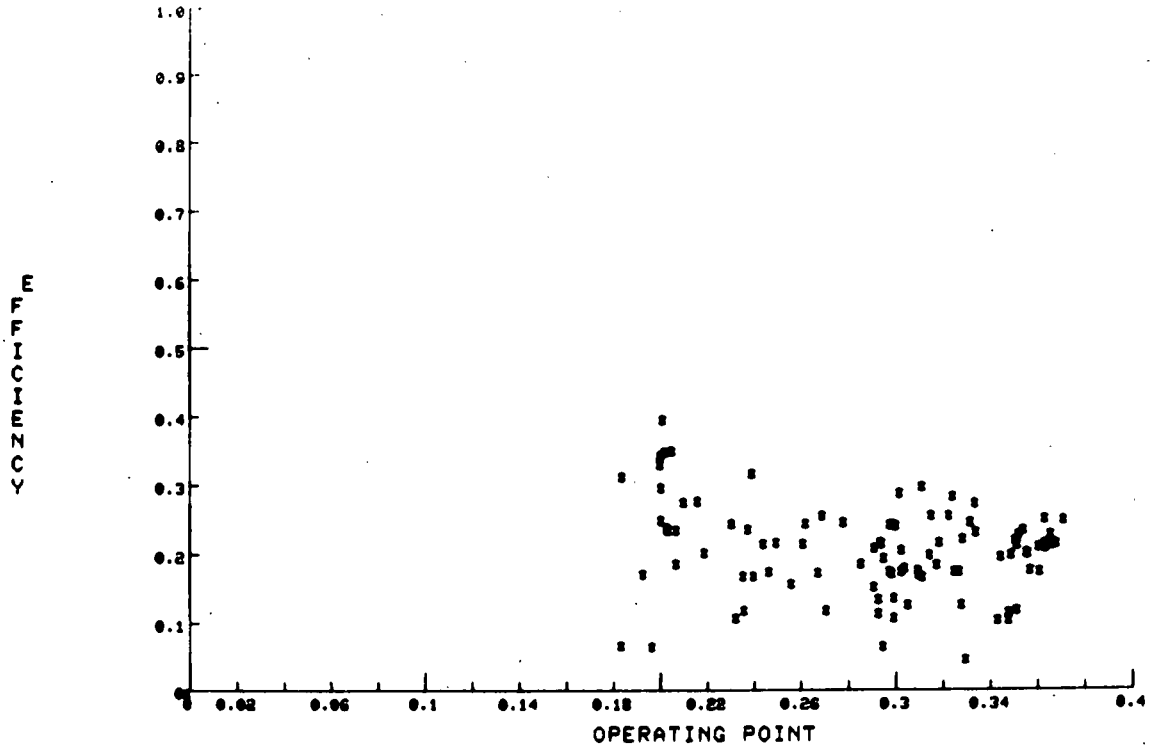


Figure 7. Fresnel Lens Type Concentrator Final Scatter

Figure 7 is the final scatter diagram for an array of Fresnel lens tracking concentrating collectors. It was not possible to reduce the point scatter beyond that shown by using standard filters. In these situations, the collector analysis tool may be used to diagnose the probable causes of non-convergence by iterative selection of filter settings. This particular array was found to be primarily influenced by wind velocity, which, it is postulated, may introduce tracking error or higher losses via manifold heat losses.

CONCLUSIONS

The abundance of raw data available from solar energy demonstration systems permits reference of field performance to the HWB equation. The technique presented in this paper allows for reduction of scattered operating points to a set consistent with the requirements of ASHRAE 93-77. The HWB model thus obtained provides engineers, designers, architects, contractors, and other interested personnel with a model representative of the design's performance, which may then be incorporated into future designs and cost trade analyses. The HWB model obtained from field measurements may also be compared to the predicted performance or controlled test performance data available for collector components. This comparison then allows a more accurate estimation of collector area required to satisfy design loads, ultimately minimizing the cost of solar energy systems.

The technique also provides information as to the impact of environmental conditions on the performance of collector arrays. Sensitivity to wind is of particular importance. Used as an analytical tool, the filters may quantify the local environment; as, for example, in the creation of a site specific wind rose.

The technique has been proven effective. Future papers will include detailed collector array performance analyses, transient source identification and sensitivity to environmental effects for specific collector types.

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Thermal Performance of the Scattergood School Solar Energy System

Kenneth L. Shenfish

INTRODUCTION

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy as mandated by the Solar Heating and Cooling Demonstration Act of 1974 (1). The International Business Machines Corporation is contributing to The National Solar Data Program of the Department of Energy by monitoring, evaluating, and reporting performance of designated solar-energy systems in the program. This paper briefly describes the Scattergood School solar-energy system (a PON-1 site), its modes of operation, and presents an evaluation of the system performance for the period September, 1977, through April, 1978. This evaluation is based on comparison of measurements of climatic, load, and operational conditions with those which were expected based on predictions and long-term averages.

SYSTEM DESCRIPTION

Scattergood School is located near West Branch, IA approximately 35 miles southeast of Cedar Rapids. Its solar-energy system is designed to supply approximately 75 percent of the average annual energy requirements for space-heating the gymnasium and for heating hot-water for an adjacent locker room. Solar energy is also available for a grain-drying silo recently added to the site. The site has an array of flat-plate collectors with a gross area of 2496 square feet that faces south at a tilt of 50 degrees from the horizontal. Air is the medium used for transferring energy from the collector array to storage or directly to the gymnasium. Energy is stored in a bin containing 130,000 pounds of rock and in two 120-gallon water-preheating tanks. When solar energy is insufficient, propane gas heaters furnish auxiliary energy for space heating. Auxiliary energy for hot water is provided by standard electric immersion heaters in the 52-gallon domestic hot-water heater. The system shown schematically in Figure 1, has four modes of solar operation, and grain drying.

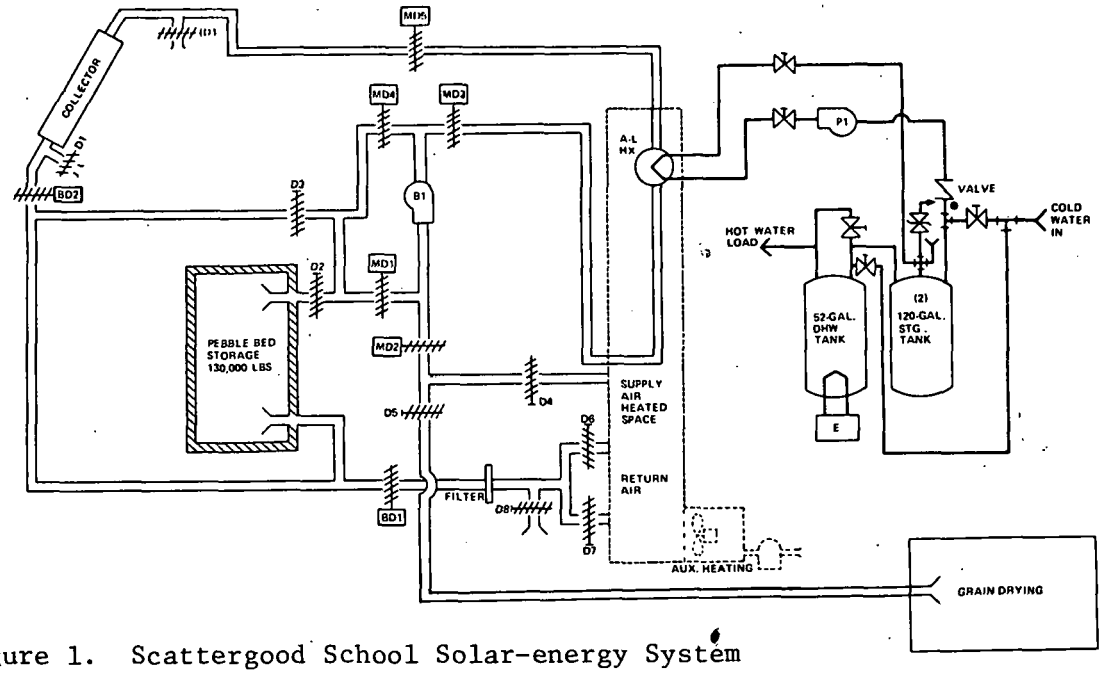


Figure 1. Scattergood School Solar-energy System

Mode 1 - Collector-to-Space Heating: This winter mode is initiated when there is a difference in temperature of 45°F between the outlet of the collector and a temperature representative of the gymnasium and the bottom of storage; and a demand for space heating exists as indicated by the manually preset, two-stage thermostat. Air from the collector is circulated through the air-handling unit to the gymnasium, through motorized dampers, and returned to the collector, bypassing the storage bin. Circulation continues in this mode until the difference in temperature between the outlet and inlet of the collector is less than 30°F or the demand for space heating is satisfied. Stage one of the thermostat requests solar energy, and stage two operates in conjunction with stage one to activate auxiliary heaters to supplement solar energy when the gymnasium temperature drops below a level determined by the thermostat setting.

Mode 2 - Storage-to-Space Heating: This winter mode is initiated when there is a demand for space heating, the collector loop is not active, and the temperature in the rock bed is 90°F or higher. Air is drawn through motorized dampers from storage and circulated through the air handling unit to the conditioned space and returned to storage, bypassing the collector.

Mode 3 - Collector-to-Storage: This winter mode is initiated when the difference in temperature between the collector outlet and a temperature representative of the gymnasium and the bottom of storage is 45°F or higher, and there is no demand for space heating. Air is drawn from the collector via the air-handling unit into the rock bin through motorized dampers and recirculated through the collector. Circulation continues in this mode until the difference in temperature between the outlet and inlet of the collector is less than 30°F. Mode 1 has priority over this mode.

Mode 4 - Collector-to-Water Preheating: This summer operation mode is initiated when there is a demand for water heating and the difference between the collector outlet and a temperature representative of the gymnasium is 45°F or higher. Air is circulated from the collector through motorized dampers to an air-to-liquid heat exchanger, via the air-handling unit, and returned to the collector, bypassing the storage bin and the conditioned space. This mode continues until the temperature in the preheat tank reaches 140°F or until the collector differential temperature drops below 30°F. This preheated water is stored in two, 120-gallon tanks and delivered on demand to a commercial, 52-gallon domestic hot-water tank with an auxiliary electric heating element. Water can also be preheated in Modes 1 and 3 during the heating season when energy collection is present and a demand for hot water heating exists.

PERFORMANCE EVALUATION OBJECTIVES

Comprehensive monitoring of program instrumentation provides detailed data by which a thorough evaluation of the performance of the solar-energy system can be made. This evaluation extends not only to the system but also to subsystems and critical components as well. It has three objectives. First, the ability of the solar-energy system to meet the demands of the conditioned space and the demand for hot water must be determined. Then, the savings of energy resources resulting from this use of solar energy is derived. Finally, this in-

formation is compared to design data so that demonstration results can influence future designs. As a side benefit, an accurate record of the climatological data at a location is recorded for design comparisons and future designs. To meet these objectives, the thermal performance parameters for evaluating solar energy systems were defined by a governmental interagency solar-heating and cooling performance evaluation committee. These parameters are defined in Refs. 2, 3.

A monthly performance report is issued for each instrumented solar-energy system in the demonstration program by the Technical Information Center, Department of Energy, at Oak Ridge. TN. This report contains an analysis of the system performance and statistical summaries of performance of major subsystems and critical components. Thus, the monthly report provides archival information on the solar-energy system's performance to a variety of users.

A seasonal evaluation report will be available on selected sites as sufficient data accrue to cover a representative heating or cooling season. In addition to a detailed description of the site and its modes of operation, this report will have a seasonal summary of the system performance including sections covering the analytic methodology, climatic and load conditions at the site, actual versus predicted performance of the system, and evaluation results. As they are published, these reports will also be available from the Technical Information Center.

SOLAR-ENERGY SYSTEM PERFORMANCE EVALUATION

The performance of the Scattergood School solar energy-system has been evaluated using two methods. The first method is based on the primary system performance parameters during a typical use season. Since the Scattergood School solar-energy system is a space-heating and domestic hot-water system, the performance evaluation is based on a heating season. The evaluation period for the seasonal analysis is September, 1977, through April, 1978, with October omitted due to data transmission difficulties during the month (8-14). The performance evaluation includes a comparison of the actual versus predicted performance in addition to an evaluation of the overall performance of the system. The second method provides a summary of the energy flows through the system for a typical month. These energy flows are presented to determine how the system is performing in terms of its management of energy flows to and from each subsystem.

Seasonal Performance

The Scattergood School solar-energy system operated throughout the winter heating period of September, 1977, through April, 1978. The space-heating subsystem satisfied 86 percent of the space-heating demand of 107.3 million Btu. The system achieved a fossil-fuel savings of 115.2 million Btu. The savings are based on a comparison of the projected energy requirements of a conventional propane heater with an efficiency of 80 percent with the energy requirements of the solar-energy system. The hot-water preheat subsystem operated until November 25, 1977. On that date the air-to-water heat exchanger froze and burst, dumping 2000 gallons of water on the gymnasium floor. The subsystem failure oc-

curred when excessive leakage through a control damper allowed cold air to be circulated through the collectors and passed the heat exchanger when the system was operating in the storage-to-space heating mode. The heat exchanger was repaired immediately but further repairs and the addition of another control damper were necessary to prevent a similiar recurrence. These repairs were not completed until late February, 1978. The hot-water subsystem has been used sparingly since it was returned to operation. Thus, the hot-water subsystem performance before November 25, 1977, represents what can be expected of that system. During this period, the system provided 1.4 million Btu of energy to satisfy the hot water demand with solar heating satisfying 79 percent of the demand. This percentage is expected to be lower during the colder winter months. However, the actual performance could not be determined because the system was not operational.

Monthly values of total insolation measured at a tilt of 50 degrees from the horizontal, average ambient temperature measured at the site, and degree-days computed from daily ambient temperature are presented for the Scattergood School solar-energy system in Table 1. Also presented are long-term average monthly values of these climatic parameters for the geographical location. Long-term insolation data are taken from the Climatic Atlas of the United States. Local climatic data are from the NOAA Climatological Data and site environmental

Table 1. Total Insolation, Average Ambient Temperature, and Heating Degree Days for West Branch, IA

	Total Insolation at 50 Deg. Tilt (Btu/ft^2)		Average Ambient Temperature (^{o}F)		Heating Degree Days		
Month (yr)	Measured	Long-Term* Average	Measured	Long-Term Average*	Long-Term* Average	Measured	From Local Utility
Sept 77	39390	42159	61	63	128	135	97
Oct 77	**	37300	**	54	375	**	507
Nov 77	25939	32656	33	37	813	924	920
Dec 77	24124	29531	20	25	1237	1390	1425
Jan 78	38446	32420	11	19	1391	1655	1744
Feb 78	39634	35749	14	25	1136	1417	1475
Mar 78	48580	42180	32	36	937	1036	1060
Apr 78	37448	39723	49	48	480	489	512

*Estimated from measured long-term data from Dubuque, IA, and Burlington, IA

**Data not available

data supplied by the IBM site instrumentation. The cold winter of 1977-1978 is evident in the measured climatic conditions. Measured insolation during 1977 was lower than normal due to greater than average cloud cover during the winter months of 1977. However, the winter months of 1978 experienced greater than expected insolation and lower temperatures characteristic of clear, cold weather.

F-CHART, an interactive computer program, developed by the Solar Energy Laboratory of the University of Wisconsin, was used to estimate the performance of the Scattergood School solar-energy system (4). The program estimated the monthly collection efficiency based on long-term climatic conditions and on the manufacturer's specified collector performance (5). These results are presented in Table 2 along with the measured incident solar energy, measured solar energy collected, and the measured solar efficiency. The monthly collector array performance, estimated from F-CHART, was close to the measured monthly array performance. The measured and estimated instantaneous performance of the array is shown in Figure 2. The measured instantaneous performance calculation used measured collector parameters and a computational technique described in Reference 6. Figure 2 indicates that the instantaneous performance of the array subsystem was greater than the manufacturer's estimated collector performance. The increased array performance can be traced, in part, to operating the building at lower than usual temperatures ($50^{o}F$ -- $60^{o}F$) and to a slightly increased collector air-flow rate. The collector performance is lowest during the summer and highest, when needed, during the winter.

Table 2. Thermal Performance of Scattergood School Solar-Energy System Collector Array Subsystem

Month (yr)	Measured Incident Solar (Btu x 10^6)	Measured Collected (Btu x 10^6)	Measured Collector Array Efficiency	Predicted Collector Array Efficiency
Sept 77	98.3	11.2	.114	*
Oct 77	*	*	*	.155
Nov 77	64.7	19.9	.307	.295
Dec 77	60.2	17.8	.296	.306
Jan 78	95.5	31.9	.333	.316
Feb 78	98.9	32.7	.331	.322
Mar 78	121.2	41.5	.342	.299
Apr 78	93.5	6.6	.070	*

*Data not available

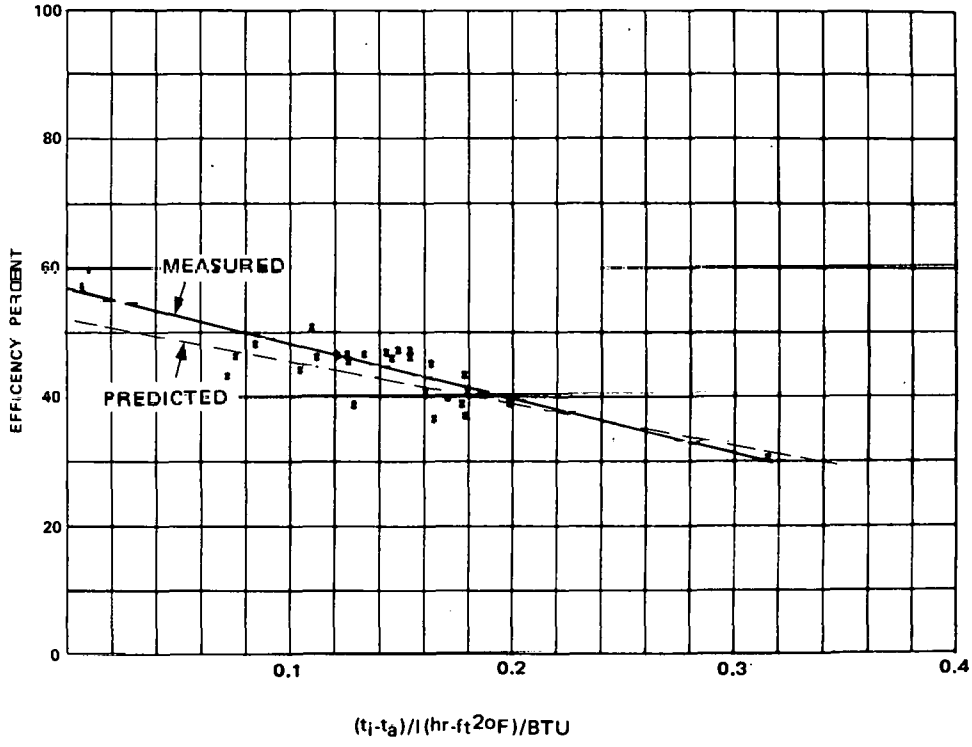


Figure 2. Collector Array Subsystem Performance

Figure 3 shows the predicted system demand (using long-term averages), the predicted demand (using measured weather parameters), and the actual demand on the system. The measured demand on the system is considerably lower than either of the predicted demands because of three factors: (1) the building heat loss coefficient, UA, is considerably lower than predicted, (2) a considerable quantity of controlled heat from the rock bin contributed to satisfying the demand, and (3) the building thermal control system was manually overriden to minimize propane consumption.

An estimate of the gymnasium UA can be obtained by computing the slope of the line that passes through the monthly load versus ambient temperature profile, as shown in Figure 4. The September demand was not used in the computation because the gymnasium was maintained at 79^{o}F during that month, which resulted in an exaggerated demand. The estimated UA from Figure 4 is 815 Btu/hr-^{o}F. This value was further substantiated by computing an effective UA from data on February 6,7, and 9. On these days, the gymnasium was maintained at 56^{o}F by the rock-bin, while the outside ambient temperature between midnight and 6 a.m. was about -3^{o}F. The space heating using solar energy during that period projected a UA of 790 Btu/hr-^{o}F. Thus, the estimated UA for the gymnasium is considerably lower than the predicted UA of 1675 Btu/hr-^{o}F and the design UA of 2333 But/hr-^{o}F.

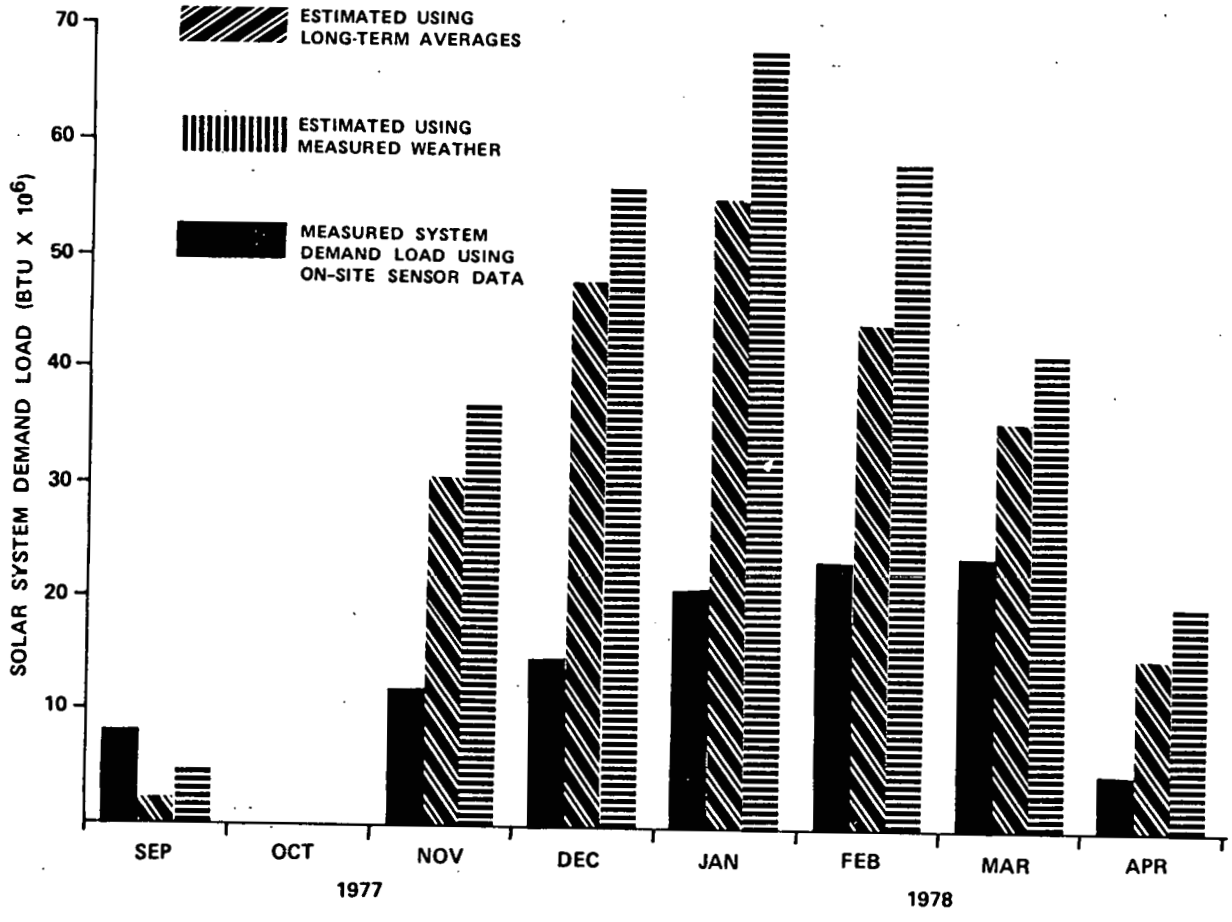


Figure 3. Demand Loads

Air-flow measurements in the gymnasium supply duct have indicated that there is an uncontrolled, low-level flow of energy from the rock bin to the gymnasium at night. By design, the default positions of the control dampers are such that the rock bin is open to the gymnasium. Thus, a chimney effect is produced because of the height of the gymnasium ceiling, the cold internal temperatures, and the hot storage bin. It results in the low-level transfer of heat from storage to the gymnasium. Because of uncertainties of measuring air flows at such levels, this energy originally was not included in computing the space heating load. However, the February, 1978, monthly performance report included calculations based on the low-level flow. Thus, the indicated space heating load for the month increased from 18 million Btu to 23.5 million

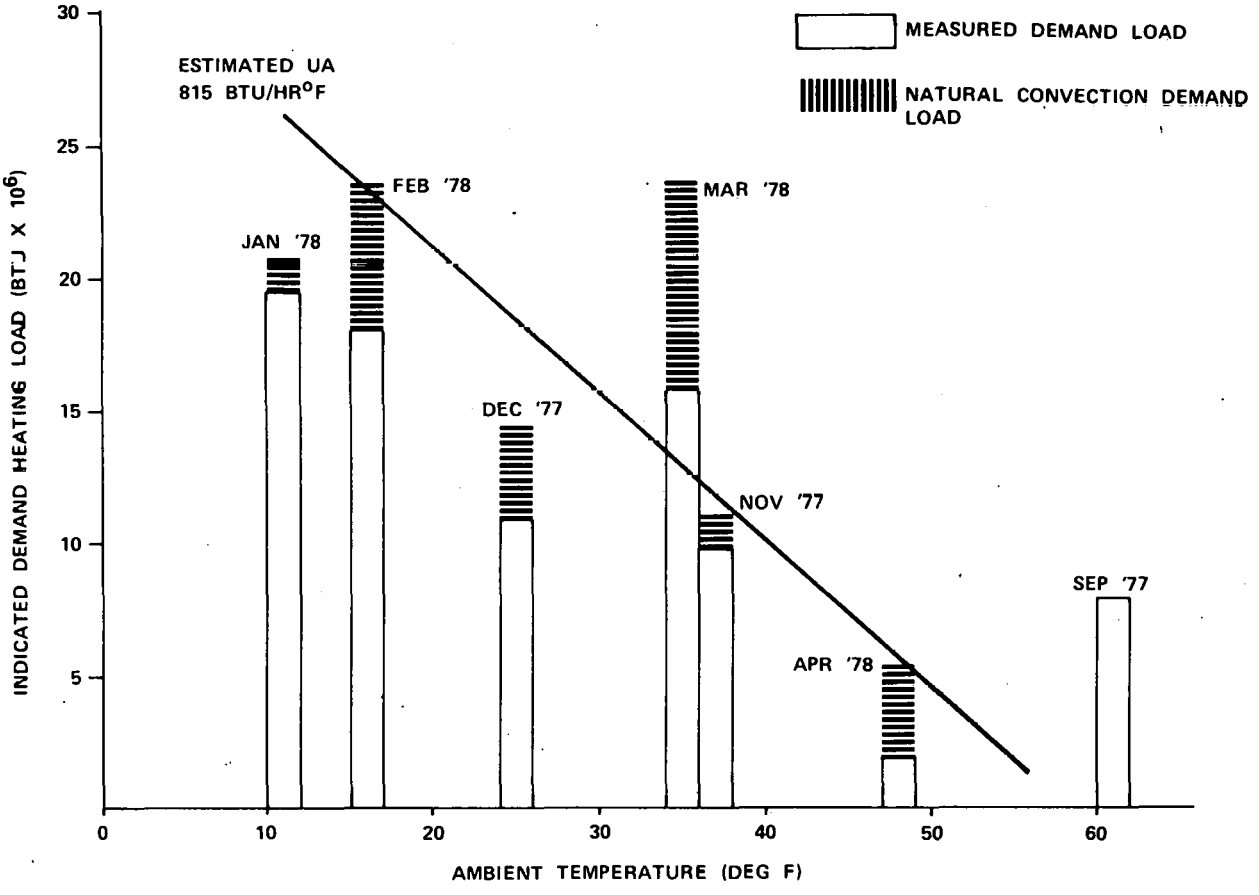


Figure 4. Monthly Demand Load vs. Ambient Temperature Profile

Btu. The magnitude of this additional quantity of energy required that it be included in computing space heating demands. It is planned to check on the accuracy of such measurements at low-level flow to verify accuracy.

During the period, the solar energy control system did not operate automatically as designed except during the time that solar energy was available to maintain the gymnasium at 60°F. On-site personnel observed that it was possible to maintain the gymnasium at a temperature above 45°F even though the solar-stored energy was depleted. The control system for the auxiliary heaters was manually overriden to maintain lower temperatures in the gymnasium and to minimize propane consumption. The heaters were used only when solar energy was unavailable for long periods and only in the afternoon when students were in the gymnasium and at night to maintain an ambient temperature of 45°F. The maintenance of the gymnasium temperature in the absence of stored solar energy and auxiliary heat is made possible by the lower than predicted UA, the large thermal capacitance of the building, and the convection of energy from rock bin to gymnasium.

Because of the previously discussed factors, the F-CHART predictions using long-term averages, estimated hot-water consumption, and predicted heating load profiles did not result in a good comparison to actual measured results. Prediction of the performance of the Scattergood School Solar Energy System, controlled as it actually was, would require a more elaborate model such as TRNSYS (7). However, lack of time and resources prevented the use of TRNSYS for this paper.

Examination of the data in Table 3 indicates that solar energy met most of the system space-heating demand. However, the same cannot be said of the hot-water preheating subsystem. Solar-energy savings become significant only when hot-water consumption is near that predicted for the system, as illustrated in Table 4. The failure of the hot-water subsystem and instrumentation deficiencies prevented an analysis of the hot-water subsystem after November 25, 1977. More accurate measurement of hot-water consumption and related energy flows will be available after a totalizer is installed. After installation, a test is to be performed in July and August to determine whether operating the hot-water subsystem with reduced summer consumption results in significant electrical savings.

Table 3. Thermal Performance of Scattergood School Solar-Energy System Space-Heating Subsystem

Month (yr)	Meas. Solar Energy Used (Btu x 10^6)	Meas. Auxiliary Energy Used (Btu x 10^6)	Measured System Load (Btu x 10^6)	Bldg. Temp. ^oF	Solar Percentage	Fossil Savings (Btu x 10^6)
Sept 77	7.6	0.0	7.8	79	100	9.5
Oct 77	*	*	*	*	*	*
Nov 77	9.0	2.9	11.9	62	76	11.2
Dec 77	12.1	2.1	14.2	54	85	15.1
Jan 78	14.4	5.9	20.8	56	69	18.0
Feb 78	19.7	3.6	23.3	56	85	24.7
Mar 78	23.7	0.0	23.7	59	100	29.7
Apr 78	5.6	0.0	5.6	62	100	7.0
Total	92.1	14.5	107.3		86	115.2

*Data not available

Table 4. Thermal Performance of Scattergood School Solar-Energy System Domestic Hot-Water Subsystem

Month (Yr)	Measured Solar Energy Used (Btu x 10^6)	Aux. Thermal Energy Used (Btu x 10^6)	Meas. Water Heating Load (Btu x 10^6)	Solar Percentage	Electrical Savings (Btu x 10^6)
Sept 77	3.0	0.2	1.105	92	0.805
Oct 77	*	*	*	*	*
Nov 77	1.7	1.70	0.316	32	.135
Dec 77	0	0.67	0.0	0	-0.183
Jan 78	0	0.58	0.0	0	-0.255
Feb 78	0	0.50	0.011	13	-0.242
Mar 78	1.39	0.42	0.072	26	-0.236
Apr 78	0.46	0.58	0.17	18	-0.019
Total	6.55	4.65	1.67	74	-0.004

*Data not available

System Energy Flows

November, 1977, is selected as a typical month to show the flow of energy through the system. Table 5 is the summary page from the monthly performance report on the system for that month. The Scattergood School solar-energy system supported the space-heating demand throughout the month and the hot-water preheating demand until November 25.

The insolation on the collectors, during the month, was 64.7 million Btu. The solar-energy system collected 19.9 million Btu for an average of 864 Btu/ft^2 per day. Thus, the system collector's efficiency was 31 percent. Of the 19.9 million Btu of collected solar energy, 3.7 million Btu went directly to conditioned space and 16.1 million Btu went to the rock bin, which supplied 5.3 million Btu to meet the space-heating and hot-water preheating demand. The rock bin lost 10 million Btu of energy due to the low heating demand early in the month and an excessive loss rate.

The hot-water subsystem utilized 1.66 million Btu of solar energy and 1.66 million Btu of auxiliary electrical energy to maintain the hot water at design temperature and to meet the hot water demand of 0.316 million Btu. Thus, the hot-water tanks lost 3 million Btu of energy during the month of which solar supplemented about 50 percent.

Table 5. November Summary Performance of Scattergood School Solar-energy System

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: SCATTERGOOD SCHOOL
REPORT PERIOD: NOVEMBER,1977

SOLAR/2003-77/11

SITE/SYSTEM DESCRIPTION:
SCATTERGOOD IS A HIGH SCHOOL WITH AN ENROLLMENT OF
SIXTY STUDENTS. THE SOLAR SYSTEM PROVIDES HEAT AND HOT WATER FOR
A 7,966 SQ.FT. GYMNASIUM. THE SYSTEM UTILIZES AIR AS THE CIRCULATING HEAT
TRANSFER MEDIUM AND A 62 TON PEBBLE BED FOR STORAGE. AUXILIARY HEATING IS
PROVIDED BY TWO 250K BTU AND ONE 100K BTU PROPANE HEATERS. HOT WATER
AUXILLIARY IS A 4.5KW ELECTRIC ELEMENT IN THE DOMESTIC HOT WATER TANK.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	64.744 MILLION BTU
	25939 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	19.915 MILLION BTU
	7978 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	34 DEGREES F
AVERAGE BUILDING TEMPERATURE	62 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.16
ECSS OPERATING ENERGY	0.392 MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	0.700 MILLION BTU
TOTAL ENERGY CONSUMED	25.658 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	0.316	11.917	N.A.	12.188 MILLION BTU
SOLAR FRACTION	32	76	N.A.	74 PERCENT
SOLAR ENERGY USED	1.661	9.015	N.A.	10.628 MILLION BTU
OPERATING ENERGY	0.183	0.131	N.A.	0.700 MILLION BTU
AUX. THERMAL ENERGY	1.665	2.902	N.A.	4.562 MILLION BTU
AUX. ELECTRIC FUEL	1.665	N.A.	N.A.	1.665 MILLION BTU
AUX. FOSSIL FUEL	N.A.	3.628	N.A.	3.628 MILLION BTU
ELECTRICAL SAVINGS	0.135	-0.131	N.A.	-0.376 MILLION BTU
FOSSIL SAVINGS	N.A.	11.269	N.A.	11.269 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.19

* DENOTES UNAVAILABLE DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT
OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 20,1978.
SOLAR/0004-78/18
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In summary, the solar-energy system supplied 76 percent of the 11.9 million Btu space-heating demand and 32 percent of the 0.316 million Btu hot-water preheat demand. The system saved 11.2 million Btu of fossil-fuel energy at the additional expense of 0.7 million Btu of electrical energy for operating the system. The energy-savings calculations are based on comparison of the projected energy requirements of a conventional propane gas heater with an efficiency of 80 percent with the energy requirements of the solar-energy system.

SUMMARY

The solar-energy system of Scattergood School provided 115.2 million Btu of seasonal fossil-fuel savings at the expense of 5.23 million Btu of electrical energy. This indicates that the system performance was beneficial. The collection system operated near that predicted for the system, providing the necessary energy to meet the system demands. Solar energy met 86 percent of the system's demands, which was greater than predicted even though the climatic conditions were much colder than long-term conditions for the locality. The greater than predicted performance was due, in part, to operating the building at a lower temperature, lower than predicted building UA, and uncontrolled solar contributions. The Scattergood solar-energy system, as a whole, operated as expected with the exception of the hot-water heat exchanger failure.

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Thermal Performance of the Perl-Mack Enterprises, Inc. Solar Energy System

Richard V. Walker

INTRODUCTION

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy as mandated by the Solar Heating and Cooling Demonstration Act of 1977 (1). The International Business Machines Corporation is contributing to The National Solar Data Program of the Department of Energy by monitoring, evaluating, and reporting performance of designated solar-energy systems in the program. This paper briefly describes the solar-energy system of a HUD-2 site and its modes of operation, and then presents a performance evaluation of the system for the period December, 1977, through April, 1978. This evaluation is based on comparison of predictions of climatic, load, and operational conditions with those which were measured.

SYSTEM DESCRIPTION

The Perl-Mack Enterprises, Inc. site is a single-family dwelling in Denver, CO. The solar-energy system is designed to provide approximately 68 percent of the annual space-heating and hot-water energy requirements for the home. It has an array of flat-plate collectors with a gross area of 470 square feet that faces south at an angle of 30 degrees from the horizontal. A water-glycol mixture is used as the medium for delivering solar energy from the collector array to storage. The energy is stored in a 945-gallon tank after the transfer fluid passes through a liquid-to-liquid heat exchanger. Preheating of incoming city water is accomplished in a 40-gallon tank immersed within the 945-gallon tank. When solar energy is insufficient, a forced-air, natural-gas furnace provides additional energy for space heating. A gas burner in a conventional, 40-gallon hot-water tank furnishes auxiliary energy for water heating. The system, shown schematically in Figure 1, has five modes of solar operation.

Mode 1 - Collector-to-Storage: This mode is initiated when the collector outlet temperature exceeds the storage tank temperature by 10°F (adjustable). The transfer fluid is circulated through the collectors, through the heat exchanger, and back to the collectors until the temperature differential drops to less than 2°F.

Mode 2 - Storage-to-Space Heating: This mode prevails when the room temperature drops to the setting of the thermostat, and the temperature in the storage tank is 90°F or higher. Energy from the tank is transferred through a liquid-to-air heat exchanger located in the air-handling unit.

Mode 3 - Domestic Water Preheating: This mode exists when there is a demand for hot water. Incoming city water flows through the preheat tank immersed in the storage tank and then to the conventional, hot-water heater.

Mode 4 - Excess Heat Rejection: This mode occurs when the storage tank temperature exceeds 170°F. During this mode, the collector pump operates to transfer energy from the storage tank through the collectors to the outside ambient air. In addition, vapor in the storage tank is vented to the outside.

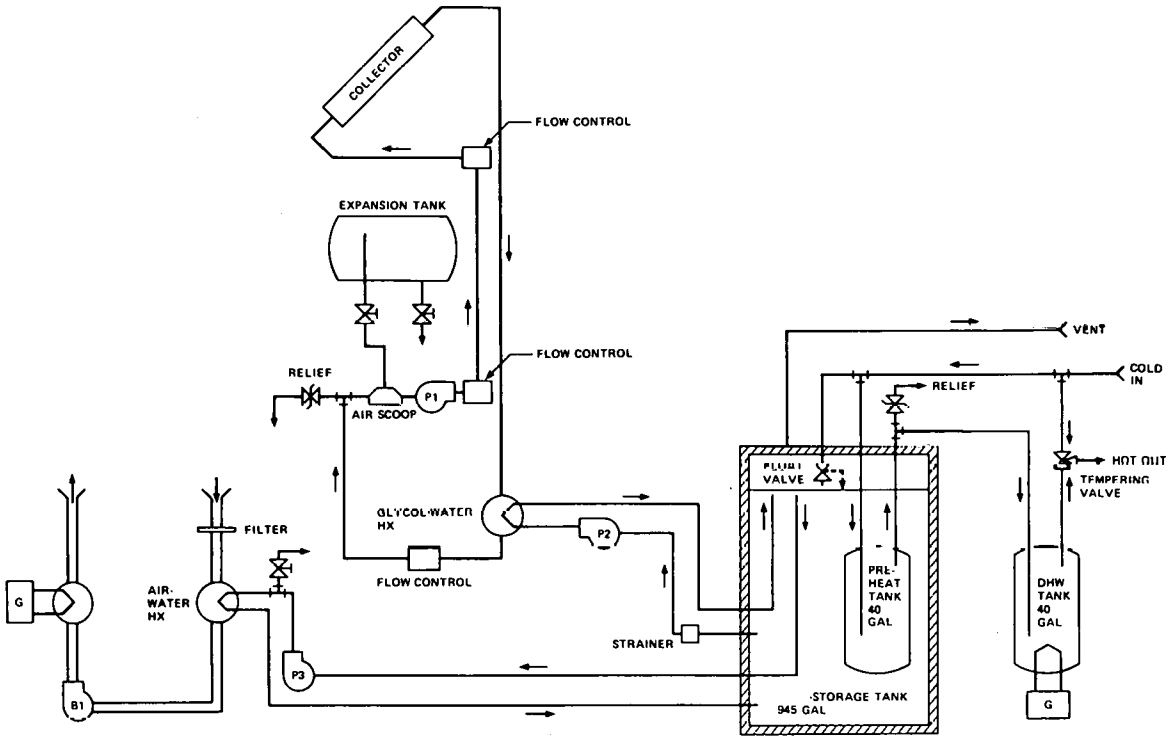


Figure 1. Perl-Mack Enterprises, Inc. Solar-energy System

Mode 5 - Snow Removal from Collector: This mode is accomplished by a manual override switch which permits the homeowner to turn on the collector pump transferring energy from storage to the collectors. This mode terminates automatically after a preset time interval.

PERFORMANCE EVALUATION OBJECTIVES

Comprehensive monitoring of program instrumentation provides detailed data by which a thorough evaluation of the performance of the solar-energy system can be made. This evaluation extends not only to the system but also to subsystems and critical components as well. It has three objectives. First, the ability of the solar-energy system to meet the demands of the conditioned space and the demand for hot water must be determined. Then, the savings of energy resources resulting from this use of solar energy is derived. Finally, this information is compared to design data so that demonstration results can influence future designs. As a side benefit, an accurate record of the climatological data at a location is recorded for design comparisons and future designs. To meet these objectives, the thermal performance parameters for evaluating solar-energy systems were defined by a governmental interagency solar-heating and cooling performance evaluation committee. These parameters are defined in Refs. 2, 3.

A monthly performance report is issued for each instrumented solar-energy system in the demonstration program by the Technical Information Center, Department of Energy, at Oak Ridge, TN. This report contains an analysis of the system performance and statistical summaries of performance of major subsystems and critical components. Thus, the monthly report provides archival information on the solar-energy system's performance to a variety of users.

A seasonal evaluation report will be available on selected sites as sufficient data accrue to cover a representative heating or cooling season. In addition to a detailed description of the site and its modes of operation, this report will have a seasonal summary of the system performance including sections covering the analytic methodology, climatic and load conditions at the site, actual versus predicted performance of the system, and evaluation results. As they are published, these reports will also be available from the Technical Information Center.

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

The performance of the Perl-Mack solar-energy system has been evaluated using two methods. The first method is based on the primary system performance parameters during a typical use season. Since the Perl-Mack system is a space-heating and domestic hot-water system, the performance evaluation is based on a heating season. The evaluation period for the seasonal analysis is December, 1977, through April, 1978 (Refs. 4-8). (Reliable data are unavailable prior to December, 1977.) This performance evaluation includes a comparison of predicted performance based on F-CHART (see Appendix A) and measured performance in addition to the evaluation of the overall performance of the system. The second method provides a summary of the energy flows through the system for a typical month. These energy flows are presented to determine how the system is performing by how well it manages the flow of energies to and from each subsystem.

Seasonal Performance

The Perl-Mack solar-energy system was in continuous operation during the five months used as a basis for this seasonal evaluation. Measured monthly values of total insolation, heating degree-days and average ambient temperature for the Perl-Mack system were recorded and are presented in Table 1. Also presented are long-term average monthly values for these climatic parameters for the same geographical location taken from the Climatic Atlas of the United States and NOAA Local Climatological Data. The data in Table I show that the available solar energy during the past heating season is significantly below that predicted based on long-term averages but that the measured heating-degree days are approximately equal to the long-term averages during the same period. These two effects taken together have negatively affected the performance of the solar-energy system.

The heating loads for the conditioned space are indicated in Figure 2. esign heating load data are based on long-term weather conditions and was furnished by the grantee. Values of expected load are also shown in Figure 2

Table 1. Total Insolation, Average Ambient Temperature, Heating Degree Days for Denver, CO*

Month	Total Insolation at Collector Tilt		Average Ambient Temperature (°F)		Heating Degree Days (°F-Day)	
	Measured	Long-Term Average*	Measured	Long-Term Average	Measured	Long-Term Average
Dec 77	32982	45712	34	32	961	1004
Jan 78	32224	51773	23	30	1302	1088
Feb 78	28988	52246	27	32	1064	902
Mar 78	47001	62304	42	37	713	868
Apr 78	53493	60885	49	48	480	525
Total	194688	272920	-	-	4520	4387

*Data taken at Fort Collins, CO.

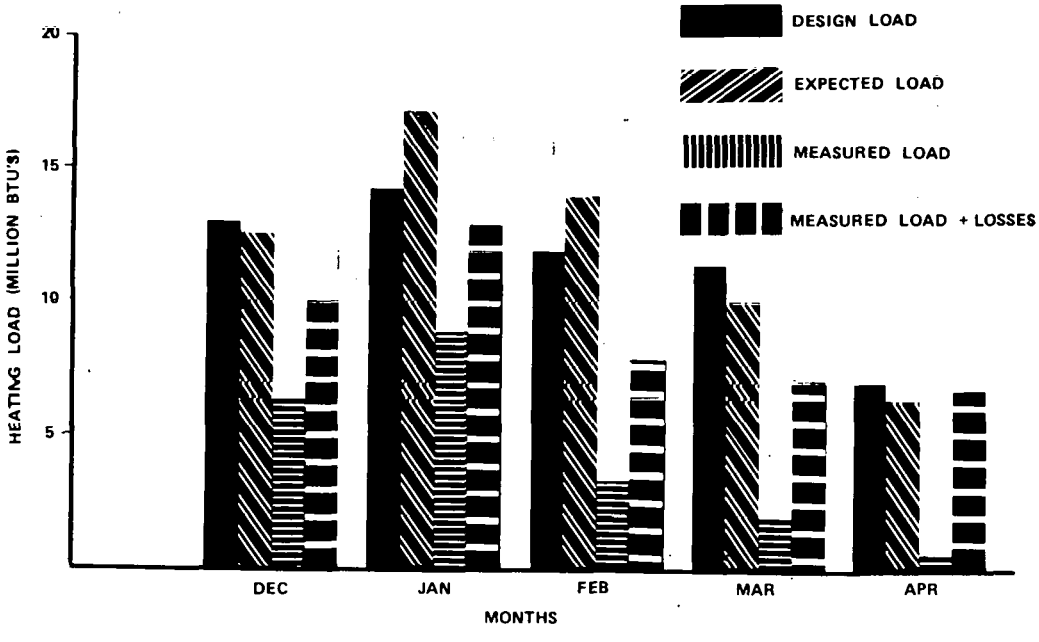


Figure 2. Space Heating Loads

and represent adjustments to long-term predictions based on the ratio of measured degree-days to the long-term average degree-days. Measured loads are based on instrumented data and represent the quantity of energy being transferred in a controlled manner into the conditioned space. As shown in Figure 2, the comparison of measured and expected loads show significant discrepancies and must be accounted for. Some deviation is expected based on errors associated with using the UA-degree-day concept for predicting loads. The major difference,

however, results from energy losses from the solar-energy system occurring largely internal to the house. These losses actually represent an uncontrolled transfer of solar energy to the house and result in a reduction in the demand for space heating. These losses can be identified through measured heat transfer between the collector, storage, and the domestic hot water subsystem and are quantified in the following section for February. If it is assumed that all the losses go into the conditioned space, these losses can be added to the measured load as shown in Figure 2. This results in a much better correspondence between the predicted and observed loads. The discrepancies between predicted loads and the observed loads after the losses have been included are believed to result from errors in the UA calculation and the UA-degree-day concept.

Figure 3 shows the correlation between the solar-energy losses and the temperature of the major source of energy loss, the storage subsystem. The collection and the storage subsystems are operated year round to provide solar energy for the domestic hot water. As a result, the losses from the storage subsystem are expected to continue increasing as the temperature of the storage tank water reaches the controlled maximum of 175°F.

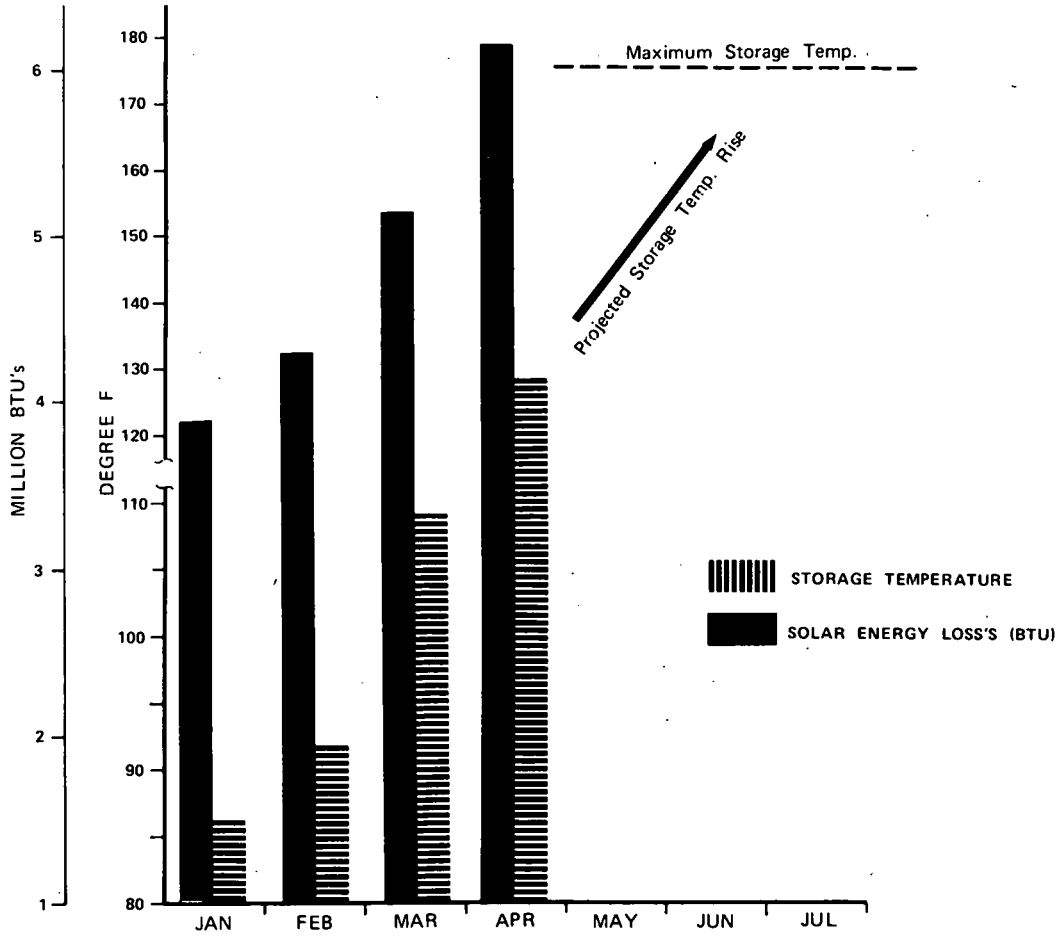


Figure 3. Storage Subsystem Temperature vs. Solar Energy Loss

The solar fraction is expressed as a ratio of solar energy used to the total load. Accordingly, the solar fraction shown in Figure 4 is a strong function of the uncontrolled losses of solar energy which contribute to the heating load of the house. Conversely, the solar fraction computed from the controlled measured data is low because the controlled-to-uncontrolled energy ratio is low. When the solar fraction is derived for measured plus solar losses, good correlation is shown with the design values based on F-CHART predictions.

The losses, which are evident in Figure 2, lead to erroneous conclusions of low fossil-energy savings resulting from solar-energy load measurements. Figure 5 shows that when the solar-energy losses are identified as contributory to this heating load of the house, the fossil-energy savings are markedly higher, as would be expected. From Figure 2 it was deduced that the design house load heating loss coefficient, UA = 547.3 Btu/Hr-^{o}F was higher than observed. This effect plus higher design solar fraction estimates are strong functions influencing the expected fossil-energy savings. The difference between design and measured plus loss fossil savings is less dramatic when these subjectively treated factors are considered. Since this is one of the most significant performance parameters used in establishing the net value of the solar installation, it is important to note that a full year of observation is required before the installation can be quantified.

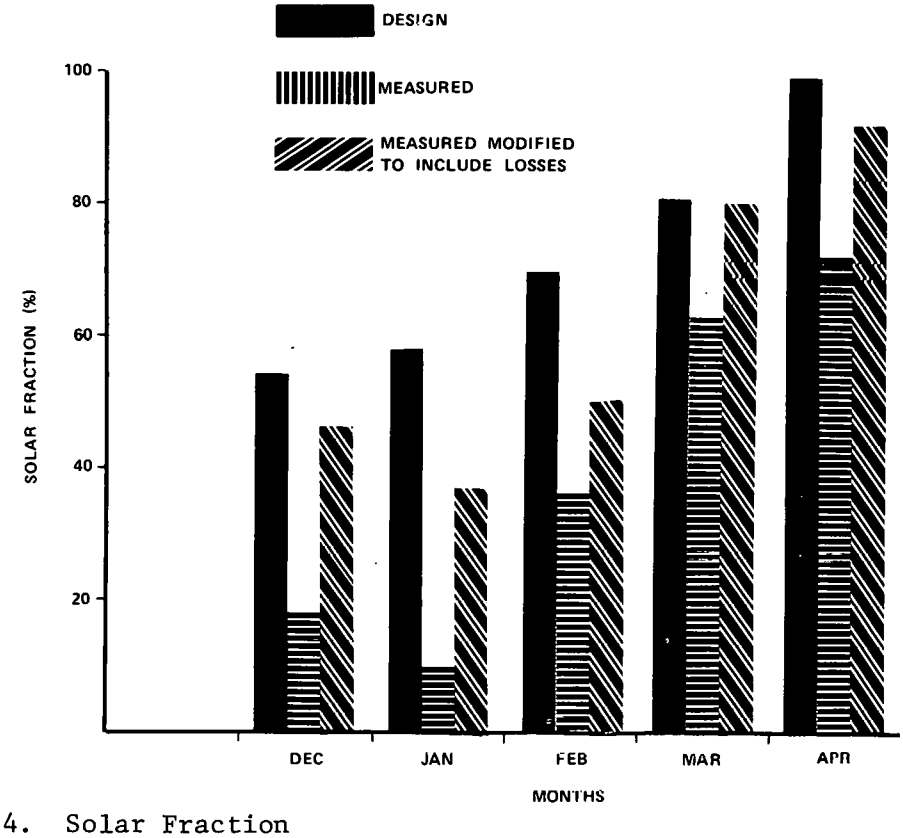


Figure 4. Solar Fraction

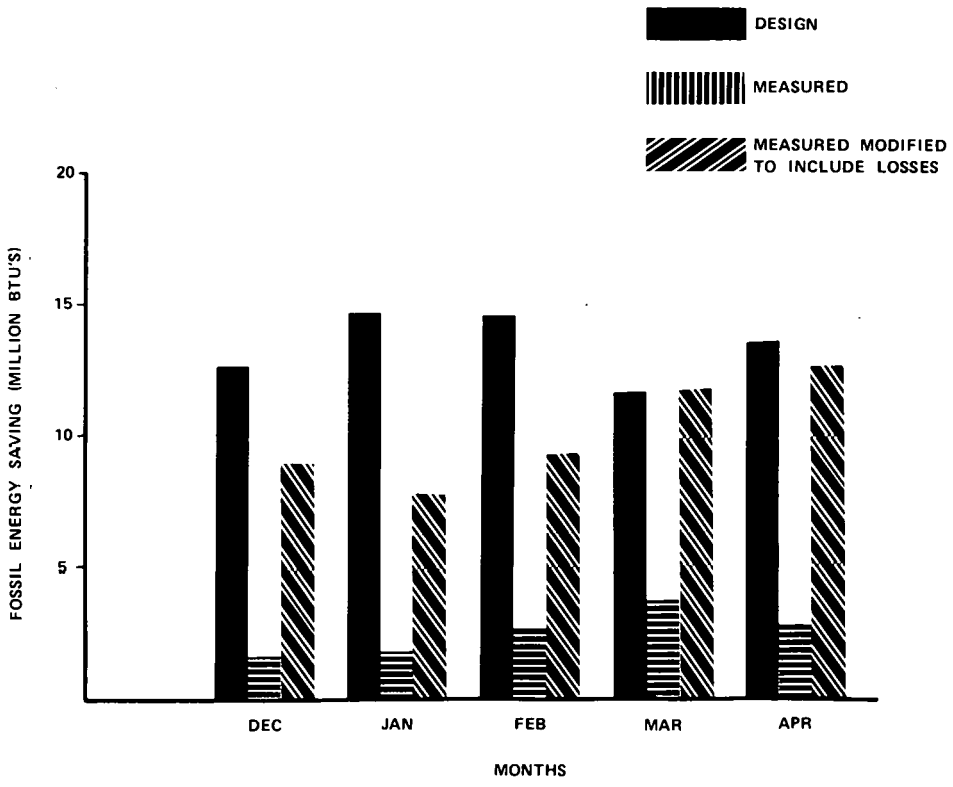


Figure 5. Fossil Energy Savings

Table 2 gives the performance of the collector array for the heating months considered. Incident solar energy is measured in the plane of the collectors at a 30^{o} angle with respect to the horizontal. The collected energy is a function of the collector efficiency. The measured efficiency is the ratio of the collected-to-incident energies.

System Energy Flows

Table 3 is the summary of performance parameter data for a typical heating month, February, 1978. Supporting data in the Monthly Performance Report give additional information on measured energies crossing the subsystem boundaries. The flow of energy through the system will be traced to identify the losses discussed in the previous section for a typical month.

The Perl-Mack solar energy system operated continuously during February with solar energy satisfying 35 percent of the combined measured heating and hot-water demand of 4.42 million Btu. The operation of the solar-energy system resulted in the saving of 2.52 million Btu of fossil energy at the expense of 0.21 million Btu of electrical energy for operating the system.

The available insolation on the collectors during the month was 13.62 million Btu for an average of 1035 Btu/ft^2 - day. The system collected 5.92 million Btu, or 44 percent of the available insolation, at an expense of 0.21 million Btu of electrical operating energy.

Table 2. Thermal Performance, Perl-Mack Collector Array Subsystem

Month (Year)	Measured Incident Solar Energy (Btu x 10^6)	Measured Collected Solar Energy (Btu x 10^6)	Measured Collector Array Efficiency Percent
Dec 77	15.494	4.998	32
Jan 78	15.138	4.463	30
Feb 78	13.617	5.924	43
Mar 78	22.079	6.898	31
Apr 78	25.129	6.857	27

Table 3. Monthly Site Summary

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: PERL-MACK ENTERPRISES
REPORT PERIOD: FEBRUARY,1978

SOLAR/1015-78/02

SITE/SYSTEM DESCRIPTION: THE SOLAR ENERGY SYSTEM PROVIDES DOMESTIC HOT WATER AND SPACE HEATING FOR A SINGLE FAMILY RESIDENCE. FLAT PLATE COLLECTORS USE GLYCOL-WATER FLUID. A HEAT EXCHANGER TRANSFERS ENERGY TO A WATER STORAGE TANK WHICH PREHEATS WATER TO THE GAS FIRED DOMESTIC HOT WATER HEATER. SPACE HEATING IS PROVIDED BY AN AIR TO WATER HEAT EXCHANGER IN THE GAS FIRED FURNACE PLENUM.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	13.617	MILLION BTU
	28988	BTU/SQ.FT.
COLLECTED SOLAR ENERGY	5.924	MILLION BTU
	12612	BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	27	DEGREES F
AVERAGE BUILDING TEMPERATURE	73	DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.12	
ECSS OPERATING ENERGY	0.205	MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	0.598	MILLION BTU
TOTAL ENERGY CONSUMED	11.499	MILLION BTU

LOAD SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	TOTAL	
LOAD	1.196	3.253	N.A.	4.420	MILLION BTU
SOLAR FRACTION	41	33	N.A.	35	PERCENT
SOLAR ENERGY USED	0.490	1.090	N.A.	1.581	MILLION BTU
OPERATING ENERGY	N.A.	0.383	N.A.	0.383	MILLION BTU
AUX. THERMAL ENERGY	0.963	2.163	N.A.	3.127	MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A.	MILLION BTU
AUX. FOSSIL FUEL	1.606	3.380	N.A.	4.986	MILLION BTU
ELECTRICAL SAVINGS	-0.052	-0.161	N.A.	-0.214	MILLION BTU
FOSSIL SAVINGS	0.818	1.703	N.A.	2.521	MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.65

* DENOTES UNAVAILABLE DATA
N.A. DENOTES NOT APPLICABLE DATA

Of the 5.92 million Btu collected, 3.63 million Btu were delivered to storage resulting in a 2.30 million Btu loss between the collectors and storage. In addition, 1.67 million Btu were lost from storage resulting in a monthly-storage efficiency of 54 percent. These losses are due to uninsulated piping, and the uninsulated bottom and the unsealed top of the storage tank.

The hot-water subsystem operated satisfactorily during February with solar energy supplying 41 percent of the hot-water demand of 1.17 million Btu. The operation of the hot-water subsystem resulted in savings of 0.82 million Btu of fossil energy at the expense of 0.05 million Btu of electrical energy. The energy-savings calculations are based on a comparison of the projected energy requirements of a conventional, gas-fired, hot-water tank with an efficiency of 60 percent and the energy requirements of the solar-energy system. All energy requirements are based on the measured demand for hot water.

The demand for space heating during February was 3.25 million Btu, a quantity significantly less than expected. The monthly average ambient temperature was slightly lower than expected. Part of the difference between the expected demand for space heating and the actual measured demand is the loss of solar energy from the system into the conditioned space. In addition to the combined losses of solar energy between the collector and storage and from the storage tank of 3.97 million Btu, it has been estimated that an additional 0.34 million Btu of solar energy were lost between the storage tank and the loads for a total loss of solar energy of 4.31 million Btu. If it is assumed that the 4.31 million Btu of solar energy losses go into the heated space thereby reducing the load, the actual demand would be approximately 7.6 million Btu which is closer to the expected demand. It should be noted that the uncontrolled delivery of solar energy to the conditioned space significantly exceed the controlled energy transferred of 1.09 million Btu.

Of the controlled energy transferred to the conditioned space of 3.25 million Btu, solar energy satisfied 33 percent. The controlled use of solar energy for space heating resulted in the saving of 1.70 million Btu of fossil energy at the additional expense of 0.16 million Btu of electrical energy. The energy savings calculations are based on the energy requirements of a conventional gas-fired furnace with an efficiency of 64 percent and the energy requirements of the solar-energy system. The energy requirements for the conventional system are based on the controlled energy transferred to the conditioned space and do not include the uncontrolled gains from the the system losses. It should be noted that, in fact, 0.16 million Btu of electrical energy provided approximately 4.31 million Btu of solar energy to the conditioned space as contrasted with only 1.09 million Btu indicated by the direct measurements.

SUMMARY

During the three months of mid-winter there is good correlation between the design load and the identified load. Measurements are made of the load on the equipment and not the load of the house. The data trends would indicate,

however, that the measured data and identification of energy transfer between subsystems can be used over the total heating season or for yearly periods of time to assess design objectives. Meteorological measurements personalize the ambient effects to the design and are essential to the design assessment. These key parameters are shown in the text. The monthly data shown are valuable in assessing the contribution of the data-acquisition system as well as the actual performance of the system under evaluation.

Even though performance factors have been standardized for uniformity in reporting, they must not be used without qualification. For analysis to give meaningful design relationships, it is important to relate performance, as measured, with observed departure from design or subsystem interaction.

REFERENCES

1. National Program for Solar Heating and Cooling of Buildings, ERDA 76-6. Washington: Energy Research and Development Administration, November, 1976.

2. E. Streed et al., Thermal Data Requirements and Performance Evaluation Procedure for the National Solar Heating and Cooling Demonstration Program, NBSIR-76-1137. Washington: National Bureau of Standards, August, 1976.

3. User's Guide to the Monthly Performance Report of the National Solar Data Program, Solar/00004-78/18. Washington: Department of Energy, February 28, 1978.

4. Monthly Performance Report, Perl-Mack, December, 1977, Solar/1015-12/77, Washington: Department of Energy.

5. Monthly Performance Report, Perl-Mack, January, 1978, Solar/1015-78/01, Washington: Department of Energy.

6. Monthly Performance Report, Perl-Mack, February, 1978, Solar/1015-78/02, Washington: Department of Energy.

7. Monthly Performance Report, Perl-Mack, March, 1978, Solar/1015-78/03, Washington: Department of Energy.

8. Monthly Performance Report, Perl-Mack, April, 1978, Solar/1015-78/04, Washington: Department of Energy.

Appendix A

F-CHART Reference Data*

Collector Area	465.3 Ft^2
FR Prime-Tau-Alpha Product	0.69
FR Prime - UL Product	0.77 Btu/H-F-F^2
No. of Transparent Covers	1.
Collector Slope	30 Deg.
Azimuth	0 Deg. South
Storage Capacity	16.86 Btu/F-Ft^2
Effective Building UA	547.3 Btu/Hr-F
Constant Daily Building Heat Gen.	0 Btu/Day
(Epsilon) (C min)/Eff Bldg. UA	0.97
Hot Water Usage	Variable
Water Set Temperature	Variable
Water Main Temperature	Variable

*W. A. Beckman, S. A. Klein, and J. A. Duffie, Solar Heating Design by the F-CHART Method. New York: John Wiley, 1977.

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Thermal Performance of the ARATEX Services, Inc. Solar Energy System

Henry L. Armstrong

INTRODUCTION

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy as mandated by the Solar Heating and Cooling Demonstration Act of 1977 (1). The International Business Machines Corporation is contributing to The National Solar Data Program of the Department of Energy by monitoring, evaluating, and reporting performance of designated solar-energy systems in the program. This paper briefly describes the ARATEX Services, Inc. (formerly referred to as Workwear) solar-energy system, a PON-1 site, and its modes of operation, and then presents a performance evaluation of the system for the period November, 1977, through April, 1978, with the exception of January, 1978. This evaluation is based on comparison of predictions of climatic, load, and operational conditions with those which were measured.

SYSTEM DESCRIPTION

The ARATEX Services Inc. site is an industrial laundry in Fresno, CA. The solar-energy system is designed to provide preheating of the process water used by the facility at 180°F. It has an array of flat-plate collectors with a net area of 6500 square feet that faces south at an angle of 30 degrees from the horizontal. Water is used as the medium for delivering solar energy from the collector array to storage. The heated water is stored in a 12,500-gallon tank. When solar energy is insufficient, auxiliary energy is supplied by a low-pressure, gas-fired boiler. Also, a heat exchanger utilizing energy from a waste-water storage tank provides additional energy to the city water input supply. The solar-energy system can be isolated from the overall heating system in event of malfunction or failure (2). The system, shown schematically in Figure 1, has three modes of operation.

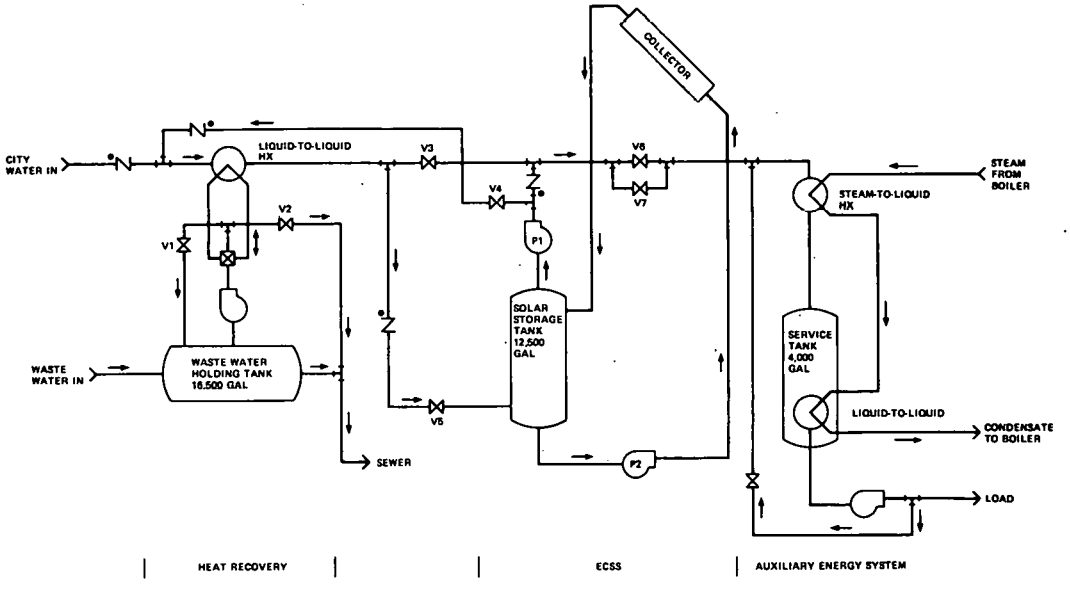


Figure 1. ARATEX Services, Inc. Solar-energy System

Mode 1 - Collector-to-Storage: During this mode of operation, water is pumped from the 12,500-gallon storage tank through the collectors and back into the tank. This mode is initiated when the temperature of the collector outlet exceeds the storage tank temperature by 4.5°F and continues until this differential temperature drops below 1.5°F.

Mode 2 - Hot-Water Demand: This mode exists when there is a demand by the laundry for hot water. City water entering the system is preheated using the waste water in the 16,500-gallon holding tank. The temperature of the input city water is raised, thereby, to approximately 115°F before being dumped into the 12,500-gallon storage tank. Then, as this water is withdrawn from the tank, it is pumped through a steam-heat exchanger where auxiliary energy is added, as required, to maintain the water in the 4000-gallon service tank at 180°F. Additional energy is also supplied in the service tank by extracting energy from the condensate line of the heat exchanger which passes through it.

Mode 3 - Storage-to-Waste Water: When the water in the 12,500-gallon, solar-storage tank reaches 180°F, it is circulated by reverse flow through the waste-water heat-recovery system, thus storing any excess solar energy in the waste-water tank. This mode is used to prevent damage to the 12,500-gallon fiber glass storage tank and enables the use of the waste-water tank as a secondary, solar-storage tank.

PERFORMANCE EVALUATION OBJECTIVES

Comprehensive monitoring of program instrumentation provides detailed data by which a thorough evaluation of the performance of the solar-energy system can be made. This evaluation extends not only to the system but also to subsystems and critical components as well. It has three objectives. The first of these that must be determined is the ability of the solar-energy system to meet the demands placed upon it by the plant's need for hot water. Then, the savings of energy resources resulting from this use of solar energy is derived. Finally, this information is compared to design data so that demonstration results can influence future designs. As a side benefit, an accurate record of the climatological data at a location is recorded for design comparisons and future designs. To meet these objectives, the thermal performance parameters for evaluating solar enengy systems were defined by a governmental interagency solar-heating and cooling performance evaluation committee. These parameters are defined in Refs. 3, 4.

A monthly performance report is issued for each instrumented solar-energy system in the demonstration program by the Technical Information Center, Department of Energy, at Oak Ridge, TN. This report contains an analysis of the system performance and statistical summaries of performance of major subsystems and critical components. Thus, the monthly report provides archival information on the solar-energy system's performance to a variety of users.

A seasonal evaluation report will be available on selected sites as sufficient data accrue to cover a representative heating or cooling season.

In addition to a detailed description of the site and its modes of operation, this report will have a seasonal summary of the system performance including sections covering the analytic methodology, climatic and load conditions at the site, actual versus predicted performance of the system, and evaluation results. As they are published, these reports will also be available from the Technical Information Center.

SOLAR-ENERGY SYSTEM PERFORMANCE EVALUATION

The performance of the ARATEX solar-energy system has been evaluated using two methods. The first method is based on the primary system performance parameters during a typical use season. Since the ARATEX system is designed to provide only hot water, the use season should be a year to encompass seasonal variations. This evaluation is based on the period from November, 1977, through April, 1978, less January, 1978, (5-9) and should be considered preliminary. This performance evaluation includes a comparison of actual versus predicted performance in addition to an evaluation of the overall performance of the system. The second method provides a summary of the energy flows through the system for a typical month. These energy flows are presented to illustrate how the system is performing by showing how well it manages the flow of energies to and from its subsystems.

Seasonal Performance

The ARATEX solar-energy system has operated under a reasonably constant load profile during the six months period covered by this report. The hot-water requirements for the site generally occur between the hours of 5:30 a.m. and 3:30 p.m., Monday through Friday each week, excluding holidays. The daily usage during a typical work day is approximately 28,000 gallons.

Monthly values of average daily insolation and average ambient temperature measured at the ARATEX site are presented in Table 1. Also presented in the table are the long-term, average monthly values for these climatic parameters.

Table 1. Climatic Data for ARATEX Solar-Energy System, Fresno, CA.

Month	Insolation (Btu/ft^2 - Day)*		Ambient Temperature ($^{\circ}$F)	
	Measure	Long-Term	Measured	Long-Term
Nov 77	1291	1346	63	54
Dec 78	711	902	60	45
Jan 78	**	**	**	**
Feb 78	1008	1494	51	50
Mar 78	1291	1945	59	54
Apr 78	1541	2087	58	61

*Total insolation in plane of collector

**Data not available

Long-term insolation data are taken from the Climatic Atlas of the United States. Other climatic data are from the NOAA Local Climatological Data and site enviromental data supplied by the IBM site instrumentation. Data contained in Table 1 clearly indicate that the average daily measured insolation is significantly below the long-term average. Correspondence from the National Weather Service at Fresno, CA indicates that "It has rained so much ... that this season of 1977-78 will be at least the third wettest year since the records began almost 100 years ago." Similarly it has been quite warm in the winter and spring season of 1977-78 (10). This reduction in available energy, due in part to unusually high amounts of rainfall, has resulted in a reduction in the overall performance of the solar-energy system.

An interactive computer program, F-CHART, developed by the Solar Energy Laboratory at the University of Wisconsin has been used to predict the performance of the ARATEX solar-energy system (11). This program was used to predict the solar energy collected based on both actual as well as anticipated climatic conditions. Comparison of these results provides a basis for relating actual system performance to design performance since design data is most often based on long-term climatic conditions. Results of these predictions and measured performance are compared in Table 2. The comparison of the F-CHART predictions of the solar energy collected using actual climatic conditions and long-term climatic conditions shows the impact of system performance.

Table 2. Actual Versus Predicted Performance of ARATEX Solar-Energy System

Month	Load (Million Btu)		Solar Energy Collected (Million Btu)		
	Measured	F-CHART	Measured	F-CHART (Actual Climatic Conditions)	F-CHART (Long-Term Climatic Conditions)
Nov 77	395	386	89	72	69
Dec 77	320	399	31	6	18
Jan 78	*	*	*	*	*
Feb 78	240	360	41	21	78
Mar 78	337	399	69	72	135
Apr 78	308	386	80	95	146

*Data not available

The prediction of solar energy collected using the actual climatic conditions is significantly below that predicted using the long-term climatic conditions especially for January through April. The table also shows that for this system there are discrepancies between the F-CHART predictions of the solar energy collected, based on measured climatic conditions and the measured solar energy collected. It is believed that this is caused by the differences in the load profile used in developing F-CHART and the load profile at ARATEX. F-CHART was developed using a constant daily load profile similar to that expected for a residential application; whereas the ARATEX load profile is fairly constant during the 40-hour, five-day working week. (The daily consumption for the performance predictions is an equivalent daily consumption found by averaging the weekly consumption over seven days.) In addition to the differences in load profiles, the higher system temperatures at ARATEX may affect the comparison. Although it does not appear that F-CHART can be used for predicting the performance of the ARATEX system, it can be used to indicate the effect of various climatic conditions. To predict the performance of systems similar to ARATEX, a more elaborate model such as TRNSYS (12) should be used. However, lack of time and resources prevented the use of TRNSYS for this paper.

Table 3 summarizes the most significant system performance parameters for the inclusive six months. The data presented in this table are taken from the Monthly Performance Reports except where noted. The load without the heat-

Table 3. Thermal Performance, ARATEX Solar-Energy System

	Load Without Heat Recovery System (Million Btu)	Heat Recovery Energy (Million Btu)	Load With Heat Recovery System (Million Btu)	Solar Energy to Load (Million Btu)	Auxiliary Energy to Load (Million Btu)	Solar Fraction	Fossil Savings (Million Btu)
Nov 77	605	210*	395	55	340	14	92
Dec 77	509	189*	320	31	289	10	52
Jan 78	**	**	**	**	**	**	**
Feb 78	343	103*	240	29	210	12	49
Mar 78	562	225	337	52	285	16	87
Apr 78	490	182	308	59	249	19	99
Average	502	182	320	45	275	14	76

*Estimated from other performance parameters

**Data not available

recovery system is the load that would have existed had not the heat-recovery system existed. The heat-recovery energy is the amount of energy conserved by the use of the heat-recovery system. Table 3 shows that the use of the heat-recovery system has effectively reduced the load by the conservation of an average of 182 million Btu per month. This conservation of energy reduced the load to an average of 320 million Btu per month of which solar energy satisfied 14 percent. The use of solar energy has resulted in an average savings of 76 million Btu of fossil energy per month. The savings are based on a comparison of the projected energy requirements of a conventional, fossil-energy boiler with an efficiency of 60 percent and the energy requirements of the solar-energy system.

System Energy Flows

April, 1978, was selected as a typical month to illustrate the flow of energy through the system. Table 4 is the summary of the primary system performance parameters for the selected month. The ARATEX solar-energy system operated continuously during April with an average daily hot-water consumption of 18,300 gallons. However, if only the days when the laundry was operating are considered, the average hot-water usage per day was 27,500 gallons.

Table 4. April Performance Summary ARATEX Services, Inc. Solar-Energy System

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: ARATEX SERVICES, INC. SOLAR/2008-78/04
REPORT PERIOD: APRIL,1978

SITE/SYSTEM DESCRIPTION:
THIS SITE IS AN INDUSTRIAL LAUNDRY WHICH USES SOLAR ENERGY TO SUPPLY HEAT FOR HOT WATER. IF SUFFICIENT SOLAR ENERGY IS NOT COLLECTED TO SUPPLY THE HEATING REQUIREMENTS FOR HOT WATER, AUXILIARY ENERGY FROM A GAS-FIRED LOW PRESSURE STEAM BOILER IS USED TO MEET THE HEAT NEEDS.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	301.901 MILLION BTU
	46247 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	80.421 MILLION BTU
	12315 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	58 DEGREES F
AVERAGE BUILDING TEMPERATURE	N.A. DEGREES F
FOSS SOLAR CONVERSION EFFICIENCY	0.20
FOSS OPERATING ENERGY	1.658 MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	12.270 MILLION BTU
TOTAL ENERGY CONSUMED	508.165 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	308.023	N.A.	N.A.	308.024 MILLION BTU
SOLAR FRACTION	19	N.A.	N.A.	19 PERCENT
SOLAR ENERGY USED	59.234	N.A.	N.A.	59.234 MILLION BTU
OPERATING ENERGY	10.571	N.A.	N.A.	12.270 MILLION BTU
AUX. THERMAL ENERGY	248.789	N.A.	N.A.	248.789 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	414.573	N.A.	N.A.	414.573 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-1.698 MILLION BTU
FOSSIL SAVINGS	98.724	N.A.	N.A.	98.724 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.73

* DENOTES UNAVAILABLE DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/19
READ THIS BEFORE TURNING PAGE

The supply water entered the system at 67°F after being conditioned with water softeners in a holding tank. The heat-recovery system increased the supply water temperature to 107°F by extracting 182 million Btu of energy from the waste-water holding tank. This 182 million Btu effectively reduced the load on the solar-energy system by 37 percent to 308 million Btu, thus the heat-recovery system provides a very efficient means of energy conservation for the system.

The available insolation on the collectors during the month was 302 million Btu for an average of 1541 Btu/ft^2-day. This is significantly below the long-term average for April of 2087 Btu/ft^2-day and resulted in degraded performance of the solar-energy system. The system collected 80 million Btu, or 27 percent of the available insolation, at an expense of 1.70 million Btu of electrical energy for system operation.

The average temperature of the storage tank for April was 133°F, with a daily range between 116°F and 178°F. Because of data system problems during the month, the amount of the solar energy delivered to storage could not be determined. Therefore, it was assumed that all of the solar energy collected was delivered to storage. This assumption effectively includes the losses between the collector and storage with the losses from storage but has no affect on other performance parameters. Of the 80 million Btu of solar energy collected, 16.6 million Btu were lost to the environment, resulting in an average storage efficiency of 79 percent.

The hot water consumed by the laundry during April placed a net load of 308 million Btu on the solar-energy system. As previously stated, this load is that remaining after the conservation of 182 million Btu by the heat-recovery system. Solar energy satisfied 19 percent of this load, which resulted in the savings of 99 million Btu of fossil energy at the additional expense of 1.70 million Btu of electrical energy for operating the solar-energy system. The energy savings calculations are based on a comparison of the projected energy requirements of a conventional, fossil-energy boiler with an efficiency of 60 percent and the energy requirements of the solar-energy system. All energy requirements for the savings calculations are based on the measured demand for hot water.

SUMMARY

The ARATEX solar-energy system has operated during the period from September, 1977, to April, 1978, with no major problems. This industrial laundry utilizes both solar energy and energy extracted from waste water to reduce the use of fossil fuel.

The heat-recovery system has effectively reduced the hot-water load by 36 percent per month by the conservation of 182 million Btu per month. Solar energy supplied 14 percent of the load, resulting in savings of 76 million Btu per month of fossil-energy resources.

During the period covered by this paper, the available solar energy has been lower than expected. This causes a corresponding reduction in the performance of the ARATEX solar-energy system.

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Reliability, Maintainability and Materials Performance of Solar Demonstration Systems

Prem S. Chopra

INTRODUCTION

The worth or effectiveness of an energy supply system is measured by its performance--how much energy it provides when working, and its reliability--how long a system is capable of working without failure. A major problem in the design and operation of an energy system arises from a conflict of the desire to render reasonably continuous service with the inherent fallibility of equipment and the cost associated with the corrective action necessary to improve system performance. Since the primary sources of cost in solar heating and cooling systems are capital costs and maintenance, the economic consequences of performance degradation and unreliability are significant impediments to successful commercialization of these systems.

The Department of Energy (DOE) is conducting the National Program for Solar Heating and Cooling of Buildings. A major element of that program is the National Solar Data Program which includes data collection, evaluation and report publication. Information and technical data are being collected and reported on a number of residential and commercial sites. Recently, a program was initiated at Argonne National Laboratory (ANL) under the auspices of the National Solar Data Program to collect, evaluate, and publish reliability, maintainability, and material performance data from these sites. This paper describes the plans which have been made and some of the early results which can be expected from the ANL Solar Data Program.

One of the key activities of the ANL program is to evaluate the reliability and materials problems normally associated with construction in the building industry and generic problems unique to solar systems. The ANL program has been planned to identify these generic problems the causes and solutions. Data from solar heating and cooling demonstration systems, if collected and utilized effectively, can contribute significantly to the improved lifetime performance, life-cycle cost reductions, overall cost effectiveness and consumer acceptance of solar systems. The ANL Solar Data Program consists of two elements: reliability and maintainability; and materials assessment.

RELIABILITY AND MAINTAINABILITY

Objectives

The objectives of the reliability and maintainability (R&M) activities of the ANL Solar Data Program are: (1) obtain solar system R&M data from operational demonstration sites; (2) identify problems or conditions that degrade system performance or cause early system failure and unavailability; (3) publish solutions for reducing or avoiding those problems or conditions; and (4) publish guidelines for the design, construction and operation of reliable and efficient solar systems. The information obtained in this program will be documented and published in a timely manner for the use of architects, engineers, designers, component manufacturers, contractors, operation and maintenance personnel and for potential solar system users.

Data Requirements and Acquisition Method

Considerable information is becoming available on DOE solar demonstration sites including system design descriptions, costs and performance reports. A number of residential and commercial sites have been instrumented for continuously collecting performance data via the National Solar Data Network. The ANL program will utilize much of this information. In addition, special effort will be directed to the full utilization of the experience gained by contracting officer's representatives (COR) and project managers (PM) during their site monitoring activities.

Trained ANL field engineers will visit solar demonstration sites, after they are operational, to obtain reliability and maintainability information by discussions with operating and maintenance personnel and with the architect-engineers, system designers, contractors or component manufacturers, as appropriate. The first visit will be followed by periodic visits or a monthly telephone call to a toll-free ANL number to record the sites operating and maintenance experience. Data will be recorded on R&M forms by the ANL field engineers and filed in an R&M library for subsequent use in evaluation activities and publication.

Data collection emphasis will be on component failures which cause the solar system to be inoperable for extended periods and on performance data indicating system degradation or reduced system heating or cooling output. The cause of the problem, the manner of detection and the corrective action will be documented. From the collected data generic component and system failures will be identified for possible failure analysis.

Data Evaluation and Publication

The reliability and maintainability information obtained in this program will be evaluated and published promptly for the use of the various interest groups identified earlier. Two basic categories of reports will be prepared. Those that address the identification of generic problems and their resolution; and those related to system reliability performance.

Reports on Generic Problems

An attempt will be made early in the ANL program to identify generic problems unique to solar systems. Examples of such problems include leaking, freezing, boiling, air-locking, sensor failure, etc. Each generic problem will be evaluated to determine the contributing factors and the impact of the problem on system performance. The results of the evaluation will be published in a generic problem report. This report would include information on the percentage of similar systems that experienced a particular generic problem. If a significant percentage of systems experience a particular generic problem, detailed analysis would be conducted and the results published in a failure prevention bulletin. This would alert solar system contractors and designers and help reduce the frequency of similar system failures.

Reports on Solar R&M

Operational data will be used to evaluate consequences of reduced reliability on solar systems after early problems associated with the commercial demonstration sites have been identified. These data will be supplemented by failed component analysis, failure mode analysis and analytic studies so that system reliability can be assessed.

As operational time of a solar system increases, various components will fail. Failure may be due to: design inherently incapable of performing its intended function; environment beyond the capability of the component or the system; faulty component or one damaged in manufacture, test or installation; and normal wear-out. Failure analyses may be performed on some components using information, where applicable, from materials assessment activities. An R&M bulletin will be issued summarizing the failure analysis results and including recommendations to reduce the frequency of failure.

Predominant solar system failure modes will be identified based on the generic problem studies, operational data and failed component analysis. Using this information in conjunction with general solar system schematics, failure modes and effects analyses will be performed in order to develop a solar system critical items list.

For example the R&M report for architects/engineers will include R&M calculation procedures, component failure statistics, failure analysis, failure modes and effects analysis and design examples. In contrast, the report for the potential solar system users will contain general discussions on solar systems, solar sizing criteria, expected maintenance actions, and economic considerations.

Expected Early Results

The ANL R&M activities were initiated during the first quarter of this year. Basic data requirements have been defined and the initial version of R&M forms and the procedure for data collection have been established. Accumulation of background information on the sites from IBM, PRC, and COR's has started and a few sites have been visited to verify the R&M data collection procedure.

Based upon a preliminary review of the background data obtained, the generic problem areas that have been identified are: freezing, boiling, leaking, air-locking, and sensor failures. A preliminary description of generic R&M problems in solar heating and cooling systems will be published at the end of this fall. Initial evaluation efforts will be focused on leaks in collector to manifold connections and on freezing. Evaluation reports on these problems will be published by the end of this year.

MATERIALS ASSESSMENT

Objectives

The degradation of heat-transfer fluid (HTF) properties and corrosion behavior in a solar system can have a significant effect on the cost and performance of the system. Materials assessment activities have been implemented at ANL to obtain data needed to interpret possible changes in system-performance efficiency caused by materials corrosion and HTF degradation. A major objective of these activities is to provide information for the selection of durable cost-effective materials for solar systems in various climatic regions. These activities are being conducted under four tasks: (1) Atmospheric corrosion, (2) HTF corrosion, (3) Heat transfer properties, and (4) Heat transfer scaling.

Atmospheric Corrosion

Atmospheric corrosion of metallic supporting structures (battens/enclosure) depends on the synergistic effects of humidity, temperature and atmospheric constituents. On-site monitoring will be conducted at 15 NSDN sites. These selections were based on climatic conditions, SDAS channel availability, and contractor cooperation.

The atmospheric corrosion sensor (Cu-Zn couple) that registers that galvanic current (during the time of wetness) together with the relative humidity sensor and ambient temperature probe will be used to correlate the weight change data on the atmospheric corrosion rack. The rack contains six coupons each of four materials; aluminum, galvanized steel, aluminized steel and painted steel. These materials were selected based on current utilization in commercial collectors. Weight changes of corrosion coupons will be measured after exposure to the atmosphere for 3, 6, 9, 12, 15, and 24 months.

Heat Transfer Fluid Corrosion

When the HTF or its corrosion inhibitors degrade with time and/or temperature to form acids, the internal surfaces of the solar collector system become susceptible to corrosion and corrosion-erosion. The damage is expected to be more severe at a collector surface that emits heat to a fluid than at a pipe surface that is heated by a fluid. The early detection of HTF or inhibitor degradation and the subsequent corrosion-erosion effect on solar collectors materials can be detected by an on-site voltage corrosivity sensor designed by Texas Instruments for use in liquid heat transfer systems. Sensors will be installed at five selected sites and tied into the Site Data Acquisition Subsystem. Laboratory tests will be conducted using HTF collected from the selected sites to correlate with other properties measured from these sites.

Heat Transfer Properties

Data on the specific heat and density of the HTF at operating temperatures are needed to calculate accurately the instantaneous thermal efficiency

and the useful energy collected by the solar collector system. At present, nominal values are used in calculations. Heat-transfer fluid will be collected from 40 instrumented sites to determine actual specific heat and density at three operating temperatures. For aqueous non-freezing HTF, measurements will be made at 40, 120, and 200°F. For non-aqueous HTF, measurements will be made at 40, 150, and 240°F. Calculations will be made to evaluate the influence of differences between nominal and measured values on thermal efficiency and energy collection. After one year of service, measurements will be repeated to ascertain whether further changes in HTF properties affect system performance.

Heat Transfer Scaling

Scaling at heat-transfer surfaces of solar collectors and heat exchangers reduces thermal efficiency and can affect operational reliability. Radian Corporation has developed a model to calculate scaling potential of aqueous HTF as a function of temperature, pH and the concentration of key scaling species. The model uses equilibrium relationships among the different dissolved species and takes into account solution nonideality and the effects of ion complexing. The generic problems associated with water chemistry and scaling of materials will be analyzed for five selected instrumented sites. These analyses will be based on water compositions at the sites. Calculations will be made of the scaling potential and the effect of the rate of scaling on thermal efficiency.

Expected Early Results

Site instrumentation for monitoring atmospheric and heat transfer fluid corrosion will be installed by this summer and three month exposure data will be reported by the end of the year. Heat transfer fluid samples have been collected from 12 sites and will be analyzed this summer. Properties of heat transfer fluids of the total 28 sites selected will be reported this fall. The rate of scaling in systems using aqueous heat transfer fluids will be evaluated and its influence on thermal performance will be reported by the end of this year.

SUMMARY AND CONCLUSIONS

The program plan for ANL reliability, maintainability, and materials assessment activities has been established and its implementation has been initiated. Early evaluation reports based on the data collected in this program will contribute to the improved R&M performance and to the selection of durable and cost effective materials for solar systems in various climatic regions.

ACKNOWLEDGEMENTS

The work described in this paper is being performed under the auspices of the U.S. Department of Energy, Division of Conservation and Solar Application. The guidance provided by Mr. H. Jackson Hale, Manager, National Solar

Data Program in developing and implementing this program is greatly appreciated as is the assistance of the ANL Solar Data Program staff.

Solar Systems Reviewed To Date

System	Number of Sites
Water	16
Glycol	19
Air	2
Air with DHW	2
Oil	1
Total	40

Figure 1

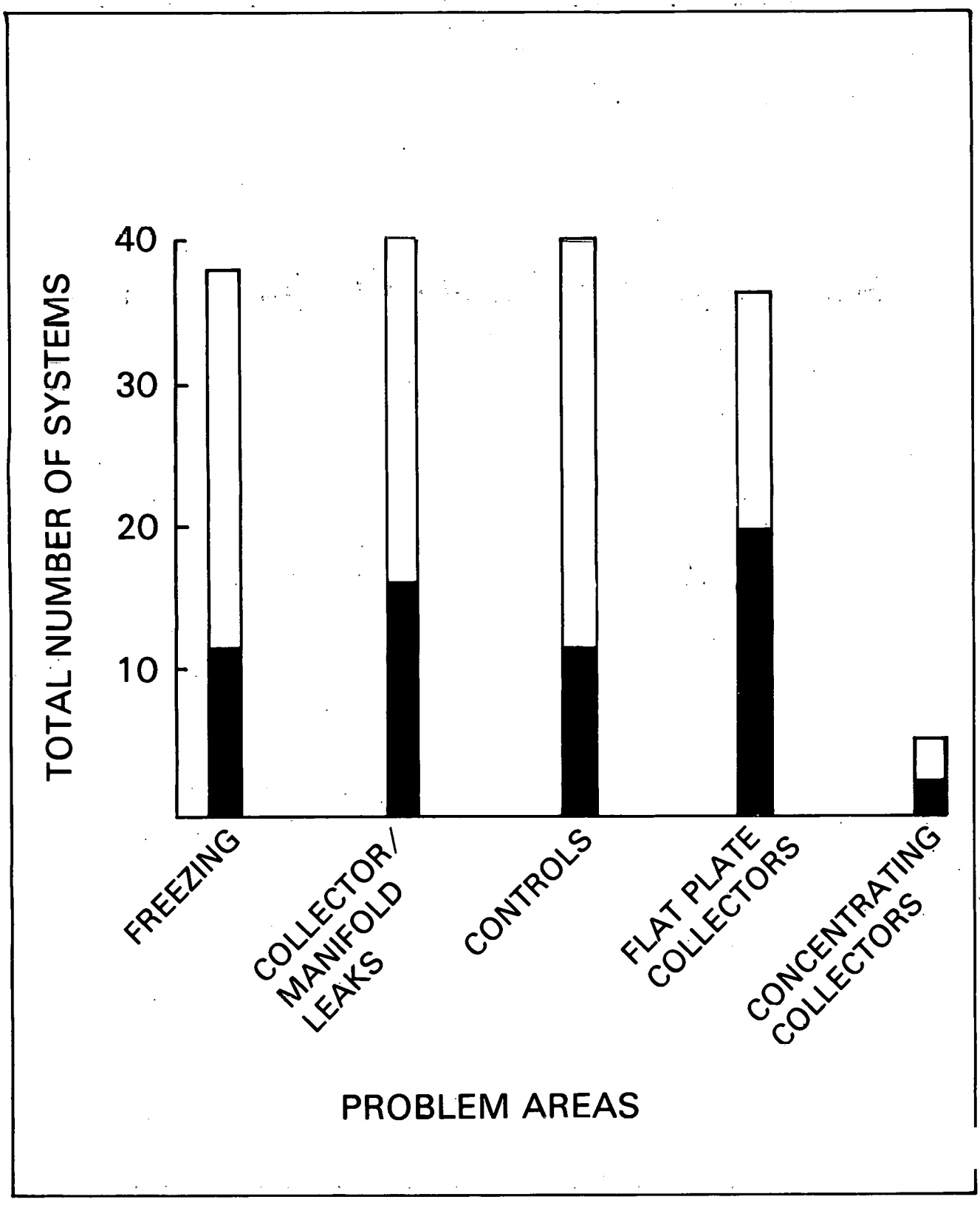

TOTAL NUMBER OF SYSTEMS
40
30
20
10
FREEZING
COLLECTOR/ MANIFOLD LEAKS
CONTROLS
FLAT PLATE COLLECTORS
CONCENTRATING COLLECTORS
PROBLEM AREAS

Figure 2

Recommendations For Avoiding Freezing

- Vent valves
  - Location
  - Insulation
  - P-T rating
- Control valves
  - Seals
  - P-T rating
- Manifolds
  - Slope
  - Expansion joints
- Air dampers
  - Edge Seals
  - Maintenance
- Aqueous solar fluids
  - Sensor location
  - Detection
  - Concentration

Figure 3

Materials Evaluation

- Solar fluid degradation
  - Early detection
  - In-Situ monitoring

- Voltage corrosivity sensor
  - Measure static solution potential
    Warn lowering of antifreeze concentration
  - Predict freezing temperature (development)
  - Detect breakdown of fluid/inhibitor to acid (corrosion-erosion)

Figure 4

Laboratory Coolant Corrosivity Measurements for 50% Antifreeze (Periodically Overheated)

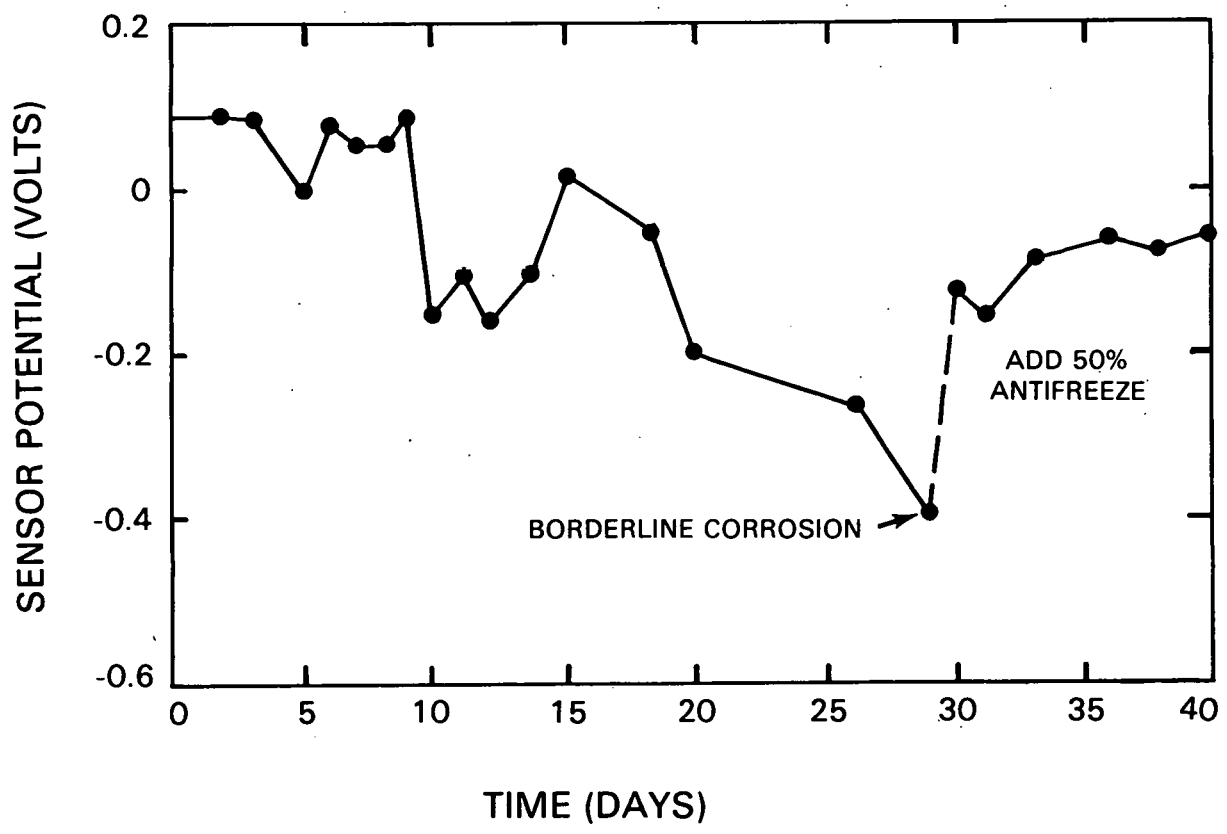


Figure 5

Causes Of Interconnection Leaks

- Hose materials
- Hose clamps
- Connector design

Figure 6

Hose Materials Considerations

- Temperature and pressure resistance
- Flexibility
- Environmental resistance
- Compression set resistance

Figure 7

Hose Materials

Major hose manufacturers' recommendation:

- EPDM
- Viton
- Hyphlon
- Silicone

Other acceptable materials:

- Butyl
- Neoprene

Not recommended:

- Natural Rubber
- Buna-n
- Buna-s

Figure 8

Hose Clamp Considerations

- Screw type clamps
  - Greater initial pressure
  - Easy to install
  - Periodic adjustment
- Constant tension clamps
  - Accommodate temperature/pressure variations
  - More difficult to install

Figure 9

Connector Design Considerations

- Tube terminations with ferrules
- Clamp located to trap hose
- Metal connections

Figure 10

Metal Tubing Interconnections

- Initially more expensive than hose connections
- With proper consideration of:
  - Thermal expansions
  - Flexibilities
  - Insulation stiffening effects
  - Tolerance build-ups
  - Dielectric couplings
- Metallic connections should last as long as the solar collectors
- Serious leaking problems not reported

Figure 11

Interconnection Design Summary

- Choose proper hose material
- Develop clamping details
- Provide for service
- Recognize that hoses will probably last 5-7 years

Figure 12

Expected Early Results

- Generic problem reports on:
  - System freezing - fall '78
  - System interconnection leaks - Dec '78
  - Controls - March '79
- Failure prevention bulletins
- Evaluation of voltage corrosivity sensor - Dec '78
- Atmospheric corrosion - Dec '78
- Heat transfer scaling - Oct '78

Figure 13

Conclusions

- Reliability and materials program established
- Preliminary data obtained and evaluated
- Reports forthcoming

Figure 14

A Perspective On the Cost of Non-Residential Solar Energy Systems

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I. INTRODUCTION

One purpose of the National Solar Heating and Cooling Demonstration Program is to assess the economic viability of solar heating and cooling systems now and in the future. To achieve this goal requires accurate data concerning the actual installation costs and performance of these systems coupled with projections for the future. The Demonstration Program now consists of approximately 221 projects, in various stages from design through completion and operation, that can provide an extensive data base for cost information.

Although many potential uses for the cost information are obvious, it is useful to list them here to identify the major applications for accurate cost data.

1. DOE Planning and Management

Improved planning of future Demonstration cycles could result if Program Managers knew exactly how much past projects cost and why. Better cost information would permit identification of future Demonstration sites that are viable from a cost standpoint.

2. Economic Projections and Analyses

The best figure-of-merit for assessing the viability of a solar heating and cooling system is "Cost/Btu," that is the life-cycle cost of the system divided by the energy provided by the system. (Life-cycle cost include, initial cost, operating costs and maintenance costs.) An extensive program of instrumented data collection is underway to determine the performance of the Demonstration systems. To be meaningful though, the performance assessment must be accompanied by actual system cost data.

3. The Solar Infrastructure

Engineers, architects and contractors need to know how to estimate solar system costs. Owners need to know what they can expect to spend for a system and what their return will be. Banks need to know what are reasonable costs for financing purposes. Insurance companies need this information to establish rate structures.

In pursuit of the stated goal, Mueller Associates, Inc. is preparing individual Solar Project Installation Cost Reports and summary documents under subcontract to the Argonne National Laboratory as part of the National Solar Data Program. The remainder of this paper will provide insight into cost data collection problems, identify the approach that has been taken by Mueller Associates, and describe the output expected from this study.

Before continuing, two points should be stressed:

1. The focus of this work is to collect initial cost data for the systems and not the operating or maintenance costs. Determining these two cost types requires very different approaches and efforts within the Data Program are underway by others to determine operating and maintenance cost elements.

2. This discussion is, in general, applicable only to commercial systems. The data requirements and data collection constraints of the residential program are different and although related to the commercial sector, require different approaches and treatment.

II. BACKGROUND

Before initiating the data collection process, two major questions had to be addressed:

1. What level of cost information is reasonable and obtainable?
2. When is cost information best obtained for a project?

Past efforts at cost data collection have provided some insight into the answer to the first question:

1. No universal method of cost estimating or cost control is employed in the building industry. Some contractors have elaborate computerized systems to track labor and materials costs; others keep invoices in loose files and maintain few records of labor requirements.

2. Past efforts at cost data collection have sought excessively detailed information that is not generally available for a building project.

3. Many different types of organizations and contractual configurations are encountered in the Program and each has unique capabilities, experience and inclination to collect the types of data sought. Some companies that have been awarded contracts act as the general contractor for construction, while others hire a general contractor. A single approach to data collection is difficult to apply to every case.

Question 2 above, "When is cost information best obtained for a project?," addresses the fact that some projects are now completed and operational; some are in construction; some are still in planning. Different constraints to cost data collection apply for each case.

A review of the cost figures that evolve during the various phases of a "typical" project is helpful to understand the data collection approach presented here.

1. Preliminary design estimate

The costs presented to DOE in PON submittals are usually preliminary engineering estimates based on system conceptual designs. The A/E team has developed a first evolution design and has provided the owner with a cost estimate with an accuracy commensurate with the detail to which the design is known. Generally, the designer bases his "guesstimate" upon his experience with similar systems. If he has not had previous solar experience he might use published information.

2. Final design estimate

When the owner gives the engineer the notice-to-proceed (subsequent to PON negotiation and award), the A/E team will begin the final design process. At

the completion of final design, a final system cost estimate (that is usually obtained from a detailed take-off) is made. In the case of a solar energy system, the designer with limited solar experience still must guess at certain unfamiliar aspects of the system, such as collector mounting, collector piping, controls and possibly insulated and buried storage tanks. For the conventional HVAC systems and equipment, estimating guides are available, such as "Means" or the "Dodge Manual." These manuals provide a detailed materials and labor breakdown for a wide variety of equipment types. In addition, they indicate the types and quantity of labor required for each task. Normally, within the building industry, the final "engineering estimate" must be within ± 10% of the lowest general contractor's bid or the system must be modified to be within that cost range at the designer's expense.

3. Bids from the contractors

A number of bids are received after the drawings and specifications are completed. It is not unusual to find significant variations among the bids. The reasons for the variation are diverse but can include: a "fear factor" of contractors unfamiliar with solar energy systems; a contractor who wants solar experience and bids low; contract documents (drawings and specifications) of poor quality that do not define the system well; a subcontractor who does not particularly like working with a specific general contractor (but will work for him if the price is right).

4. Winning contractor's bid

The lowest solar energy system subcontract bidder does not always receive the construction contract. Often selections are based upon the contractor's ability to perform the work and/or his past experience, in addition to the cost. Also, if the solar system is not a large part of the total construction project, the lowest cost for the solar system may not affect the general contractor's total price. For instance, if a very large office building is to be built and it will include a solar energy system whose price is small compared to the total construction price, the general contractor who has the lowest and winning price may not necessarily have the solar sub-contractor with the lowest solar system bid.

It is the winning contractor's price that is perceived to be the "real" cost of the system. However, for the purposes of estimating future project costs, it is more useful to know the contractor's actual construction cost.

5. Contractor's actual costs

To help designers estimate costs, the most valuable information to be obtained from previous projects is how much it actually cost to install those systems, not how much the installers bid. The bid information is not valid if the installer lost money, or if he made an excess profit. Thus, it is the contractor's actual labor and materials costs that should be available after a project is complete and be used as the basis for future projects. Unfortunately, these are the costs that are most difficult to obtain, because they are rarely recorded in one source, if they are recorded at all.

II. METHODOLOGY

The approach to aggregating the data into solar system cost categories for

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every installation will be to resolve the data into elements at two levels of detail, primary and secondary. Table 1 provides an indication of the level of disaggregation associated with the primary and secondary cost breakdowns.

In general, the primary cost categories follow work categories typically performed by different trades or subcontractors on building systems construction projects, and these are expected to be separable, identifiable costs. The secondary cost categories represent a more detailed breakdown of the primary categories and are more difficult to obtain. In general, this information is sought through discussions with the subcontractors and others, and by reviewing their records.

In all cases, obtaining the accurate total project cost will be the focus of the data gathering effort. The costs presented in the site reports will not include the DOE Contractor's overhead and profit or general and administrative costs. There is a general sensitivity to the publication of these latter costs among corporations in a competitive market. Also, the bare costs, (without overhead and profit) are more useful to others who could apply the information in this report to their projects by applying their own overhead and profit figures.

General contractors will be the focus of data collection since they will be able to provide the most cost information for each project. However, where possible each major sub-contractor will also be interviewed to obtain more specific information pertaining to the respective subsystems. We attempt to interview the personnel from the contracting firms who were actually on site performing the work and those that kept the cost records.

For each cost category the following types of information are sought:

- o Labor type utilized
- o Number of workers utilized
- o Number of hours required
- o Time per unit of equipment installed
- o Materials cost
- o Labor rates
- o Delivery costs of major items
- o Overhead factors
- o Total costs

This information is obtained from cost files, invoices, time logs, government payment request vouchers, monthly progress reports, bills-of-materials, and the interviews.

In addition to the above data, each contractor and sub-contractor is questioned concerning observed areas for cost reduction and cost estimating employed to date. Engineers, architects and building owners are interviewed to obtain preliminary and final engineering cost estimates, range of bids received and any other pertinent cost information.

It must be emphasized that this cost information can only be assessed in relation to review of a detailed system description, which will be provided by PRC/EAC as part of their non-instrumented site data collection activities.

Table 1 - Site Specific Cost Breakdown

PRIMARY	SECONDARY
Collector Support Structure[a]	o Materials o Labor
Collectors	o Materials[b] o Delivery o Mounting on Support Structure[c] o Collectors Connecting to Manifold[d]
Piping Systems	o Collector Distribution System[e] o Materials o Labor o Other Piping [f] o Materials o Labor
Ductwork	o Collector Distribution System o Materials o Labor o Other Ductwork o Materials o Labor
Insulation	o Collector Distribution System o Materials o Labor
Heating/Cooling Equipment[g]	o Materials o Delivery
Storage[h]	o Materials o Delivery o Installation[i] o Insulation
Controls	o Materials o Labor
Electrical	
General Construction	o Roofing o Equipment Room o Architectural o Excavation o Painting
TOTAL PROJECT COST[j]	

NOTES:

a. Includes all framework, structural beams and supporting system for the collectors.
b. Total materials invoiced by collector manufacturer (including tracking mechanisms if applicable).
c. Labor and materials cost of moving collector to roof and securing to support structure.

d. Labor and materials cost of connecting collectors to external manifolds or interconnecting collectors with internal manifolds.
e. Includes exterior piping/ductwork, external collector manifolds, and piping/ductwork from equipment room to collectors. Does not include connecting collectors to manifold (see "d" above).
f. Includes pumps, expansion tanks, valves, etc.
g. e.g., absorption chillers, heat pumps, air handling units and heat exchangers not part of auxiliary systems.
h. Includes pad, supports, linings and coatings. Includes insulation but not internal heat exchangers.
i. Includes excavation, crane rental and labor to secure storage tank. Does not include piping/ductwork connections to storage.
j. Includes all costs of project attributed to solar energy system only.

IV. COST ANALYSIS AND REPORTING

Individual Solar Project Cost Reports are being prepared for a wide variety of projects drawn from the National Solar Demonstration Program. Each report will contain a brief project description, an identification of data sources, an analysis of the project construction costs consistent with the breakdown shown on Table 1, and a discussion of the special characteristics of each project. Major project specific impacts that may have affected the representativeness of construction costs will also be addressed.

In addition to the individual project reports, periodic summary reports are planned. These summary documents will compare the costs for a variety of systems by cost category and system type. A range of costs for each category will then be developed, and through analysis of the available system description and other background information, the impact of various cost factors can be assessed. A very large data base is needed to define completely the range of impacts of all factors. However, trend information should be obtainable through analysis of a sample number of projects.

To date, project cost reports have been completed for the following projects:

- o Radian Corporation Office Building, Texas
- o Aratex Services, Inc., Industrial Laundry, California
- o Iris Images, Inc. Film Laboratory, California
- o Terrell E. Moseley Office Building, Virginia
- o Scattergood School Recreation Center, Iowa
- o Kalwall Corporation Warehouse, New Hampshire

Additional sites are being evaluated, and ultimately all instrumented solar demonstration projects are planned for cost analysis.

This first series of site cost evaluations and resultant project reports is drawn from various geographical regions and represents a wide range of system types, sizes and unit costs as can be seen in Figure 1. The costs presented in Figure 1, and in following figures, are based on cost per unit of solar collector area ($\$/ft^2$) associated with the project. It is recognized that this

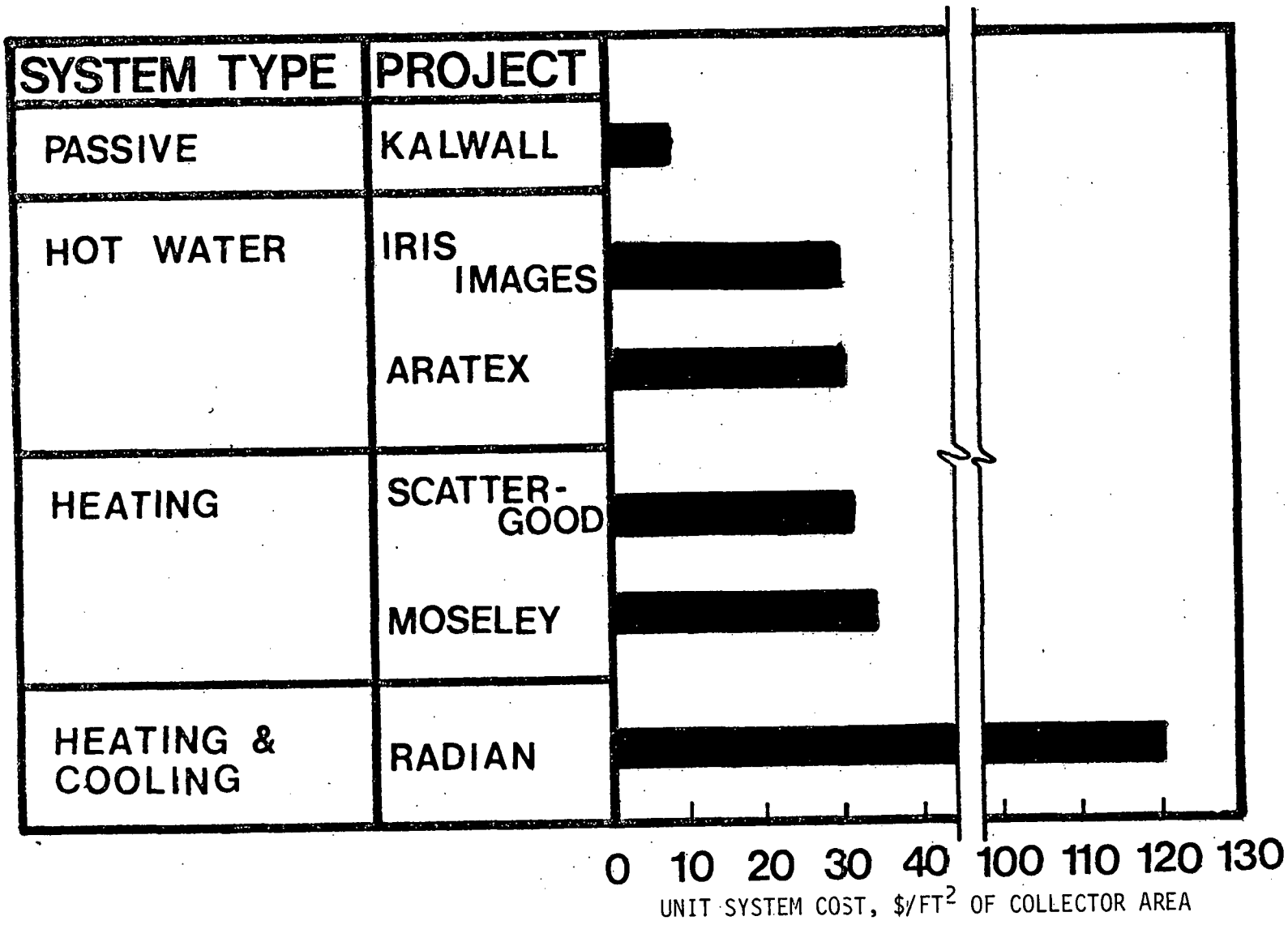


FIGURE 1. UNIT COST COMPARISON OF SELECTED SITES

convention is only meaningful when comparing systems of similar performance, construction aspects, building type, on relative terms. [More will be mentioned about cost/performance ratios ($/mmBTU) later.]

At this point, the reader is cautioned against using these cost data out of context and without first reviewing the Project Description Reports which serve as essential companion documents for interpreting the project costs.

The remainder of this paper summarizes primary cost breakdown data -- including labor and materials breakouts -- from this first series of reports. In addition to the information summarized in this paper, other aspects of the projects which have an impact on cost are discussed in various reports. Many of the following factors are assessed:

- System and subsystem design
- Physical condition of the site and building
- Aesthetic requirements
- Taxes
- Construction delays of all types
- Quality of contract documents
- Prepurchasing of major equipment items by owner
- Union/non-union labor
- Labor skill type
- Size of project
- New versus retrofit system
- Contractual configuration

Comparing primary cost breakdown data yields some interesting relationships. Figure 2 compares four different systems: Iris Images and Aratex provide service water heating, and Moseley and Scattergood are space heating applications. The Radian system is not included here because it provides space cooling and Kalwall is not included because it is a passive system.

An inspection of Figure 2 demonstrates how the relative distribution of costs varies as the subsystems are combined. Comparing the collector array and support structure breakdowns with the total of the two cost elements is very revealing. By investigating the characteristics of the specific projects, insight can be gained into relative differences. For example, though relative costs of the liquid collector arrays are comparable ($9.00 - 12.10/ft^2), the incremental costs of the attendant support structure are disproportionate ($6.80 - 2.70/ft^2). See Figures 3 and 4. Both the Iris Images and Scattergood School projects involved extensive architectural treatment of the support structure which inflated construction costs. On the other hand, the Aratex and Moseley systems permitted the use of more utilitarian structures fabricated from angle iron and steel pipe respectively.

The labor/materials breakdowns shown in Figures 3 thru 8 provide further insight into solar system costs. It is easy to identify the site built collector arrays: both Iris Images and Moseley were more labor intensive than the other projects shown. A comparison of the piping costs of Iris Images and Aratex -- both water heating applications -- show a wide disparity in unit costs, $4.00 vs. $10.20/ft^2. The preliminary indication is that the benefits of scale may not occur in the deployment and piping of large collector arrays since the respective collector areas for these two projects varied by an order of magnitude: 640 ft^2 vs 6500 ft^2. However, much more data are required before such conclusions can be drawn with certainty.

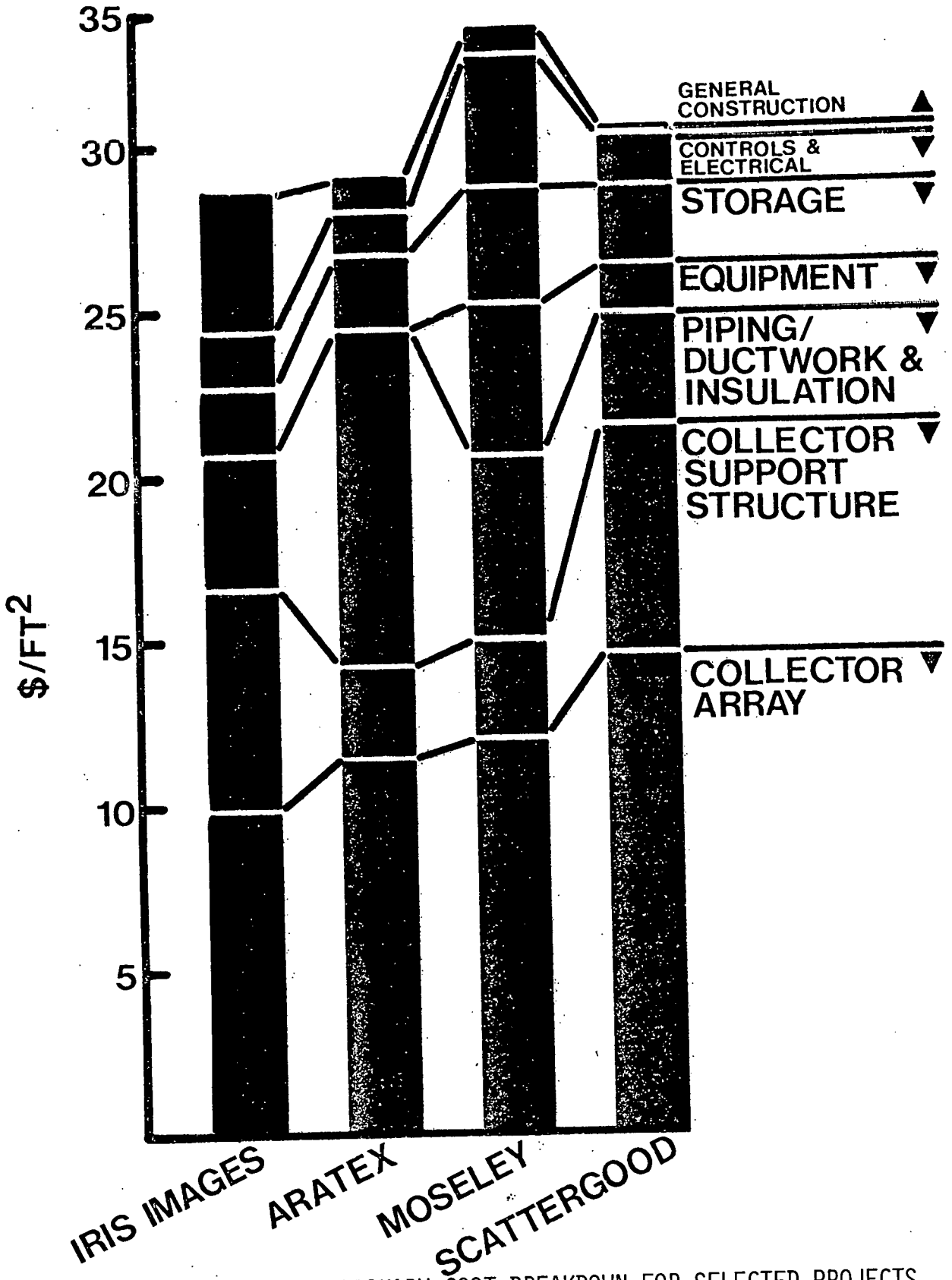


FIGURE 2. PRIMARY COST BREAKDOWN FOR SELECTED PROJECTS

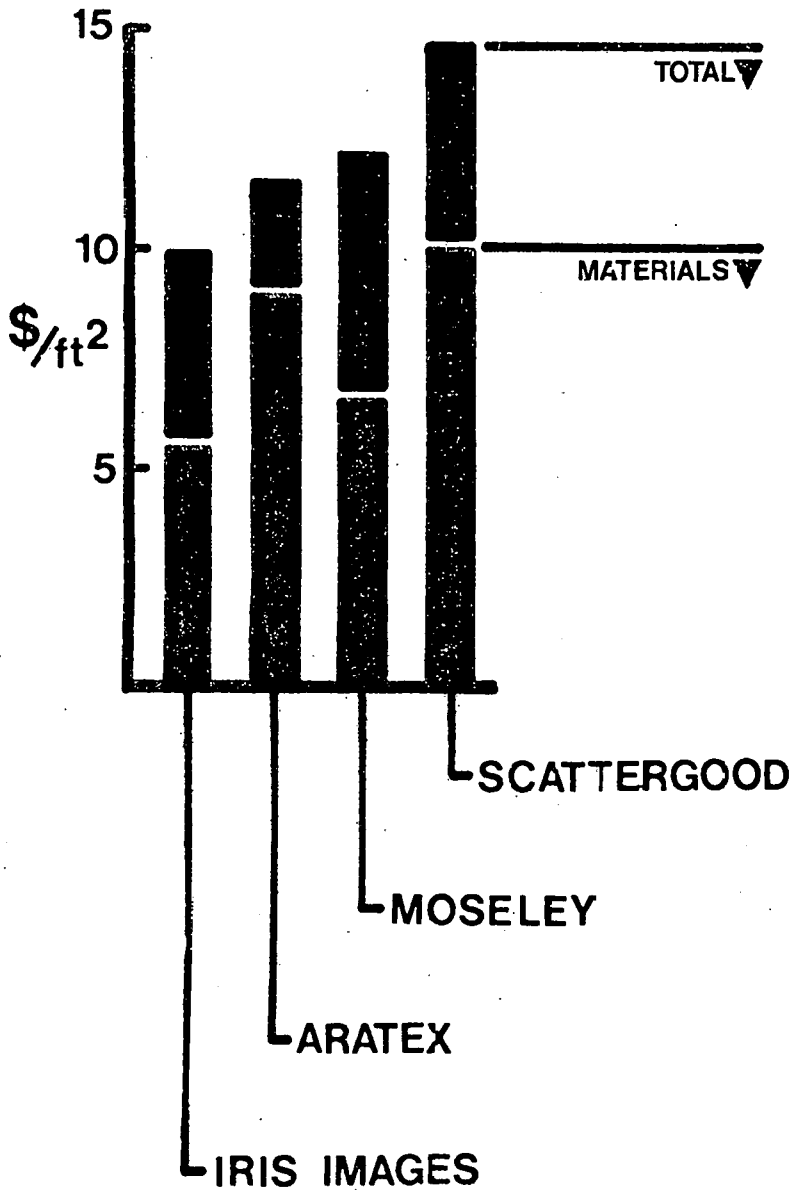


FIGURE 3. COLLECTOR ARRAY COST BREAKDOWN

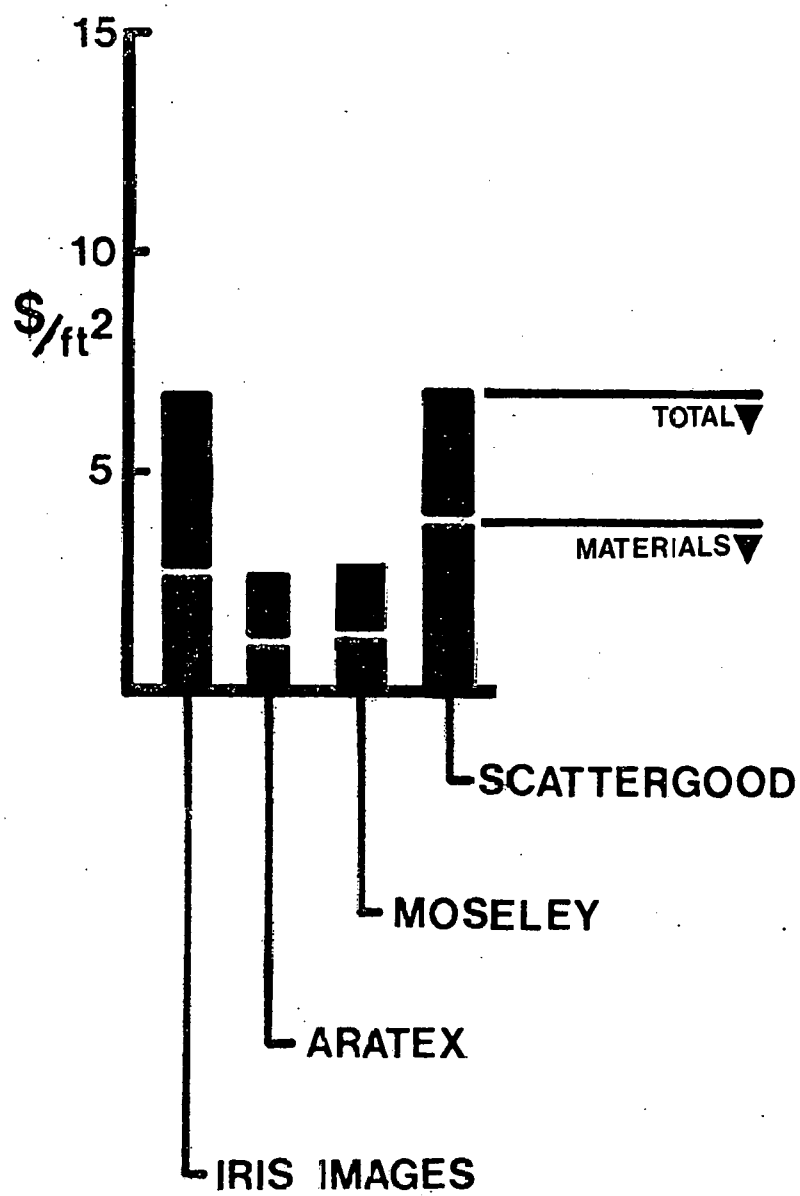


FIGURE 4. SUPPORT STRUCTURE COST BREAKDOWN

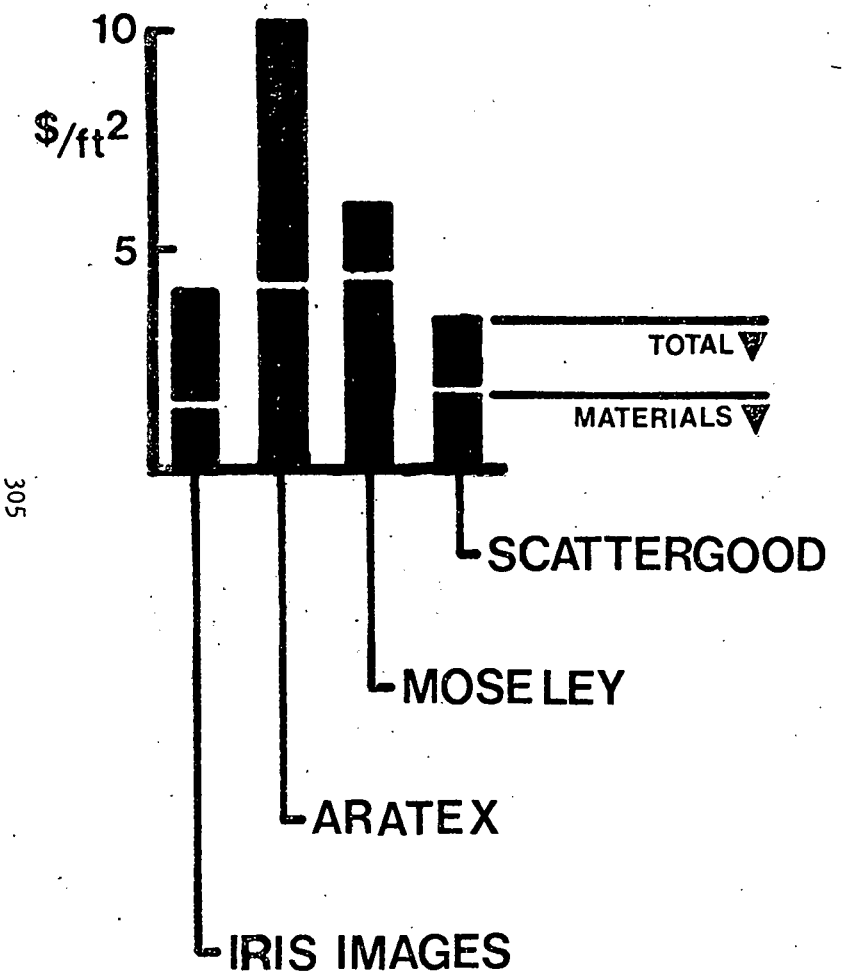


FIGURE 5. PIPING/DUCTWORK & INSULATION COST BREAKDOWN

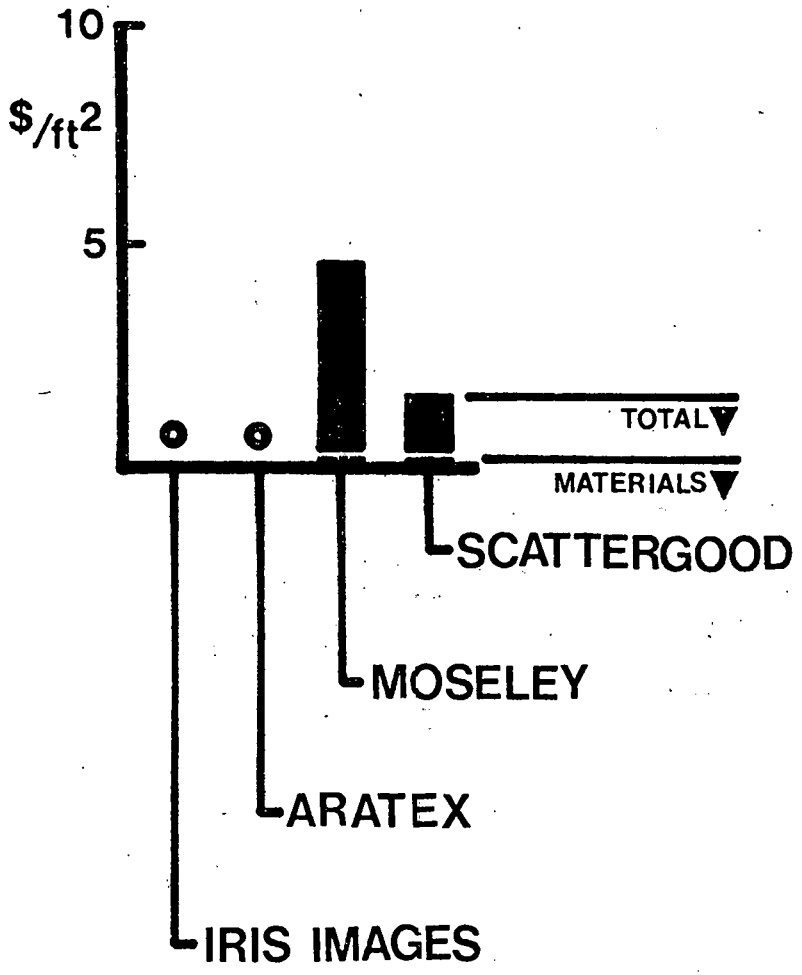


FIGURE 6. EQUIPMENT COST BREAKDOWN

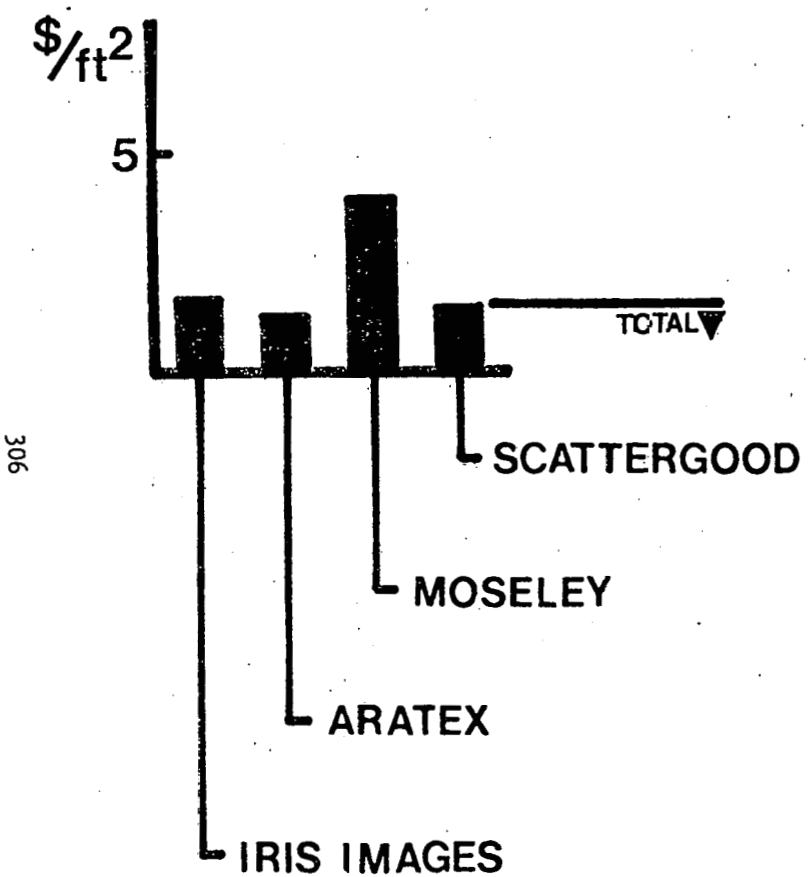


FIGURE 7. ELECTRICAL & CONTROLS COST BREAKDOWN

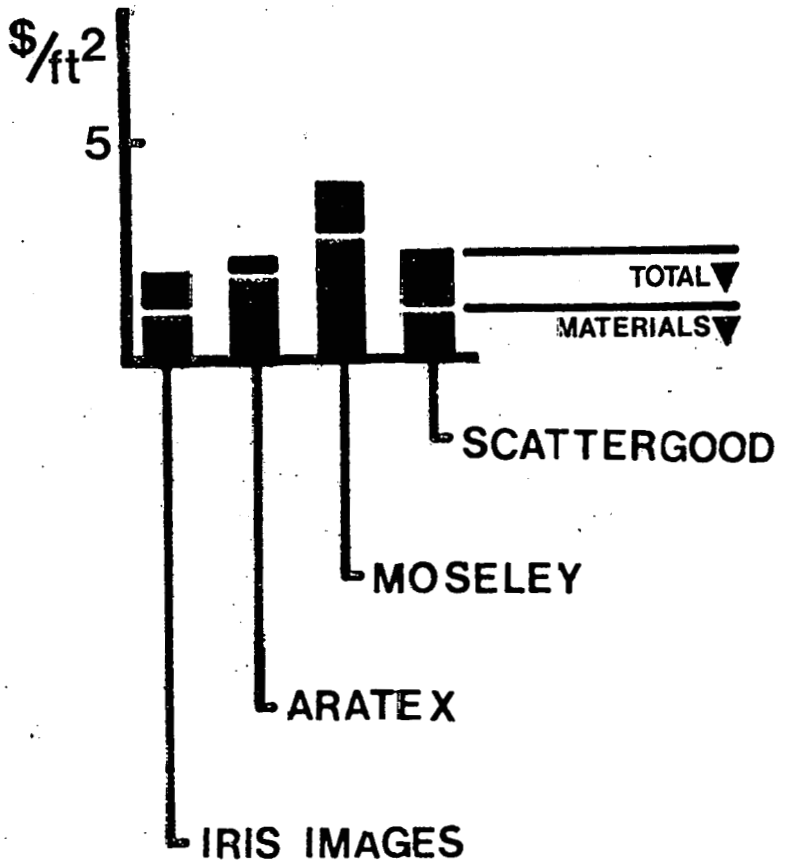


FIGURE 8. STORAGE AND INSULATION COST BREAKDOWN

By inspecting the "Equipment" cost breakdown in Figure 6, it is apparent no major items are required for the water heating installations to integrate the solar energy system with the existing system. On the other hand, the relatively high unit cost associated with the Moseley project requires closer scrutiny. At the Moseley site, a water source heat pump was essential for delivery of solar energy to the load. Therefore, the heat pump cost was considered part of the installed solar system cost. In this case the necessity for the heat pump had a rippling effect on other costs. Figure 7 shows the relatively high unit cost which occurred at Moseley due to the increased complexity of controls required for heat pump operation and the heavier electrical service required to power the compressor.

The storage subsystem cost has been readily identifiable in all the projects surveyed to date. What is most interesting is the small incremental cost associated with the installation of the storage tank and its insulation. The unit costs shown on Figure 8 vary from \$2.00 to \$3.90/ft^2 of collector area; and although this represents a one hundred percent variation, the impact on total system cost is small. A more meaningful method of comparison for liquid systems may be based on unit cost per storage volume combined with knowledge of the type of storage vessel employed. At the Moseley site, an above ground atmospheric vented tank, insulated with fiberglass board was installed for \$.77/gallon. The Radian project (which does not appear on Figure 8) and the Aratex project both employed above ground fiberglass tanks for storage, both of which were insulated with sprayed on polyurethane foam, and both had comparable prices of \$1.27 and \$1.20/gallon respectively. The Iris Images project employed three preinsulated 120 gallon glass-lined tanks (water heaters) which produced a higher unit cost of \$3.55/gallon.

The comparisons drawn in this paper are meant to demonstrate the potential value of the data which will result from detailed cost breakdowns. Potential users of these data should realize that six sites represent only a very limited sample of the Demonstration Program and, as such, are not necessarily indicative of all similar projects. Further, for the data to be usable it is necessary to be sensitive to the special characteristics of individual sites and how those characteristics affected costs. It is essential that the Solar Project Description Reports be consulted whenever attempting to use these cost data.

A third document which the user of these cost reports may find helpful is the Performance Evaluation Report. Performance reports are being prepared for a wide variety of projects, including the six listed here. It is a goal of the National Data Program to combine performance and cost data to arrive at that elusive cost/performance ratio which will be the most meaningful basis for comparing the relative merits of various solar energy systems.

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Architectural and Engineering Factors Involved In The Design of Solar Systems

By Stephen D. Weinstein, AIA

A key part of the national solar demonstration program is the acquisition and dissemination of data generated by the demonstration projects. The Ehrenkrantz Group, Architects and Planners, as a subcontractor to Planning Research Corporation/Energy Analysis Company under contract to the Department of Energy has been involved in this process for over a year. The following paper is based on the review and analysis of over 70 projects, and will focus on some of the most common design and construction problems. It will not be covering mechanical considerations such as collector selection, but rather on the physical aspects that must be addressed in detailing and specifications and some of the cost trade-offs that can make for a more cost-effective project.

ECONOMIC CONSIDERATIONS

THE SOLAR DESIGNER IS WORKING WITH RELATIVELY LOW LEVELS OF THERMAL ENERGY.

THIS LIMITS THE AMOUNT OF MONEY THAT CAN BE PRUDENTLY EXPENDED ON THE COLLECTION AND TRANSPORT OF SOLAR ENERGY.

The whole solar installation must be valued-engineered to arrive at the lowest first cost consistent with quality of materials and workmanship required. The desire to extract every theoretical BTU from a system often leads to the installation of extra devices that will not be cost-effective and will only increase the payback period of the project.

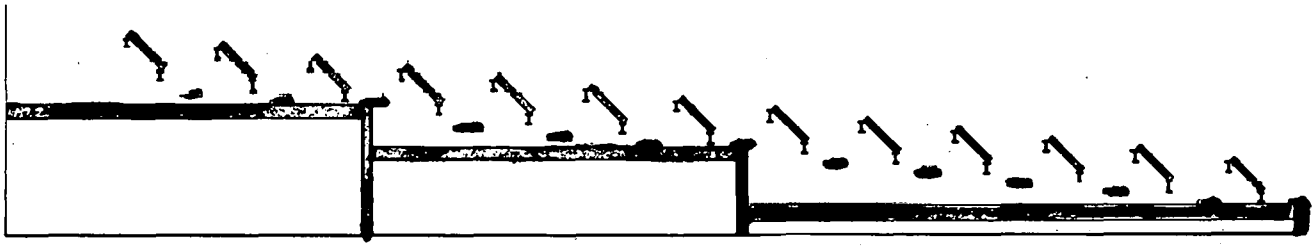
CONSTRUCTION CONSIDERATIONS

SOLAR COLLECTION SYSTEMS TYPICALLY REQUIRE CONSIDERABLY MORE EXPOSED EXTERIOR CONSTRUCTION THAN THE BUILDING TRADES ARE ACCUSTOMED TO.

THEREFORE THE DESIGNER MUST ISOLATE AND SOLVE CONSTRUCTION PROBLEMS AND NOT LEAVE DECISIONS TO THE CONTRACTOR.

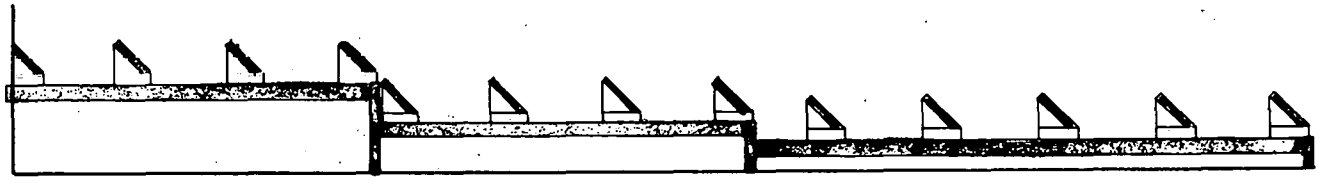
If we look out over a typical residential or commercial building roof-scape we would see a minimum amount of exposed construction, especially piping. As a result, the building trades cannot be expected to bring to bear prior experience to solve typical problems that accompany solar projects and their large amount of exposed exterior construction.

LAYOUT & ACCESS VS. COST -- Two considerations that have an impact on cost involve the collectors and structural layouts and the degree of accessability provided to the collectors and piping for servicing. We have found that, especially in the case of evacuated tube designs, the designer feels that immediate ready access to all part of the array is manditory. One of the more handsome designs we have seen provides accessibility for each row of collectors.

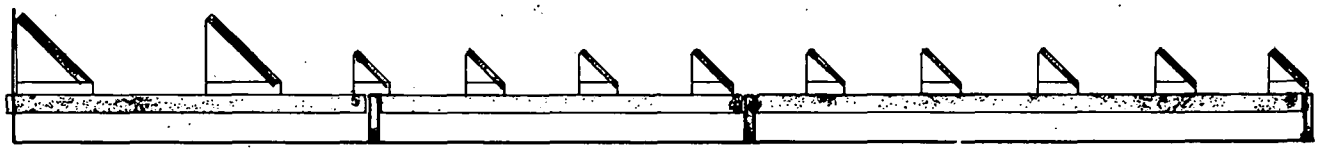


Each row of collectors is slightly higher than the one behind with accessibility to piping and collectors in the form of a walkway provided at each location. This makes everything extremely accessible and extremely expensive. The large amount of miscellaneous metal that goes into this design is very expensive and has caused delays to the project.

Simpler and less expensive approaches would extend the array to the full extent of the available space provided by the structure, simplify the design of the collector support and eliminate the walkways.



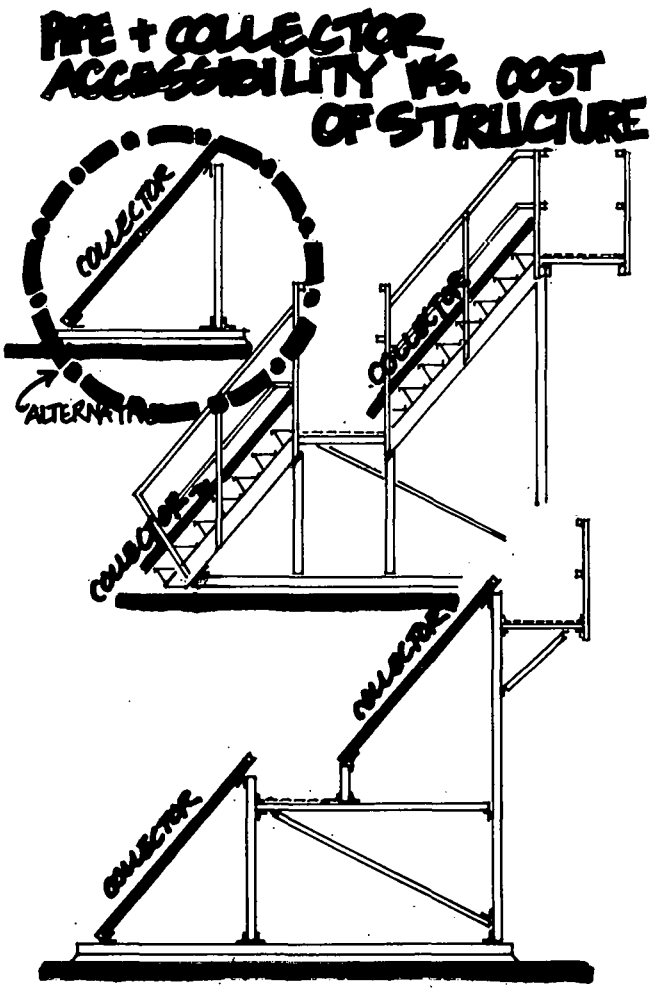
One can see by changing the level of the structure only slightly it would be possible to simplify the installation.



Another approach would be to double up the last two rows of collectors and keep the structure level.

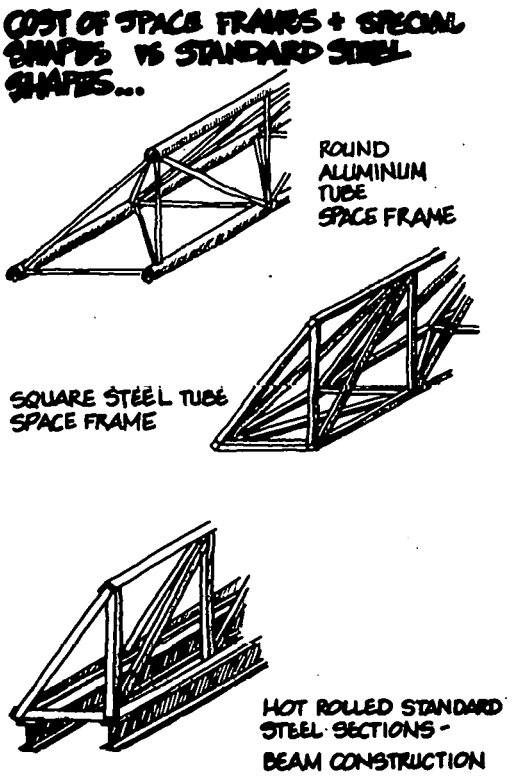
In either case, by keeping the whole construction near the roof, accessibility could have been from the roof with a ladder rather than from walking surfaces.

This next design I like to call the "O.S.H.A. Special." Notice that ladders have been provided as well as walkways and handrails. Again, extremely expensive. In this particular project, which was done with Unistrut the structure is much too flexible, and the particular collector used in this project will leak if there is any movement in the structure.

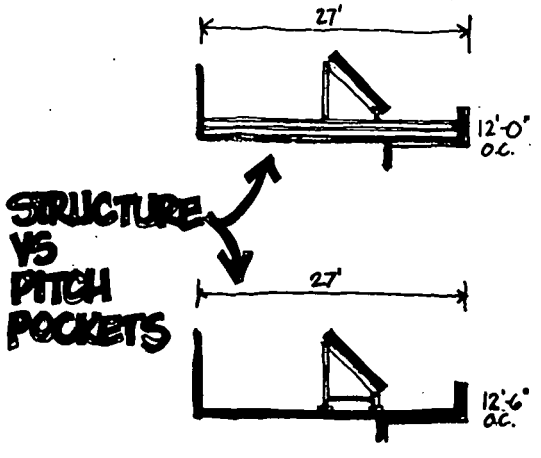


A much less expensive, faster and easier alternative would have been to place two single rows of collectors (as noted in the circle) on the roof assumming there is sufficient space available. The simpler structure would be sufficiently rigid, of course, and access would be from the roof.

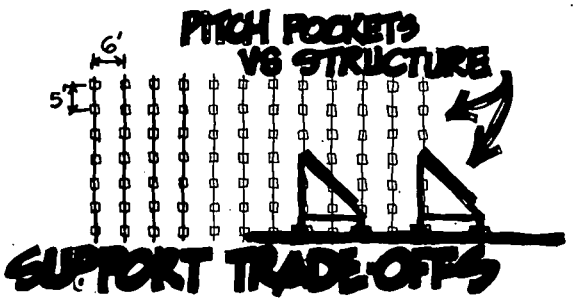
COST OF SPACE FRAMES AND SPECIAL SHAPES VS. STANDARD STEEL SHAPES -- Another cost trade-off involves the design of the collector support. For some reason, it seems that whenever we come to the requirement for triangular support, and fairly long spans, the first thing that comes to the designer's mind very often is special shapes and space frame. In one case, it's an aluminum tube space frame; in another case it's a square tube space frome out of steel. Both of them will be handsome structures if one can afford to build them. However, a much more efficient, less expensive and therefore economically a more viable approach is the use of simple rolled steel angle sections using steel beams for the major span.



SUPPORT TRADE-OFFS -- Ultimately the collector supports must be tied down to the roof structure. In some cases, the designers have decided to try not to penetrate the roofing. In this illustration, you see an attempt to span between a wall and a parapet so as not to penetrate the roofing. After a review, it was found that $40,000 could be saved by just putting in two pitch pockets 12'6" on center rather than this 27 WF steel beam 12' on center.

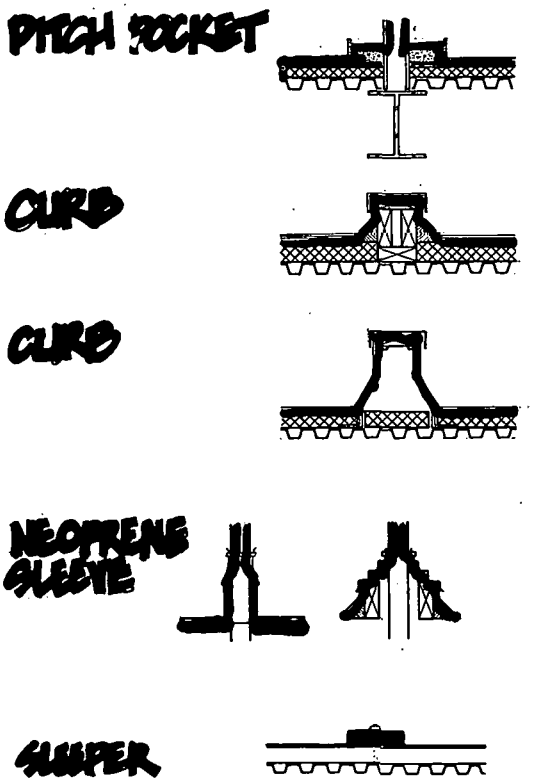


In this illustration, the structure could not take any point loads. As a result, the designers tried to distribute the load over the whole structure and came up with 700 pitch pockets. If you believe that won't leak, you have more faith than I do.



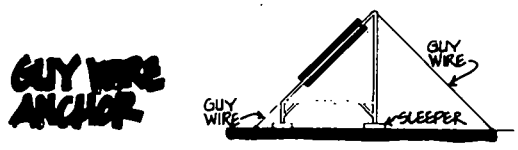
Now, once you've decided on your basic structural approach, the next question is how you're going to actually anchor it down.

There are regular pitch pockets, there are curbs constructed in the field, there are manufactured curbs or, if your vertical support is a regular shape such as square or round, you can use a neopreened sleeve. There's also a simple sleeper than can just be bolted down.



In some designs there has been an attempt to minimize or eliminate roofing penetrations.

For instance, in this case, the designer had a light frame structure and used sleepers not attached to the roof structure and used guy wires to anchor everything in place.



Again, the structural members span between available vertical supports. In this case, it was not economical but sometimes it is. If you use this approach be sure to allow for temperature expansion.



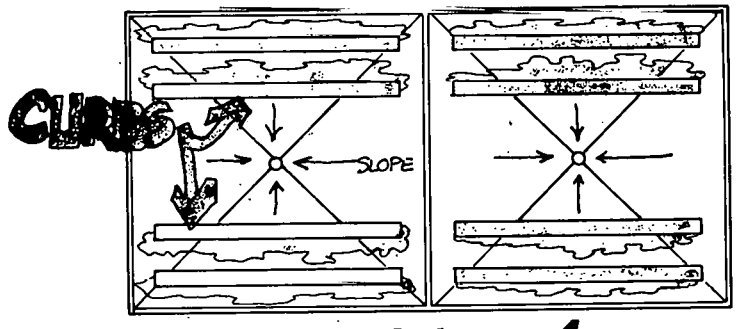
Another interesting approach used heavy dead-load concrete blocks tied together with structural members to take the horizontal forces of the wind. If your roof can take it, that's an interesting way to go, but you'll pay an awful penalty in the extra structure required to handle the dead load.



MORE ANCHORAGE DETAILS

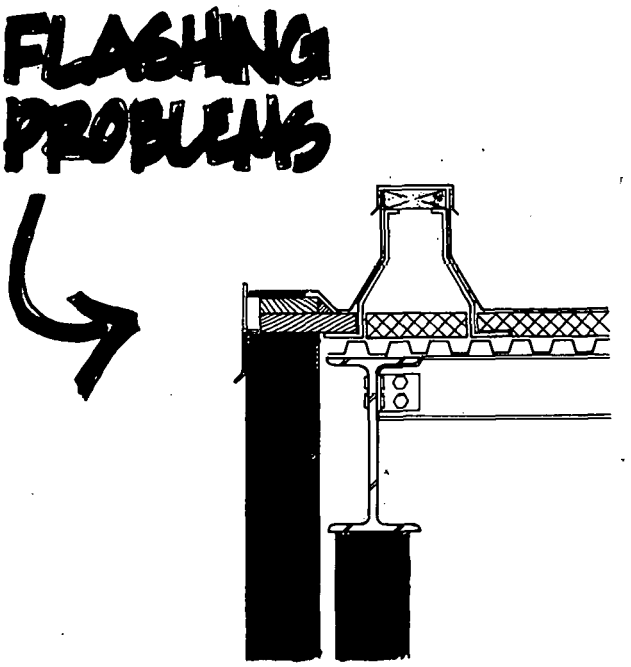
FLASHING AND DRAINAGE PROBLEMS -- Remember that flat roofs are not flat; they pitch for drainage. If you decide to use sleepers or continuous curbs, there's a good chance that you will be cutting off the natural drainage for the roof. Be sure that your roof can take puddling. Some roofing materials can and some will deteriorate under puddled water conditions.

If you are doing a retrofit, check the existing material, and in a new installation be sure that the correct roofing material is specified.

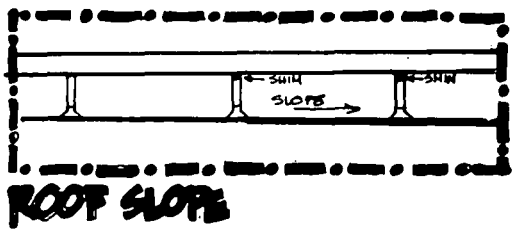


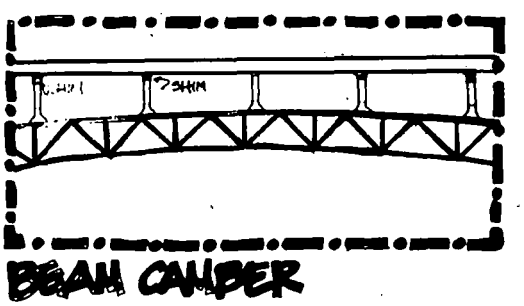
DRAINAGE PROBLEMS

In order to utilize as much of the roof surface as possible with the result that there is a great tendency to put supports close to the roof edge on a roof structure and to have interference between the two sets of flashing. This need not be a problem as long as you make allowances in your detailing.



SHIM REQUIREMENTS -- I have already noted that flat roofs are not flat; they either pitch to drains, or in long spans there is the camber of the beams to take into account. Therefore, the design must allow for shimming of the structure. Don't leave it to the contractor. Detail and/or specify the location and type or you may get what you deserve.

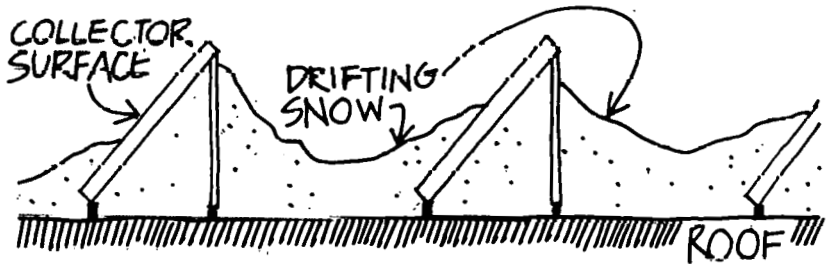


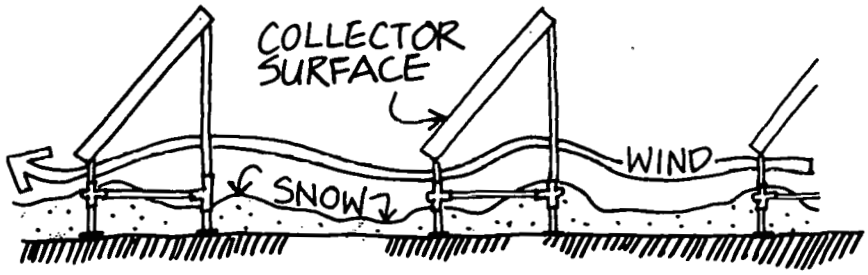


SHIM DETAILS

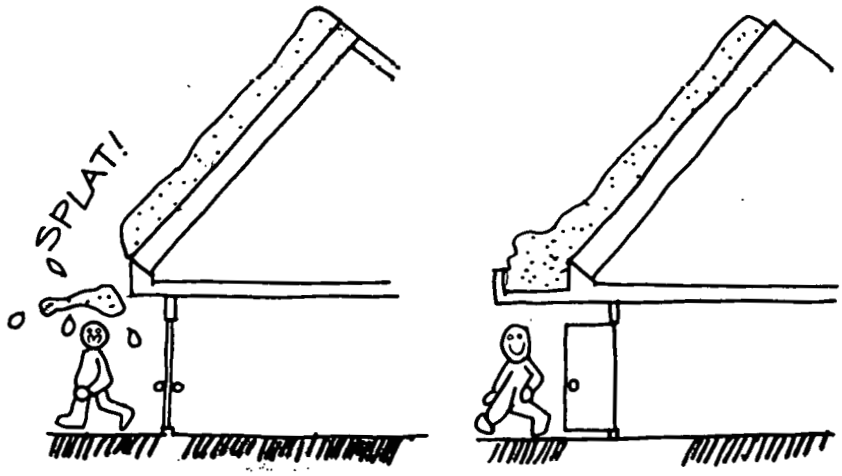
SNOW LOADS, ROOF MAINTENANCE, DRAIN DOWN -- These items may seem unrelated however, they should all be considered prior to establishing your final collector support design.

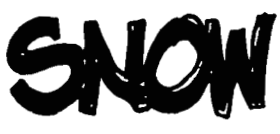
SNOW LOADS-If collectors are installed close to the roof, they will act as a snow fence and will actually precipitate additional snow. Besides the extra load that you're going to get, buried collectors obviously are not going to work too well for the first week or two. If you lift them above the roof and let the wind do your shoveling you can solve a lot of maintenance problems, lower your snow load and improve the efficiency of your collector.



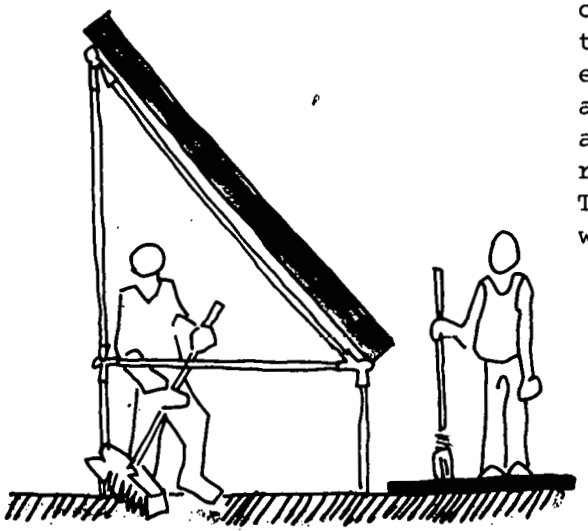


And, by the way, if your collectors happen to let out over an entry or a walkway, please protect the predestrians. I think the pedestrian and your client will appreciate it and so will OSHA.

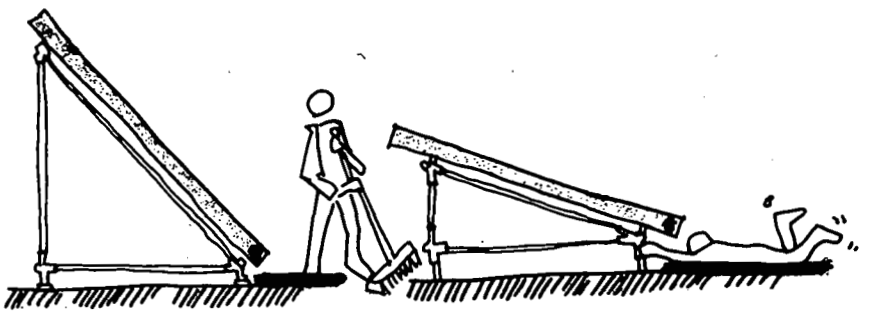




ROOF MAINTENANCE -- As far as roof maintenance goes, the higher you keep the collectors, including the structure and pipes, the easier it will be to either maintain, repair or even replace the roof in the future. And, if you provide a walking surface accessway to those places that require service for maintenance persons with or without ladders, you will find that it will be very worthwhile and save much wear and tear on the roof. Again, it's preferable not to have your collector way down as it is very hard to repair the roof under the collectors, especially down South, where collectors are often put in at a very shallow angle in order to get the best solar results to accommodate cooling loads. The condition illustrated on the right would be a real "bear" to work under.

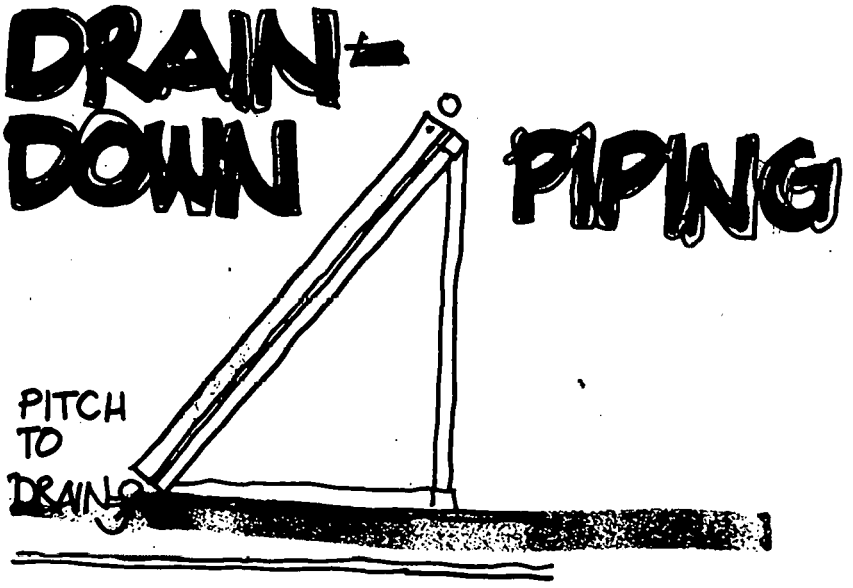


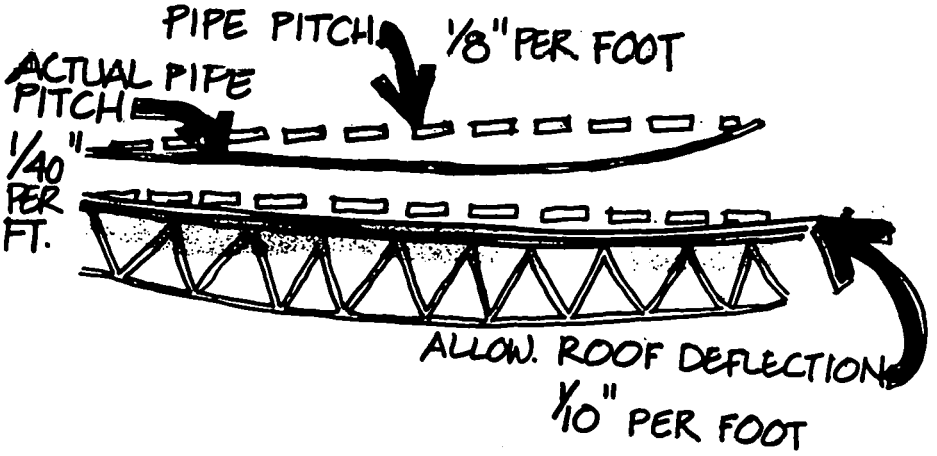
ROOFING PROTECTION



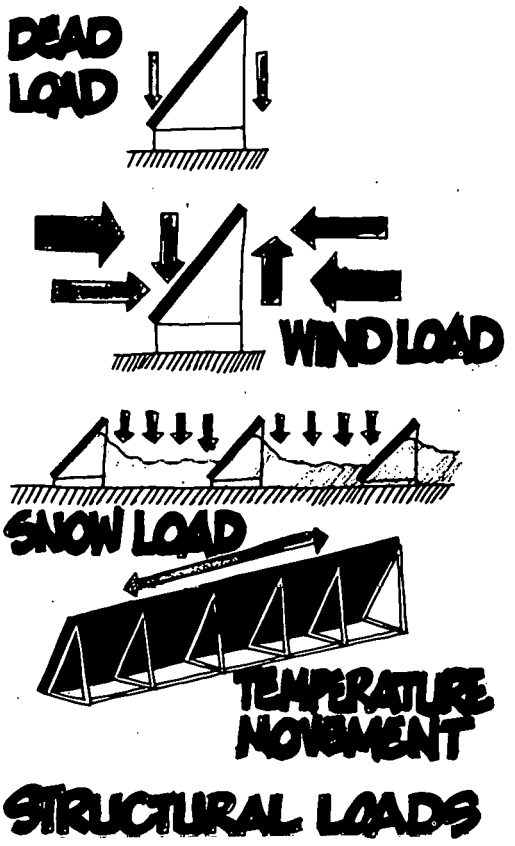
ROOF MAINTENANCE

DRAIN DOWN -- When designing a draindown system, it is very common to draw your collector support and note on the drawings or in the specifications to pitch the pipes to drain. In this particular case, as illustrated, the designer drew the collector and did not even leave room to install a pipe nonetheless, pitch it to drain. If you want the collectors and piping to pitch to the drain, be sure you detail it so that they can. Either pitch the steel or lift up the collectors so that the pipes can pitch. And while you're at it, most people would like not to have pitching pipes all over the place. It does create a vertical problem in installing collectors. Therefore, many designers are tempted to design the piping with 1/8" pitch per foot. If you consider that the allowable roof deflection on a normal beam is 1/10" per foot, what you end up with, at certain parts of that span, will be a pipe pitching at 1/40 of an inch. Normally, we call this a frozen pipe.

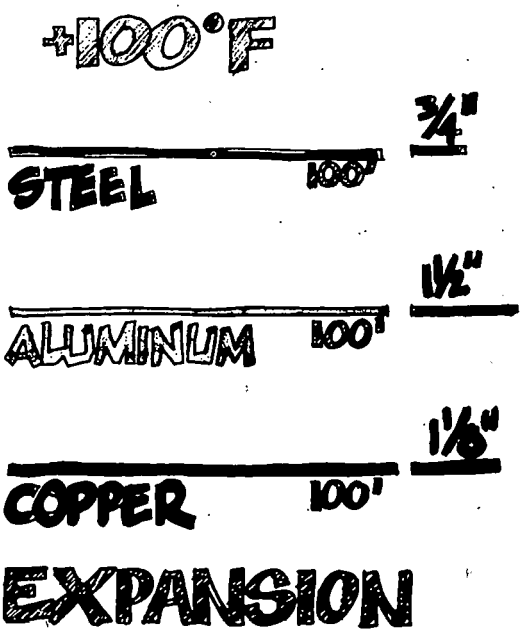




STRUCTURAL LOADS -- The loads that are imposed by solar installations are pretty well known. There is the dead load, the wind load with its horizontal and vertical components, and the snow load that can be greater or less depending upon your design. But, due to the extent of exterior construction, we have a new one, temperature movement: Expansion and contraction due to temperature differential.

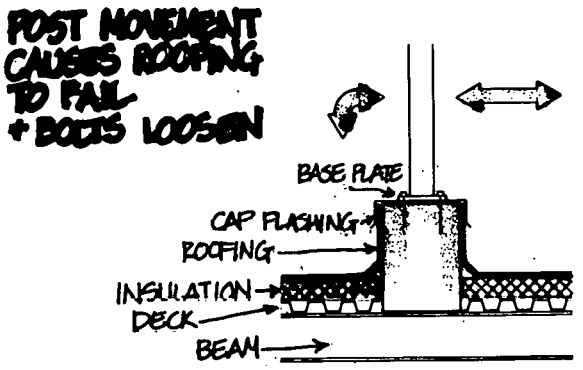


If you consider that a structure could well see a differential temperature of 160° between being in the summer sun and a cold winter night, and your piping could see well over 200°, there is a considerable problem that must be answered as far as expansion and contraction goes.

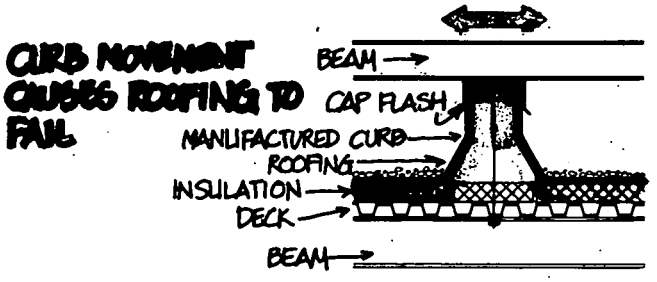


We have found few problems involving the actual structural support of the collector loads, however, the architectural implications of these loads sometimes go unnoticed.

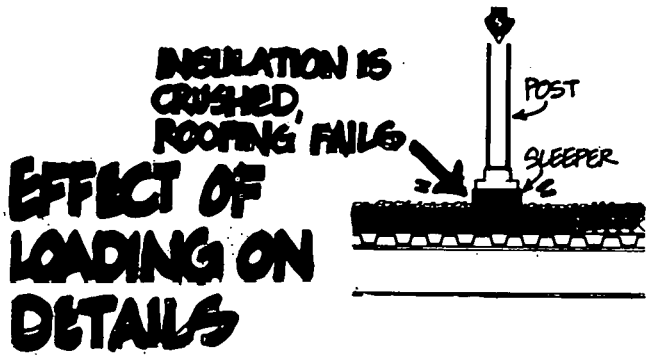
For instance, if you fasten a post and base plate to a wood curb, you will have some problems if you only have metal fasteners holding the metal base plate going through metal flashings. Metal to metal to metal will undoubtedly allow water to enter through the holes caused by the fasteners. However, when you add to that the back and forth movement due to wind forces and temperature differentials, you can see that you can actually cause these fasteners to pull out slightly, and if your wood is not treated it can deteriorate causing further problems. Also, as the post rocks, the base plate will tend to cause metal fatigue to the cap flashing at the edges of the cap flashing.



In this next case, the design called for a prefabricated curb bolted to the structure with a beam over it. When the beam moves back and forth, either by wind load or expansion and contraction, or both, there will tend to be movement of the curb where it joins the roofing that could very well cause a roofing failure. An easy way to avoid this problem is to be sure you specify the edges of the curb be secured to the roof structure. Also, when detailing wood curbs to be constructed in the field be sure that you provide sufficient lateral strength.



A very common problem we have encountered is the use of sleepers on a retrofit where the designers do not want to disturb the existing roofing so they just install the sleeper on top of the roofing and bolt it down. If you put a load onto a sleeper, over normal insulation, the normal insulation will not be able to take the compressive loads that can be applied through this approach. What will happen is that the sleeper compresses the insulation and actually shears the waterproofing membrane along the edge of the sleeper, causing leaks.



"So we see there is more than one way to cause a leak, and if there is one thing we would prefer not to have, it is that solar buildings become synonymous with leaky buildings.

KNOW YOUR COLLECTOR

Prior to making the final selection of your collector be sure that you understand all the attributes of your collector and not just the mundane ones such as collector efficiency and stagnation temperatures. The truly important concerns relate to attachment requirements and rigidity requirements.

1. ITS SPECIAL REQUIREMENTS

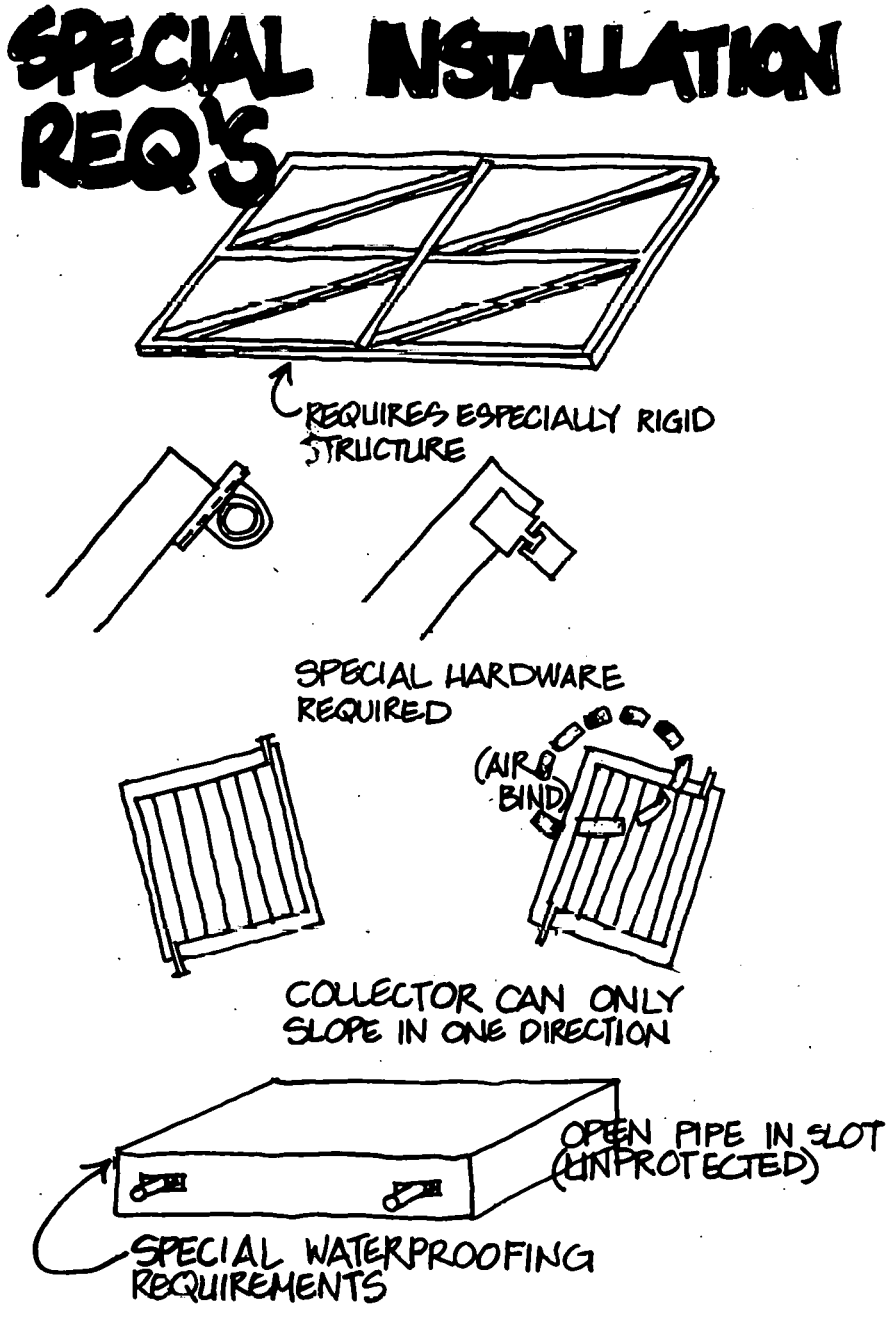
2. ITS SPECIAL CAPABILITIES

What are the special installation requirements of your collector. There's one I mentioned earlier that, if there is any movement in the structure, which must be especially rigid, the collector will leak.

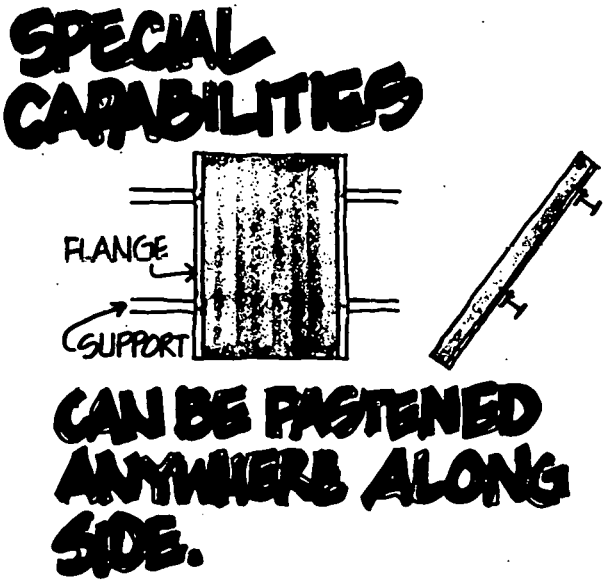
Other collectors require special hardware mounting.

Some collectors can only be tilted in one direction, or they will air bind.

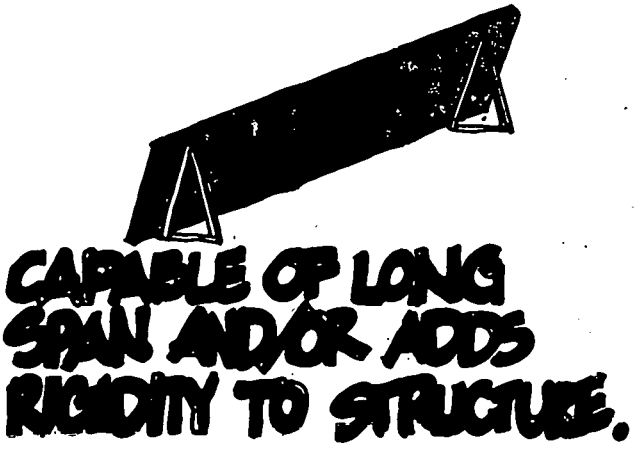
Others have waterproofing problems, especially where the pipes extend out of the collector box.



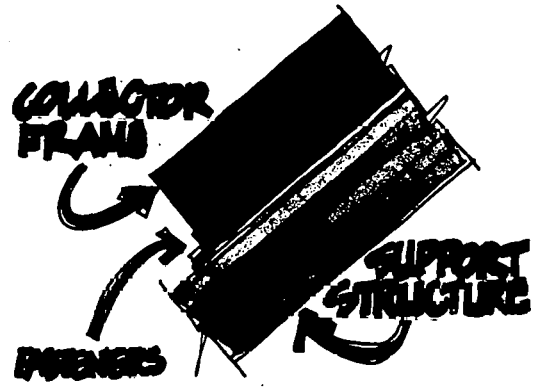
Now, sometimes collectors have special capabilities. Among these special capabilities is the ability to be fastened in very particular ways -- at the corner or some other fashion. If the collector is capable of spanning and being fastened at different places, it simplified the structure.



Other collectors are quite long and require very little support as they are sufficiently rigid to take lateral movement. Therefore, put as little structure behind them as possible and use the strength of the collector.



For a successful project, provide for the collectors' requirements and use its capabilities. Whatever your collector problems may be, realize what your collector frame material is, what your support structure material is and what your fastener material is. Also if there are any differential metals involved, there should be non-metallic materials separating them to prevent galvanic action.



NON-OPTIMUM COLLECTOR TILT OR ORIENTATION OF 10° ± WILL AFFECT THE TOTAL SYSTEM PERFORMANCE BY LESS THAN 10%.

DIFFERENTIAL METALS

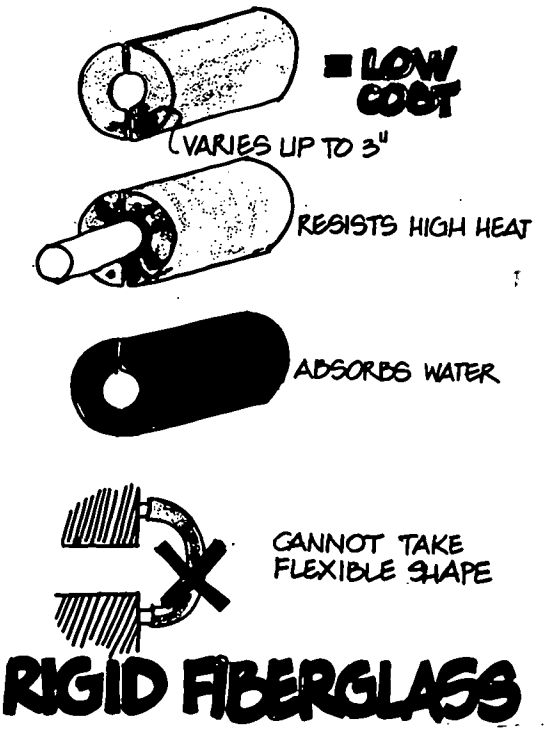
HOWEVER

When you consider that most cooling equipment requires liquids in the area of 180-200°, and that most collectors are very hard put to supply that type of energy, you realize that any loss due to piping or storage can make the whole system non-operative.

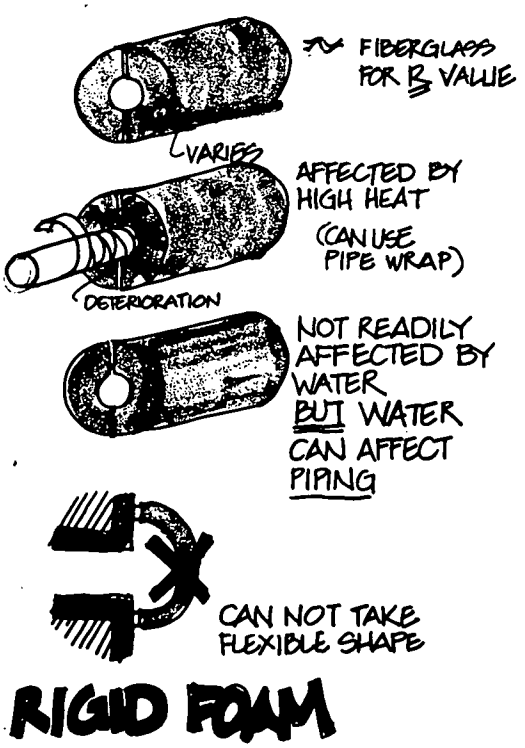
A POOR PIPING INSTALLATION CAN AFFECT THE TOTAL SYSTEM PERFORMANCE BY MORE THAN 50%.

INSULATIONS -- Most of the insulations that we deal with were not developed for the solar field. They are being used and adapted to solar but are not really usable in all cases. Let's look at some of the problems.

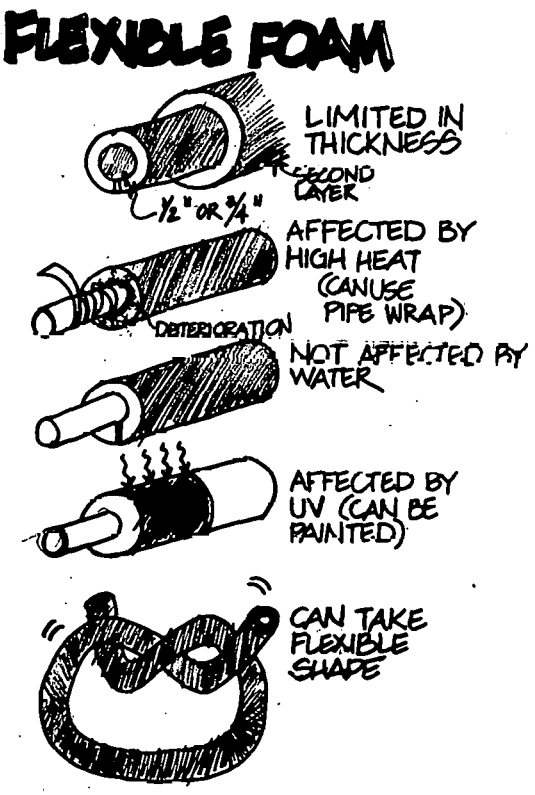
Rigid fiber glass is a very common material. It is relatively low-cost, you can get it in sizes that vary up to 3", it resists high heat; but it absorbs water like a sponge and, if there is any water that gets into it, it will be a better radiator than it will be an insulator. Also, it cannot take the flexible shape very often encountered in solar installations.



Rigid foam is about comparable in cost for the same R value. As glass, it too varies up to about 3". However, it deteriorates very badly if exposed to high heat associated with stagnation. If that is a problem, you might consider some sort of pipe wrap as an inner protection. It is not readily affected by water, but it is not waterproof -- you cannot use it as waterproofing. As a matter of fact, water coming in contact with some rigid foams and pipe will cause a mild acid that will deteriorate the pipe. So, it must be well waterproofed. Also, rigid foam cannot take the flexible shapes that we encounter with solar.

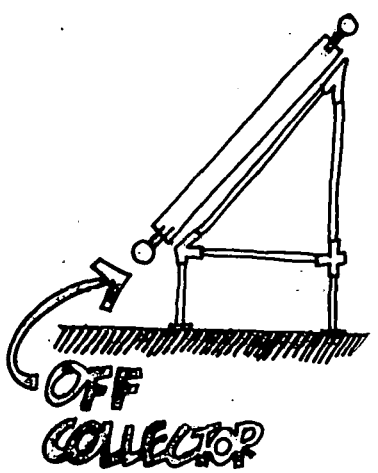


Flexible foam is very restricted in the available thicknesses: only ½" or 3/4". If you want to better R value, you must put on a second layer with double the cost. It is affected by high heat. Possibly, the use of pipe wrap would aid in that area. It is not affected by water, it is waterproof and can be used as its own waterproofing. However, it is affected by the sun's ultra-violet rays but it can be painted to protect against ultra-violet deterioration. If you do not paint it, we've seen very bad deterioration in 6 months, and I expect failure within a year. Flexible foam is capable of taking any shape you can come up with.

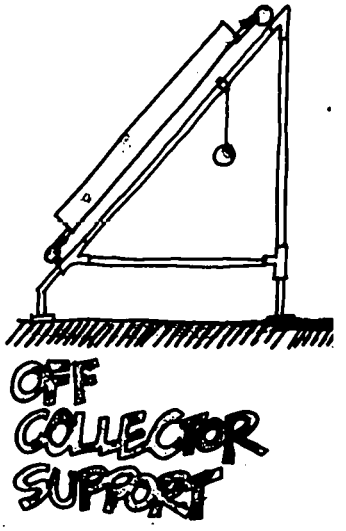


PIPE SUPPORTS -- It is very important to decide how to support your pipes within a solar collector array.

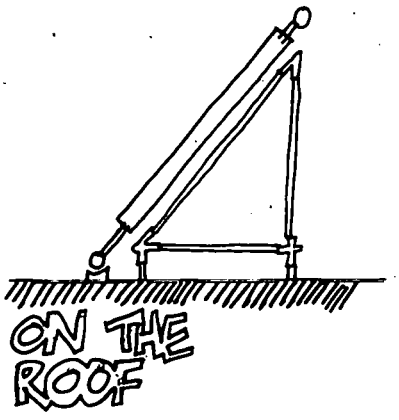
Pipes can be supported off the collector. This is normally done by the use of soldered copper nipples. Be very careful that the mechanic does not burn out the waterproof seals of the collector. We find this a constant problem as the solder required is a particularly high temperature.



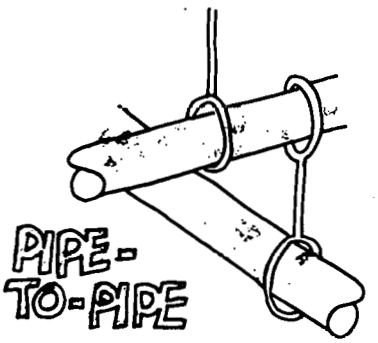
You can support pipes off the collector support. If you do, be sure you have designed space on the collector support to support the piping. You might consider supporting the pipes off the back of the support as an alternate.



Sometimes, the pipes are just supported on the roof surface. But try and design it in such a way that the workmen do not use them as a platform.

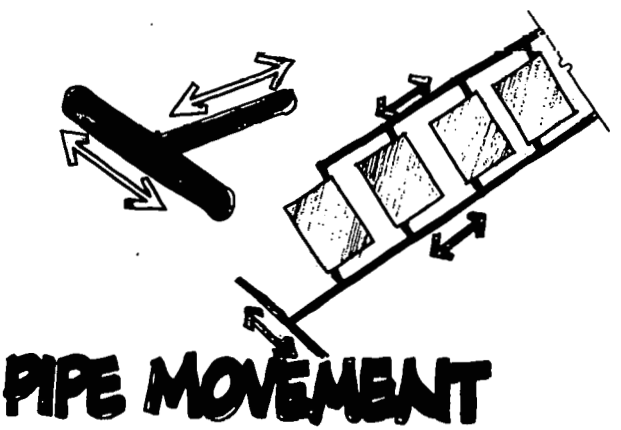


A fairly common way of support pipes is off other pipes, especially in reverse-return designs. In this case, be sure that the pipes are well supported, one from the other, and that they are both free to move.

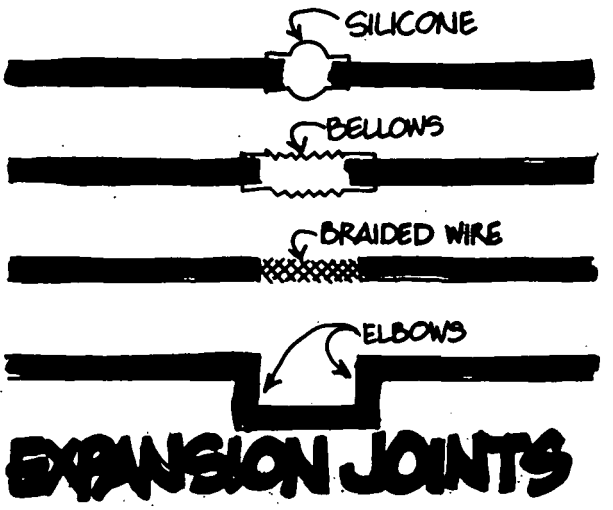


Another common pipe detailing problem we have found is that pipes are shown as lines on paper and when they cross nobody worries about it. Remember that pipes have thicknesses, usually 3" or more, and you must account for this thickness in your design. Also, if you need valves or expansion compensators, be sure that you've designed enough space between collectors to allow for the installation of this equipment.

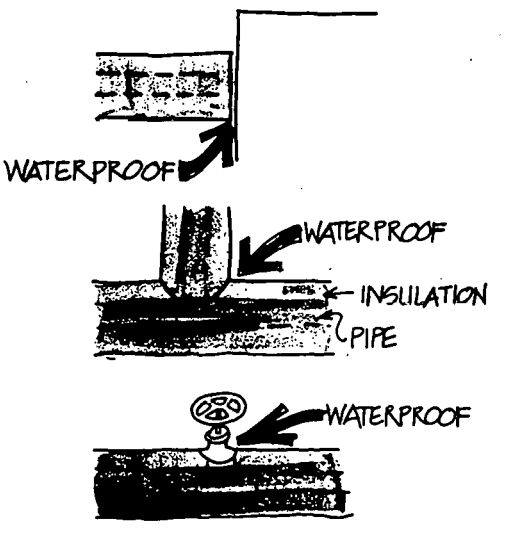
PIPE MOVEMENT -- We've shown that there could be as much as 2-2½" of movement in the pipe. And, you can bet that they're always in opposite directions or at right angles. So, always allow for this pipe movement at change of direction or in extremely long lengths.



Some of the ways you can compensate for these movements are with silicone bulbs, bellows, braided wire or with elbow configurations to the piping. Whatever it is, design it and show it.



WATERPROOFING -- Common waterproofing areas occur between collectors and piping at joints between pipes, change of direction in pipes or pipe T's or where valves or monitoring equipment protrude through the waterproofing. Be sure that whatever your design is, it answers these problems. Especially with fiber glass where any water getting into this will really lower the efficiency of the whole system.



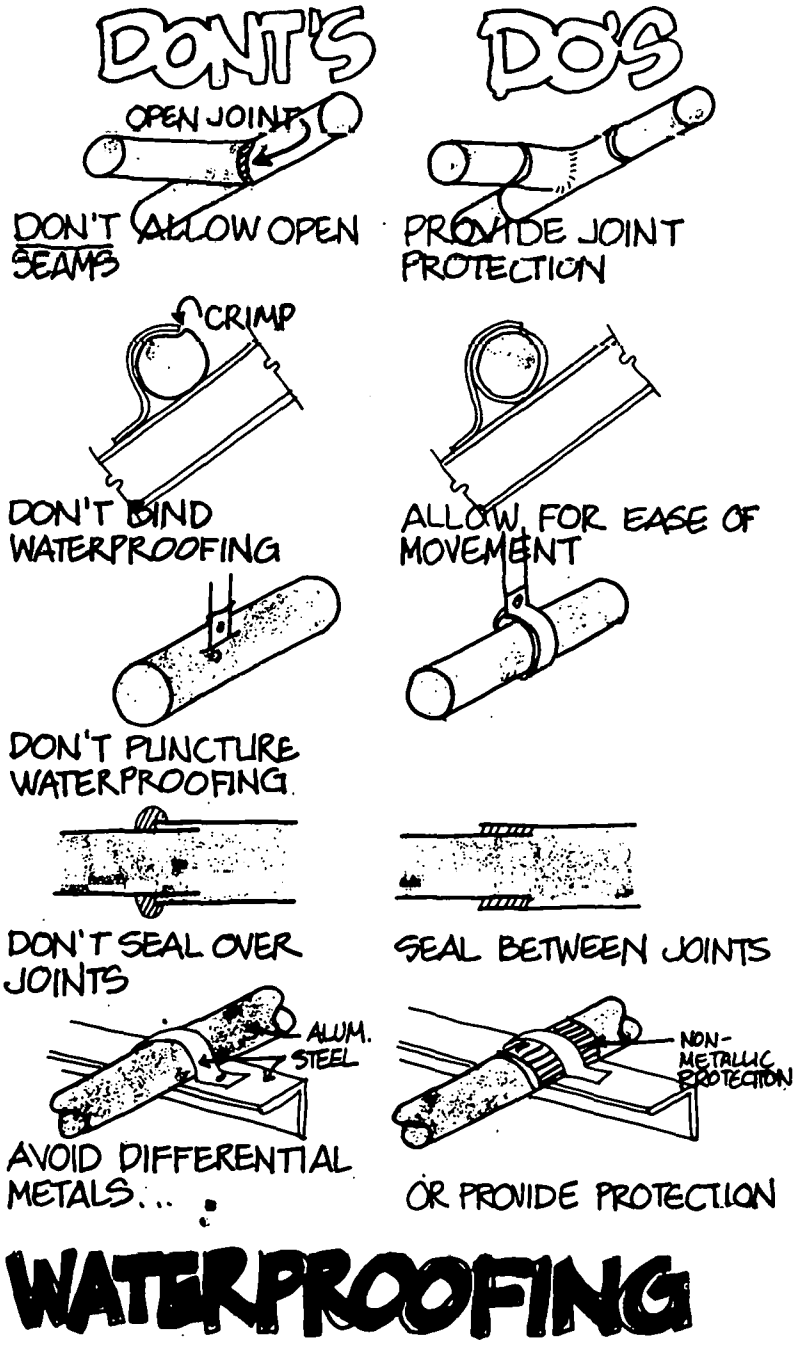
Don't allow open seams. Provide joint protection at all elbows and tees.

Don't bind your pipes when supporting them. Be sure that the pipes are free to move or, with pipe movement, you will either tear your waterproofing or your insulation.

Don't support piping by puncturing your waterproofing; especially in terms of supporting the pipe directly. Not only do you puncture the waterproofing and reek havoc with the insulation, but you also allow for a heat bridge to radiate additional energy. Support the pipe loosely on the outside of the waterproofing.

Don't seal over the ends of sheet waterproofings. Seal between the seams or the sealant will fail with movement. End seals will fail, seam seals will tend not to.

Lastly, avoid differential metals, if you are using aluminum waterproofing. And, if you have steel structure or steel clamps, be sure that you have non-metallic protection to prevent galvanic action. We saw one very lovely installation where they had very nice aluminum waterproofing and a sheet of galvanized steel under it and there was no protection for it. That waterproofing will fail.



CONCLUSION:
COST CONSIDERATIONS

FOR SOLAR PROJECTS TO BE COST-EFFECTIVE THE ARCHITECT/ ENGINEER MUST ISOLATE THE DIFFERENT COST TRADE-OFFS AND CHOOSE THE MOST EFFECTIVE APPROACH.

CONCLUSION CONT.
CONSTRUCTION CONSIDERATIONS

- THE A/E MUST ISOLATE ALL CONSTRUCTIONS PROBLEMS.
- THE A/E MUST ALSO SOLVE EACH PROBLEM.
- DETAILS AND SPECIFICATIONS MUST ADDRESS EACH PROBLEM.
- THE A/E MUST FOLLOW UP WITH SUFFICIENT FIELD VISITS.
- DON'T LEAVE PROBLEMS FOR THE CONTRACTORS TO SOLVE.

So we see there is a lot more to designing an effective solar assisted mechanical system than just choosing your collector area and mechanical approach. But rather, a successful project demands a high level of attention to all details.

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WORKSHOP OVERVIEW AND ANALYSIS

Workshops on the Commercial Demonstration Program and the National Data Program were held in four regional locations in July, 1978. They provided a dialogue between government and the public and make major contributions to the overall program. The workshops were held during the morning of the second day at each of the locations. In the afternoon, a summary of both workshop results was then presented to attendees. The following summaries provide a general overview of the workshops and their conclusions.

WORKSHOP 1 - COMMERCIAL DEMONSTRATION PROGRAM

A common theme of the four Commercial Demonstration Workshops was the general lack of awareness among involved individulas and organizations concerning details of the Commercial Demonstration and Data Programs. For example, knowledge concerning the background and status of the Program Opportunity (PON) was limited. For this reason, a briefing was held at the beginning of the workshops informing participants of the purpose and status of the Commercial Demonstration Programs. This information was structured into a discussion entitled, "General Discussions in Reply to Program Opportunity Notice (PON) Questions." A standard overview chart was also used at each of the workshops to help stimulate discussion.

In general, the interest and concerns expressed at the four workshops were similar with the following exceptions:

Atlanta - The interest was related to the aspects of utility involvement with solar energy programs; the role of architects, engineers and solar equipment manufacturers; and the potential impact of the solar energy program on lower income families. There was considerable interest in the application of solar cooling systems. The participants expressed concern over the need for more architectural and engineering firms to become involved in the commercialization of solar energy technology.

San Francisco - Attendees were interested in the expansion of passive solar energy programs and simpler technology, including retrofits for low income groups. They also emphasized the need for improved educational and communication techniques, including public relations programs. The group also felt that PON cycles should allow more response time, involve more "decision makers" (bankers, realtors, etc.), and clarify standards, warranties and consumer protection.

Chicago - The participants appeared interested in various technological considerations. They were especially concerned with comparisons of collector and storage subsystem types, tilt angles, collector locations, working fluids and control functions. They expressed interest in passive design applications and small business opportunities. Other areas of discussion including status of the overall research and development program, agricultural applications, use of photovoltaics on buildings, and the potential for hybrid and combined systems, including solar and wind energy.

Boston - Attendees were concerned about the interface between solar energy systems and the utilities and the relationships between energy saving through conservation techniques and the application of solar energy. They also expressed

interest in the application of the "handy man" approach for saving energy in a region where utility rates are very high. As in Chicago, participants showed interest in photovoltaics. They also discussed the question of net energy gains of solar and other energy conversion sytems. Their discussions also included the cost effectiveness of solar energy systems and the overall Commercial Demonstration program, including ways of becoming involved, PON evaluation techniques, public visibility of the demonstration sites, and training requirements.

WORKSHOP 2 - NATIONAL SOLAR DATA PROGRAM

The content of the workshops on the National Solar Data Program and the concerns of the participants were similar in the four locations. The sessions were structured so that approximately equal times were allotted to the following six areas: National Solar Data Program, control system evaluation, analysis of collector arrays, architectural and engineering factors, solar energy system costs, and reliability, maintainability and materials.

National Solar Data Program - The attendees expressed interest in site selection criteria and the sites that are currently being evaluated. They also queried the availability and form of the climatological and system performance data. Typical questions were: Can raw data be obtained? Will each system be analyzed in reports? Will the various systems be compared and rated?

Control System Evaluations - The participants were concerned about obtaining more information on controls, problems and solutions. They also showed interest in the types of control problems currently being investigated.

Analysis of Collector Arrays - Attendees expressed concern about collector arrays.

Architectural and Engineering Factors - Workshop participants generally felt that examples of good aesthetic design and basic design guidelines should be provided by DOE. They also discussed interface between professionals working on solar projects.

Reliability, Maintainability & Materials - The participants expressed interest in the range of problem types being monitored by Argonne National Laboratory. The availability of reports on the problems and their solutions seemed to be a common concern.

Solar Energy System Costs - Workshop participants generally felt that information to be used in estimating costs of the installation of solar energy systems would be very helpful. They also showed interest in getting cost-trend data and summaries of overall system costs for systems in the data program.

COMMERCIAL DEMONSTRATION PROGRAM PANELS
(Workshop 1)

Atlanta - July 14, 1978

Gene Doering - DOE - Chairman
Carl Conner - DOE
Myron Myers - NASA
Larry Watson - NASA
John Crane - PRC
Richard Rademaker - Rademaker Corporation
Harvey C. Jones - Reedy Creek Utilities
Michael Sizemore - Energy Planners, Architects, Engineers
George Hightower - Conditioned Air Engineers
William Hudson - Independent Living, Inc.
Gene Clark - Trinity University
David L. Christensen - The University of Alabama in Huntsville

San Francisco - July 18, 1978

Gene Doering - DOE - Chairman
Carl Conner - DOE
Richard Davis - DOE
John Crane - PRC
Myron Myers - NASA
Stephen Weinstein - Ehrenkrantz Group
Marvin Rubin - La Quinta Motor Inns
John Yellott - Arizona State University
Delano Erickson - BWBR Architects
Richard Supple - Bridgers and Paxton
Harry Whitehouse - Pacific Sun
David L. Christensen - The University of Alabama in Huntsville

Chicago - July 21, 1978

Gene Doering - DOE - Chairman
Carl Conner - DOE
Ted Kurkowski - DOE
Myron Myers - NASA
John Crane - PRC
Duane Rost - Solar Energy Engineering
Stephen Weinstein - Ehrenkrantz Group
Emil Martinec - Argonne National Laboratory
Harry Gordon - Burt Hill Kosar Rittelmann Associates
Bill Fagan - City of Chicago
Donald Anderson - Mid-American Solar Energy Complex
David L. Christensen - The University of Alabama in Huntsville

Boston - July 25, 1978

Gene Doering - DOE - Chairman
Carl Conner - DOE
Ted Kurkowski - DOE
Myron Myers - NASA
Stephen Weinstein - Ehrenkrantz Group
Gordon Tully - Massdesign Architects & Planners
Daniel Brown - Cary Arboretum
John C. Christopher - Contemporary Systems
John Zvara - Aerospace Systems
Vince Gisone - Balco, Inc.
David L. Christensen - The University of Alabama in Huntsville

NATIONAL SOLAR DATA PROGRAM PANELS
(Workshop 2)

Atlanta - July 14, 1978

H. Jackson Hale - DOE - Chairman
Larry Murphy - IBM
Kenneth L. Shenfish - IBM
Richard V. Walker - IBM
John C. Bartlett - IBM
Prem Chopra - Argonne National Laboratory
William H. McCumber - IBM
Stephen Weinstein - The Ehrenkrantz Group
Robert Hedden - Mueller Associates

San Francisco - July 18, 1978

H. Jackson Hale - DOE - Chairman
Ron Kirkpatrick - PRC
Larry Murphy - IBM
Henry L. Armstrong - IBM
Richard V. Walker - IBM
John C. Bartlett - IBM
Prem Chopra - Argonne National Laboratory
William H. McCumber - IBM
Stephen Weinstein - The Ehrenkrantz Group
Robert Hedden - Mueller Associates

Chicago - July 21, 1978

H. Jackson Hale - DOE - Chairman
Larry Murphy - IBM
Henry L. Armstrong - IBM
Richard V. Walker - IBM
John C. Bartlett - IBM
Prem Chopra Argonne National Laboratory
William H. McCumber - IBM
Stephen Weinstein - The Ehrenkrantz Group
Robert Hedden - Mueller Associates

Boston - July 25, 1978

H. Jackson Hale - DOE - Chairman
Tom Morris - IBM
Kenneth L. Shenfish - IBM
Richard V. Walker - IBM
John C. Bartlett - IBM
William H. McCumber - IBM
Prem Chopra - Argonne National Laboratory
Stephen Weinstein - The Ehrenkrantz Group
Andrew J. Parker - Mueller Associates

GENERAL DISCUSSIONS IN REPLY TO PROGRAM OPPORTUNITY NOTICE (PON) QUESTIONS

The Solar Heating and Cooling Demonstration Act of 1974 created a five-year program during which solar heating is to be demonstrated within the first three years and solar heating and cooling within five years. The Department of Energy (DOE) is responsible for the entire program, with the Department of Housing and Urban Development (HUD) and other agencies providing key support.

The DOE has responsibility for the commercial demonstrations. It has issued three competitive solicitations called Program Opportunity Notices (PON). Individuals responding to these solicitations are asked to submit projects for evaluation and selection for demonstration. HUD also has issued four similar requests called Request for Grant Authority (RFGA).

Cost-sharing is a part of the commercial program. PON requires higher cost-sharing. Owners propose an economic evaluation of the system's cost and base their share accordingly.

The average cost share by the proposer in PON 1 was about 22 percent; PON 2, about 34 percent; the Hot Water Initiative, about 50 percent; and PON 3, about 41 percent. The larger share in the Hot Water Initiative occurred because solar hot water was believed to be economically competitive with other energy forms, particularly electricity.

PON evaluation criteria are frequently ignored by the proposer despite being published in the PON. The most frequent mistake made by those not obtaining a project is in not providing the required information. System descriptions often are not clear. Apparently applicants read into the PON evaluation criteria things that are not there. They apparently make mistaken interpretations and leave key information out that is needed for the evaluation. Among the important selection criteria are a technically sound project, a reasonable cost, qualified personnel, and project visibility.

Generally, solar demonstration projects should consider energy conservation. Then they should consider other possible solar contributions such as passive methods which can also reduce fossil fuel consumption.

The Demonstration Program should also use the lessons learned in previous cycles and more widespread applications should now be made for cooling applications in future cycles.

Some conservation demonstration programs have been suggested. DOE feels that this is unnecessary since conservation techniques are already established and that to spend government funds on them would be a waste of money.

Every PON proposer is asked to provide what he can do to make his project available to the public for viewing, the educational tours, etc. This does take some of the owner's time. Owners generally do not mind unless the work load from frequent visitors becomes a harassment.

There is a limit as to what you can ask the owner to do, in terms of his own effort, when he is not getting paid for it. However, he is getting something from the government that is going to be his and contribute to his net welfare. Therefore, it is not unreasonable to expect cooperation in providing public visibility.

There was some discussion on proposal assistance for small businesses. Large firms, in many cases, have one or two people in Washington whose sole function is to keep contact with the Federal government and find out what is going on, what's coming up in the future and then feed this back to their parent organization, so they can get ready for new solicitations or programs. Small businesses don't have the funds to do this.

Regional workshops on forthcoming solicitations may be one mechanism to help the smaller firms get better information and find out what opportunities are forthcoming.

Once a solicitation is published, it is in the competitive phase; and the DOE program managers are reluctant to discuss that particular solicitation or to answer questions because of potential violations of regulations. Questions arising should be addressed to the appropriate contracting officer. His clarification will be made available to all recipients of the solicitation. Before a solicitation is issued questions can be addressed to any knowledgeable personnel. But once the PON is issued, it is competitive and the contracting officer is the source for clarification.

The time element in the PON program received comment. Specifically, the reason that it takes nearly a year from the start of the PON cycle to the award.

Once a solicitation is released, DOE prefers to have it out for 60 or 90 days, if possible. An additional six to eight weeks are needed to evaluate responses. Once the selections are made, then a reviewing official requires two to three weeks to approve the recommendations and make the announcement. Contract negotiations take a further 30 to 90 days. Thus, the process occupies between nine and eleven months.

Rejected PON proposals can be resubmitted on succeeding solicitations. Such proposals should be reviewed for specified deficiencies, which must be corrected. The resubmitted response must also be analyzed to insure that it is in compliance with the new PON.

PONs 2 and 3 have three or four passive projects. HUD has a passive design competition and demonstration ready and plans to make $7,000 design awards for the new building category, $2,000 design awards for retrofits. DOE is also considering a new PON for passive design techniques in commercial buildings. It probably will not be announced until next year.

Commercial passive cooling probably will not be as applicable as residential passive cooling because of the difference in heat loads. Commercial loads are largely cooling and passive cooling on such a scale is not easily accomplished.

In the solar heating and cooling of buildings, the R & D branch supports the solar thermal technology only. Last year, it issued five program research and development announcements and five requests for proposals; ten solicitations to work in ten different areas. There is direct link between the R & D program and the Demonstration Program. Coordination comes with the receipt of a proposal in response to a program opportunity notice or other solicitation.

If respondents feel that the technology being developed in the R & D branch is far enough advanced that they want to propose to do it, they are free to do so.

Bidders proposing projects that are largely experimental probably will be rejected in the Demonstration Program because of the primary need for reliability. However, if the concept can be proven reliable, it will be considered in the Demonstration Program.

Critical design reviews are conducted in the PON program. Once a design is completed or nearly so, an independent team reviews it from the technical, cost, structural, mechanical and electrical viewpoints. The purpose is not to change the design, nor to take the responsibility away from the designer. It is merely to provide an independent evaluation based on experience from other projects. Recommendations can be accepted or rejected. If the project team accepts them, they accept full responsibility for them. If they are rejected, the team should provide the rationale for the rejection.

Involvement in a PON can require a great deal of paperwork which is minimized or absent in the private sector. The DOE is making an effort to reduce the paperwork in the PON program; but when public funds are involved, a strict accounting requires considerable documentation.

An information sheet was included in the materials packets at each conference. Conference participants were asked to fill them out and return them to help DOE determine what the participants felt about the Solar Heating and Cooling Demonstration program. DOE always welcomes constructive criticism and needs it for program direction and feedback. The efforts of individuals interested in solar energy will make it a viable alternative energy source. Eventually, the government's role will phase out, as directed by law, when the industrial base and public acceptance has been effectively established.

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SUMMARIES OF COMMERCIAL DEMONSTRATION PROGRAMS

A great deal of information on solar energy was conveyed during the four Commercial Demonstration Workshops at the Solar Update conferences. In an effort to make this information more concise and more coherent, the following paragraphs were collected from the workshops and grouped according to common topics.

AIR VERSUS LIQUID SYSTEMS

Among the technical questions was one related to air versus liquid systems. Air systems do not freeze except when the system uses an air/liquid heat exchanger. A liquid that comes in contact with cold air through a heat exchanger can freeze.

Liquid leaks can cause damage, while air leaks normally do not. In either case, though, energy is lost, and air leaks are harder to detect than liquid leaks.

A comment was made that air systems are probably more cost effective than water systems. There is little cost data on air systems. This is because there are fewer air systems than liquid ones in the program, not because of a lack of interest. Fewer of these systems have been proposed on a competitive basis.

COLLECTOR LOCATION -- ROOF VERSUS GROUND

Much discussion centered on collector locations, including roof-mounted versus ground-mounted. If the real estate is readily available and accessible, collectors can be mounted on the ground. This can eliminate hazardous working conditions that might occur on a roof. Maintenance is improved since equipment is easily serviced and there are no roof penetrations. However, vandalism or accidental damage is greater with ground mounting. A roof mount is less likely to be shaded by some other structure.

FIXED-ANGLE VERSUS VARIABLE TILTING

Fixed angles versus variable tilt angles for collectors were discussed. Flat-plate collectors are generally fixed at some optimum angle. Change of the tilt angle periodically is not economic because the losses caused by the seasonal sun movement do not make much difference.

One needs to compare the rigid versus the flexible component costs and the possible energy loss due to the fixed mode. If too much energy is being lost and tilting will enable saving energy, it is an economic trade-off that should be considered. In general, flat-plate collectors do not use variable tilts or tracking systems as do concentrating collectors, which can provide higher temperatures.

CONCENTRATING COLLECTORS

The limited number of concentrating collectors being used in the demonstration program, and experiencing problems. For example, control can be a problem on cloudy days as concentrators often track the bright spot in the sky, rather than the sun, and they can be misoriented. If a cloud obscures the sun, the controls sometimes assume night has fallen and turn the collectors back to the east to wait for sunrise. These problems are being addressed and solved as the program develops.

STORAGE SYSTEMS

Liquid storage has a greater heat capacity than rock storage used for air systems (based on the same unit of volume).

Phase-change material for storage is still an advanced technology, though three or four systems that use a eutectic salt have been selected for demonstration programs.

STORAGE-HEAT STRATIFICATION

There is some concern about stratification of heat within the rock storage bed. If the heat is not removed at the right place, the stored heat can move about inside the bin without transferring into the building. Control devices are probably needed that can locate the heat and extract it from that location.

ROCK HANDLING

Using rocks for storage has its advantages and disadvantages. Rocks are cheap, available, and relatively free of problems. Dust and sand are really not problems, as the air flow through them is of such low velocity that it does not transport these materials readily.

However, handling rocks is difficult. For example, what must be done to 140 tons of rocks dumped on the ground? How are they cleaned? Coal dealers can be used to handle such things. Gravel pits can clean rocks or they can be cleaned with a cement mixer and water.

Asphalt paving firms use rocks that have to be dry, so they know how to do it. Or rocks can be placed into storage while they are still damp and will dry by air, provided they have proper venting.

HEAT EXCHANGER AVAILABILITY

Heat exchanger availability was discussed. If a conventional parallel flow or reverse flow heat exchanger for use between the collector loop and domestic hot water is not available, an immersion-type heat exchanger in the liquid storage tank might be an acceptable alternative.

FLUIDS

Various oils can be used as a heat transport fluid in liquid systems. Likewise so can water mixed with glycol, as a protection against freezing. The heat transfer capabilities, relative costs and maintenance factors are different for different fluids and must be considered in the overall system operation. There are advantages and disadvantages in each case that must be addressed. The use of drain down and thermosyphon systems should be also considered for certain applications.

VALVES AND CONTROLS

Off-the-shelf valves and controls should be considered. However, special equipment for solar applications should be listed in the standard catalogs. Operating projects are using off-the-shelf controls with satisfactory results.

There is a need for better quality control and labeling of products. If there is a mislabeled product, which happens often, it can cause problems.

Speciality controls or off-the-shelf HVAC controls and design can be used or unique control strategy devised. If microprocessors are used, they should be done in conjunction with some other uses in building. It is too expensive to devote microprocessors exclusively to solar energy control systems.

AUXILIARY HEATING EFFICIENCY

The efficiency of auxiliary heating systems was discussed, and one attendee said gas or propane systems might have a greater efficiency and make better use of energy than electricity for hot water systems. There are quite a variety of auxiliary heating systems including oil and natural gas. When these are not available, electrical heating is then usually used.

SYSTEMS APPROACH

When selecting components, one should not just look at the components individually and pick those that are optimum. An inspection of the overall system, and perhaps some sacrifice in efficiency on the optimum component, is needed to achieve an optimum system.

COOLING TECHNOLOGY

As far as solar cooling is concerned, it does not appear now that the DOE will be able to meet the five-year deadline which Congress mandated. There is too much research and development needed to bring the cost down. The DOE might request an extension of three years or some other form of demonstration program to give the industry time to make solar-cooling technology economically attractive.

A major research and development program is now underway that is investigating not only the lithium bromide system, but also the Rankine cycle, dessicants, night radiation, etc. All forms of cooling are being investigated in the search for a cost-effective solution.

Lithium bromide machines require a very high operating temperature (220°F to 240°F) in order to have a good coefficient of performance. However, most of the available collectors usually operate most efficiently in the 180°F to 190°F range, so there is a gap of 30 to 60 degrees between the two. An ammonia-water type air conditioner can operate at about 150°F, but it has a low coefficient of performance and also requires a very low condensing temperature.

As cooling with solar energyis difficult, several unique approaches might be considered. It can be done by using nocturnal radiation at night. Heating a wall to syphon air from the building and draw cool air form the northern part of the building might help. Cycling naturally cooled air through the building by letting air currents do it, or by creating a syphon, can be done. For commercially-sized applications, the cooling load can predominate so much research and development is still needed.

PASSIVE DESIGNS

The Department of Housing and Urban Development (HUD) is conducting the Passive Design Competition and Demonstration, a result of the Second National Passive Solar Heating and Cooling Review in Philadelphia last February. Passive methods have not received the emphasis that active methods have. The DOE has now decided to establish the Passive Initiative Program and Design Competion based on the apparent interest and need for this technology.

In the program, participants can submit solar designs for new or retrofitted buildings. If a new building design wins, and award of $5000 is made. A retrofi

design can be conceptual or planned for used in a existing building. If a retrofit design wins, an award of $2000 is made. To receive a demonstration award. the project must win a design award. It also must be a new building and the owner cannot be pre-identified. A demonstration award is worth $7000 for the first unit.

If two or three or four of the basic units are to be built at the same time, each one will get an additional $2000. The details of this project are now available. Responses were due in by August 8.

If participation at the Philadelphia conference is any indication of the broad interest in passive systems, there should be some very interesting responses. DOE is looking forward to developing passive systems as a major way of heating and cooling buildings.

The policy at HUD right now, in building homes, is, first, energy should be conserved as much as possible: second, passive techniques should be applied to the maximum extent; and then an active system should be considered.

Using and active system to handle the entire energy load may cost too much. If conservation and passive methods are first employed, then often what energy is still required can be handled by a much smaller and, therefore, more economical, active system.

ARCHITECTS/ENGINEERS EXPERIENCE FACTORS

Architects and engineers are sometimes reluctant to consider solar energy systems. Many of them perceive that using solar amounts merely to sticking collectors on buildings. One participant wanted to submit a proposal to PON 3, but reportedly could not find anyone willing to work with him.

As it stands, solar energy is still an expensive item and, to many, an unknown quantity. There is a fear among some architects and engineers that keeps them from getting into solar projects. This usually disappears once they have completed a system or two. Perhaps what is needed is for experienced professionals to communicate with others who have not designed or built solar energy systems and sell them on it.

The current high cost of solar energy systems tends to be prohibitive to professionals unless there is some government involvement. Those professionals who are already involved are essentially realizing little return and will probably continue to do so for the next few years. Government funds are needed in order to help maintain interest and participation.

Professionals are understandably reluctant to invest their time and efforts in designing solar energy systems on a competitive basis, since they are not assured of even winning the job.

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CLIENT VERSUS GOVERNMENT INTERESTS

Many architects are finding that their clients are interested in solar-energy systems from the standpoint of environmental concern and saving energy (which translates into saving money) and not in the idea of stimulating an industry.

Perhaps the government's emphasis should be changed from industry stimulation to conservation of energy, with the stimulation of industry to follow.

COST EFFECTIVENESS

More cost effective systems are still needed. The demonstration program does not directly address the energy problems of low-income people, at the present time. No form of direct relief is available from the program to those faced with increasingly higher energy costs. The program is structured toward getting the solar energy industry stimulated and expecting the costs to be reduced to within the reach of the low-income families.

The costs are coming down as collectors go from prototypes to mass production models; but, at the same time, the costs of energy used in the production of collectors are rising. Additionally, general inflation in the economy causes price hikes.

The real aid for low income families will likely be through tax rebates and other incentives that the government is probably going to have to enact within the next year or two.

The demonstration program is expensive and needs to be followed by an economic policy that will allow the demand for solar equipment to continue and allow the benefits of solar to reach the masses. One project that is currently underway in Kentucky is a "black attic" project, which incorporates translucent panels on the south roof of the building with the attic floor painted black. It is a very simple, cheap passive design.

The DOE and the Department of Labor have a program in which unemployed people are taught to weatherize homes, conserve energy and then install solar heating and hot water systems. This program shows promise for "do-it-yourself" type activities.

LIFE CYCLE COSTS

When looking at life cycle costs the pay-back period of active systems are very high. Some industries find pay-back periods of three to four years acceptable, but balk at the 10, 12, 15 years or longer periods.

These pay-back periods can be reduced by use of passive techniques, but they are not too well developed at this time. An approach to utilizing passive techniques more effectively is now being sought by DOE and others.

COST PER FT^2 NEW VERSUS RETROFIT CONSTRUCTION

The cost per square foot of solar energy systems in new construction versus retrofit applications came up. A panel member said it is hard to accurately esitmate retrofit costs because of the unknown factors. One retrofit project in Washington, DC, experienced cost overruns because the roof supports were not always where the drawings indicated. This required probing around trying to find them.

It is a little easier to estimate costs for new construction, which is in the neighborhood of $18 to $28 per square foot, with an average of $24 for the total system cost. One of the panel members provided these figures, which are considerably lower than the numbers coming out of other demonstration projects.

AMOUNT OF COLLECTORS MANUFACTURED

The square footage of collectors manufactured in the United States in the last three years has increased nearly thirty-fold. Only 136,000 square feet were made three years ago; and last year, over 4,000,000 square feet were produced.

SITE-BUILT COLLECTORS

There are very few site built collector projects at this time.

WARRANTIES

There were several questions on warranties. The last HUD cycle required that manufacturers submit a five-year warranty and also require a one-year system warranty from the installer. These warranties were required to be submitted in the proposals for evaluation. They had to be properly documented.

A lot of responses were rejected because of inadequare warranty information. The HUD position was to emphasize consumer protection and to maintain the warranty requirements. If the warranty is not provided the projects would be rejected.

For example, if a product supposedly has a 20-year life expectancy, then it should not be that difficult to place a 5-year warranty on it. In the PON 3 commercial cycle, the same warranty conditions were established in the intermediate Performance Standards. HUD made the warranties mandatory, but on the commercial side, it was not. Warranties were submitted for evaluation. The DOE is a bit more flexible in that regard but it is probably now going to have to take a stronger stand with respect to warranties.

NET-ENERGY ANALYSIS

There are two ways that net energy analysis can be addressed. The first is at the national level; second, is at the consumer level. At the national level the energy gathered from a solar collector is compared to the energy used to fabricate the steel, glass and other materials used in building the collector. Does it take more energy to build the collector than can ever be gained from it?

Congress obviously considered this when it enacted the National Solar Heating and Cooling Demonstration Act of 1974 and decided that there would be a net-energy gain.

From the DOE point of view, with the overall decision having been made, the assumption is that there is going to be a net energy gain from solar when we consider each project for demonstration purposes.

The cost of fuel used to fabricate the systems is going up but there is hope that the net effect will be some reduction in cost.

If the cost of regular fuels is deregulated, solar should become economically viable sooner; but it does not help the poor person because he can not afford either one.

The development of passive retrofits, new passive designs, or other design techniques which are much less expensive than the active systems could provide some relief.

Secondly, from the consumer's point of view, once the system is installed and working, there is some parasitic energy drag from the pumps and controls. Depending on how many Btu's are planned from the sun, the parasite usage must be subtracted to determine the net gain.

PIPING QUALITY

There is some concern over the quality of plumbing and piping subcontractors. Generally, when someone is using public funds, he must use competitive bidding for work on the project. The general contractor will probably be selected on the basis of the lowest bid and consequently will get the subcontractors at the lowest cost available. Sometimes, as a result, the best quality is not obtained.

The response to a PON is examined by looking at the design team and its capability to put together a good design. Generally, the construction manager probably will be listed and some of his key people. But as for the people who actually lay the brick and lay the pipe; it's beyond DOE capability to make an evaluation of their ability to do a good job. It should be left to the general contractor to satisfy the contract requirements, even with unqualified subcontractors.

COMBINED SYSTEMS

There might be a need at DOE for a program office that supports combined systems. It probably will come about as the various technologies come from the Energy Technology Office to the applications group. When wind and photovoltaics are ready for commercialization, a program office will be established or a program manager designated to take care of particular projects.

Combined systems, using wind and solar devices, are still in the energy technology area; but that branch does not believe that wind systems are ready for demonstration. They are still quite expensive.

AMOUNT OF ENERGY USED IN A BUILDING

There is some concern about the amount of energy used by a particular building. California has initiated competition for a government office building. The firm that won this design award submitted it as a PON 3 project. The California energy conservation design uses additional techniques to reduce the level to only eight percent of the pre-1975 energy requirements.

Based on the energy consumption of pre-1975 buildings, it was shown that if ASHRAE 90-75 energy conservation techniques were applied, a reduction in the energy to a level 37 percent lower than in pre-1975 buildings would be possible.

The General Services Administration also has an energy-conserving building in Saginaw, Michigan. It only uses some 26 percent of the energy of pre-1975 buildings.

The amount of energy being used by buildings today is considerably less than prior to the 1975 fuel crunch. Also, older buildings consumed about $.50 per square foot in electricity annually (including heating and air conditioning). With energy conservation and using well-water cooling and other methods, this figure can be lowered to about $.05 per square foot.

THERMAL POLLUTION

Thermal pollution of ground water with cooling systems is a concern. There are projects using ground water in the cooling process and returning it in a warmed-up condition. This could have some impact on that resource. One solution appears to be to draw the water from a deep source and return it to a shallow source.

MODEL BUILDING CODES

Model building codes for solar are still in their infancy. The DOE is trying to develop a somewhat standardized model code or help industry to come

up with one. It is working closely with standards and codes organizations to support this activity as discussed in the main program.

PHOTOVOLTAICS

Photovoltaics, though not a part of the solar heating and cooling demonstration program, are now starting to phase into the applications group from the research and development programs. This technology could be used in the heating and cooling of buildings (probably in some integrated system) as well as in meeting the primary base load.

An office and program manager have been established and the activity is now under study at the Lincoln Laboratories.

Photovoltaic devices themselves have very low efficiencies, 10 to 15 percent; and they can build up temperatures of 130°F on their surfaces. As the temperature of the photovoltaic cell goes up, the efficiency goes down. If there is some way to remove that usable heat, the efficiency of the photovoltaic cell could be maintained and some use found for the heat.

There is a federal building program for photovoltaics now being considered and a new demonstration program being proposed in Congress, requiring some $1.5 billion over a ten year period.

AGRICULTURAL AND INDUSTRIAL PROCESS HEAT

It was asked why an agricultural demonstration program did not exist. There is an Agricultural and Industrial Process Heat Branch within the solar heating and cooling program, and it has a very active program with its own seminars and workshops.

Those interested in grain and fruit drying, or chicken coop heating can talk to Jim Dollard or William Auer. They can be reached through the DOE at (202) 376-9633.

UTILITY INTEREST IN SOLAR

Solar energy systems are being viewed with mixed opinions by the utility companies. Some, like TVA, for example, are very much in favor of it since, if it were used on a wide enough scale, it could lower demand and keep them from having to build more power generation facilities. Others see solar as a very definite handicap. They feel that solar systems will only aggravate their peak demands; and consequently, they are restructuring their rates to be based on demand levels. To use utility-generated power only when solar systems could not handle the load could mean paying premium rates and hamper the use of solar.

The TVA has a trial program in Memphis in which solar water heaters have been installed in 10 homes. They are equipped with timers to keep the electric

auxiliary heaters from operating during peak demand. The next phase of that program will see 1,000 hot-water heaters installed in Memphis.

That agency's financial analysts have determined that solar hot-water heaters, equipped as these are, can have a benefit to TVA of $800 in terms of generating capacity that would otherwise have to be built, including the operation of extensive combustion turbines and purchase of energy from utilities that would otherwise be necessary. This benefit is to be shared between the homeowner and other TVA customers, with the owner getting a $300 to $400 initial grant.

TVA is also looking at low-interest loans for owners to finance the balance of system costs so that monthly payments can be kept reasonable. It is hoped that the monthly payments to the local utility, along with the electric power bill, will be no larger than before the solar system was put in. Thus, the homeowner could gain ownership of the system with not extra out-of-pocket cost.

The Santa Clara, CA, utility company also favorably views solar. It offers solar heating units to swimming pool owners. The utility company would buy the systems at wholesale, install them at the customer's home for $258 and then charge a monthly service fee, which was based on a six-month operating period. It is charging the owner a retail price on the system and making a little money as well as on the monthly service.

Monthly bills average $25 to $30, in comparison to $50 for gas and an estimated $150 for electricity. The figures for solar and gas are not firm, but seem to be valid, according to the utility manager.

SOLAR IMPACT ON UTILITIES

There are several separate considerations concerning the impact of solar-energy systems on utility costs. If solar energy is stored and used during the night, so that there is no capacity for the next day, which might be cloudy, power must be drawn from the utilities and aggravate the peak. Use of the solar storage system to meet peak demand times should be investigated to help this situation.

If storage is available and aggravation of the peak is to be avoided and there is a desire to draw heat during a very low demand time, then the storage can be charged by using the sun during the day and then drive the storage temperatures up at night, using electricity in off-peak hours.

This can be one of the uses of off-peak utility power. However, storage-tank temperatures can become excessively high, and in order for the solar collector to be able to contribute to that storage, it may operate at a very low efficiency because of the higher inlet temperatures to the collectors.

This suggests two different storage systems may be required to solve this dilemma.

ENERGY FIRMS IN SOLAR

Some oil companies are getting involved in solar energy technology. Most likely, they are doing this as a good business practice, looking at the potential of alternate forms of energy. This trend will continue as a good business practice.

PRIVATE PROGRAMS

A lot of activity is going on outside the DOE. Of the collector production for the last year, 12 percent is attributed to Federal programs and the rest is to private programs. These systems might be evaluated with DOE funds. It is not being done right now.

BARRIERS

Testing programs, certification programs, building codes are hindrances to the person who is trying to become an entrepreneur and innovator and get a product on the market. These regulations are needed to protect the consumer so he is not victimized by a manufacturer who, by design or unintentionally, puts out a shabby product. There is a need for a balance between consumer protection and design innovation.

TEAM EFFORTS

How does one put together a team to respond to PON notices? This is something DOE cannot do. It issues the PON, but the responder must either have a team in place or put one together. DOE has no provision or program to help put together a team that can respond to the PONs. Normally, the team should include an engineer, an architect, a builder owner, a financer, and enough resources to manage the program if an award is made.

TRAINING PROGRAMS

There are several types of training programs for designers and installers now being coordinated by various universities and educational institutions. Finding out what there is to offer is basically a matter of going to some educa-

tional facility and asking them. Also, the manufacturers of equipment are starting to develop training manuals and courses for their dealers. Much more work is needed in this area.

DO-IT-YOURSELF PROJECTS

A lot of people do not have the money to buy a solar energy system but do have some time that could be put into constructing one. In the commercial category, there is not much that can be done, since the systems are large and unique and have to be tailored to buildings and their loads.

Something can probably be done in the residential category. If anyone is interested in this, he may contact the National Solar Heating and Cooling Information Center in Philadelphia, using the toll free number (800) 523-2929 (800-462-4983 in Pennsylvania) and ask what literature exists on the subject.

COMMUNICATIONS AND PUBLIC RELATIONS

There are problems in communicating about solar energy with the public. The primary reason for having these meetings is to use the attendees as a key link in getting the word out to the general public. It was brought out that more visible demonstration projects and exhibits are needed. A demonstration is not mobile, and it is difficult to get people beyond 50 miles to make a trip over to see it.

The lack of success stories and the lack of communication with the general public are real problems. Too much talk these days is about all the problems in solar energy systems. But there are success stories, lots of them; and they need to be told. The positive side of solar should be emphasized.

Despite the fact that almost 200 projects are in various stages of development now and another 100 in PON 3 and in the federal sector, people do not know much about solar demonstrations.

The people who are actually working in the program understand it but the data is not getting passed on form there. There is no "domino effect." Methods to gain a higher visibility must be devised and better utilization made of the funds spent on demonstrations.

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SUMMARY OF SOLAR DATA PROGRAM WORKSHOP
ATLANTA

The following information is a summary that was prepared by the Session Chairman, H. Jackson Hale, based on inputs that were given to him by panel members after each workshop.

"The workshop on the National Solar Data Program was structured in a sequence similar to the presentation of the papers. The first area was the National Solar Data Network and the Thermal Performance Reports, second, Control Systems Evaluation; third, the Analysis of Collector Arrays; fourth, the Architectural and Engineering Factors; fifth, Reliability, Maintainability and Materials Performance, and finally, the Cost of Solar Energy Systems. Each of these areas is summarized in the discussions below.

"In the area of National Solar Data Network and Thermal Performance, there was a question asking if there is an evaluation of passive systems. The answer to that is yes; DOE is in the process of evaluating passive systems. At the present time, there are six in evaluation. The number of passive systems to be evaluated is certain to increase. In the early part of the program there were not too many proposals for passive systems. However, they will increase with time. There is a report on the Kalwall passive system. It is one of the first to be reported on.

"The next item is: Can privately funded projects be instrumented and become a part of the National Solar Data Network? That question is asked relatively frequently. With present funding levels, DOE only has sufficient money to instrument a small portion of the federally funded projects. It is scheduled to instrument 15 or 20 percent of the federally funded projects. In view of that, it is very difficult to go outside the program and bring in privately funded projects. Future activity in this area is going to depend totally on the budget. With more money DOE would try to expand out into that area; but right now it is limited to the federally funded projects.

"Another question that came up: Is climatological data available? Apparently quite a few designers are interested in these data. The answer is, yes, that information is available. There is an activity within DOE that is working closely with the National Oceanic and Atmospheric Administration (NOAA) to gather solar radiation, temperature and relative humidity data. This information is being put together into a standardized format. Climatological data for each site is available for site evaluation. In all cases, the solar radiation levels, the ambient temperatures are available and, in many cases, the relative humidity and the wind speed as well. That information is being gathered by the DOE network and will be put into a standard format. There is now some difficulty in settling on the proper format that will be the most useful to the solar designer. DOE is presently storing the data. As is known from discussions, some sites have been in operation from six months to a year. Those data are stored and will be made available to the public when a standard format exists.

"Another question was: where can simulation programs be found? The most familiar of these is the TRANSYS program of the University of Wisconsin. Apparently there has been a change in personnel at the University of Wisconsin and some of the people, at least in our workshop, had difficulty in contacting the proper person. Information on it is available in the DOE R&D Branch from Fred Morse or Mike Maybaum. They can assist anyone in getting access to the TRANSYS program.

"There also was discussion on Control Systems Evaluation. There was some discussion on the complexity of solar systems versus reliability. The general consensus was that systems design must balance complexity and reliability. There is a very definite trade-off, and all factors must be considered. There is also some public skepticism regarding control systems. The public needs more data on good working systems to gain more confidence, i.e., solar systems that have a workable control system.

"A need was expressed for additional education in the field of controls. A number of participants felt that there are a lot of poeple using control systems but do not understand their design and operation. If they are designed properly and installed properly, they will work.

"There was also a question raised concerning the comparison of control systems. DOE has an active program to evaluate the performance of collectors. That seems to be an element of solar systems that receives a lot of attention. In view of the difficulties encountered in the area of control systems, the question was raised: Are you going to do the same kind of study on control systems? The answer is that there is not an active program to focus attention on control systems. If the control system problems persist there surely will be additional studies of them. The discussion on control systems was closed saying that control system reliability is not a particular problem. It is one that has been discussed a lot, but there are many systems in the demonstration program that have very reliable control systems. As Gene Doering said earlier, it is important to note that many of these systems do work.

"A discussion then took place on the analysis of collector arrays. The question was raised: What provisions are made to evaluate the effects of scaling on collector thermal performance? The response was that the collector arrays will be evaluated for a period of up to five years. There is an active program in scaling at the Argonne National Laboratory. With the IBM activity DOE will be able to monitor any degradation of performance; and, in a number of sites, it will be possible to relate degradation of performance to the build-up of scale within the solar energy system.

"The next question was: What confidence is there in the regression line derived from the field data? There had been a previous discussion of the filters that were used on the solar performance data. For example, only data that falls within the range of up to 10 miles per hour on wind speed are considered. Another example is considering only data for insolation levels greater than 200 Btu's per hour. Another question was: When all those data points are eliminated, is confidence in the data eliminated? The IBM response to that was that the coefficient of determination, which is a measure of goodness of fit, was .7 or greater for all curves that were presented. A coefficient of determination of 1.0 is a perfect fit. Statistically, that is a pretty good fit of the data, and confidence in that filtered data is warranted.

"The question was also raised: Will DOE identify the best collectors? The answer to that is no; DOE will not identify what the best collector is because, being a part of the government it can really get in trouble by saying which collector is best and which is the worst. What DOE plans to do is to tell how the various collectors perform and present that data in a standardized format.

It will be up to the individual to evaluate particular applications and draw conclusions. It is relatively easy to draw a conclusion of which collector is best from such data.

"Another question was: How do evacuated tube collectors compare to flat plate collectors? At the present time, DOE does not have any instrumented, operating projects with evacuated tubes. It has identified and selected projects with evacuated tubes that are operating. It has identified and selected projects for instrumentation that have the evacuated tubes. DOE will be presenting this data as soon as the systems become operational. It is expected that evacuated tube collectors will generate higher temperatures and have lower losses than the flat plate collectors. This will be substantiated as the program progresses.

"Next was the Architectural and Engineering Factors. One of the questions was: Are there unique problems involved in the detailing and specification of solar installations? The answer was a very definite yes, due to the exterior construction of the solar sites.

"The question was raised: What is the best way to balance solar arrays, reverse return or balancing valves? The response is that study is needed of each case for cost and reliability. It was also pointed out that it is difficult to catch every Btu with exact balancing, and there is no need to expend a large amount of effort to get that last Btu out of the array. It probably will not pay off beyond a certain point.

"Another question raised in the workshop was: Are solar construction handbooks available based on this update; that is the presentation that was given by Steve Weinstein? As of this minute, DOE does not have it available in a final report form, but a report will be issued to the public. Finally, how is the standard interface between professionals affected by solar design? How are the architects, engineers and construction personnel to interface with each other on a solar project. The answer is that there should not be any difference between a solar project and any other construction project. However, that is not necessarily the case. Designers, architects, engineers and construction people frequently do the other person's job. This is probably an indication of the early state of the technology. Ultimately, those interface problems should be the same as for any other building project.

"Next is the area of Reliability, Maintainability and Materials Performance. The question was raised: What are the major reliability concerns? One of the big concerns is system freezing. Some of the causes were discussed: the manifold slopes, problems with control valves, sensor location, etc. Another item that came up frequently was low glycol concentration which allowed the glycol-water mixtures to freeze. That was attributed to problems with the automatic glycol buildup. There was not the proper amount of glycol in the system to prevent freezing. This problem is being studied now and a report is expected in the fall.

"Continuing in the reliability area, the question arose: What activity is underway in terms of a preventative maintenance program for the solar demonstration sites? The answer is that as of this minute there is none. It is felt that data being gathered will permit reliability and maintenance guidelines that will allow each of the sites to develop preventative maintenance programs.

"The question also arose: How is this reliability data being disseminated so that people can readily have access to it? One of the ways is through the reliability and maintainability bulletins. As this information accrues it is put out in very short briefings in the form of bulletins and given wide distribution. DOE will be developing specific reports, more comprehensive in nature, and those will be handled through the DOE Technical Information Center. As was indicated earlier, copies of ANL reports are available. Certain guidelines will be published that will help designers to insure that their system has the best possible reliability and maintainability.

"The next question was: How are heat transfer fluid properties being obtained? There is an active study at the present time which involves in situ monitoring to evaluate specific heat and specific density of transfer fluids. This is a part of the ANL project.

"What other activities are underway in the reliability and maintainability program? DOE also has a program that focuses on the in situ monitoring of atmospheric corrosion at 15 sites.

"Finally, discussion centered on cost of solar energy systems. There was a question: How does the solar community have access to this cost data? DOE is publishing reports. Many of them have been distributed for up to six sites. This activity will continue, but DOE is going to go beyond that and work with the people that publish the Dodge and Means Estimating Guides. They will consider the DOE data and use names in those documents. These data will consist of three or four additional pages in the estimating guides.

"Some concern was expressed over the possibility of standardization of techniques for doing life-cycle costing studies in many different ways and based on the techniques that are used, one may reach different conclusions. DOE recognizes that and is presently investigating the various techniques for life-cycle costing. DOE shares the concern of some attendees that there is a need for a standard technique.

"There was also concern expressed over the availability of standard fuel-inflation rates. One concerned individual expressed that he had contacted DOE and was not successful in getting this kind of information. The determination of standard fuel inflation rates is very complex. It is a tough area to put definite numbers on. DOE is concerned about it. It is being addressed and a considerable amount of effort is going into it within DOE.

"There is concern over benefit analysis in the solar data program. Benefits reports are in the process of being prepared, based on some of the information presented at this conference. DOE expects to have benefits reports available by this fall.

DOE feels this has been a very worthwhile conference. It has benefited DOE and the other people in the solar data program. I hope you found some benefit in the information that we have provided. It appeared to me that most of the major areas of concern are being addressed. We do not have all the answers but it was satisfying to me to know that no bombshells were dropped. There was no big area of concern for which we did not have an activity underway to try to reach the proper solution. I hope that we will turn out more information that will satisfy your needs."

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SUMMARY OF SOLAR DATA PROGRAM WORKSHOP
SAN FRANCISCO

The following information is a summary that was prepared by the Session Chariman, H. Jackson Hale, based on inputs that were given to him by panel members after each workshop.

"The workshop was structured by grouping the discussion into six categories. First is the National Solar Data network and Thermal Performance Reports; second is Control Systems Evaluation; third, Analysis of Collector arrays; fourth, Architectural and Engineering Factors; fifth, Reliability, Maintainability and Materials Performance; and sixth, Cost of Solar Energy Systems.

"In the area of the National Solar Data Network and Thermal Performance, there was a considerable amount of discussion on the thermal performance climatological data, how can it be obtained, etc. The solar data program has issued a bulletin listing the reports that have been issued through June, 1978. Copies of the "Solar Bulletin" can be obtained through the Solar Heating and Cooling Information Center. Individual copies of the reports can be obtained from the DOE Technical Information Center. It was pointed out that DOE has sponsored the development of a standardized format for climatological data. It is referred to as SOLMET. The solar data program described during the workshop supplements other climatological data gathering activities such as one going on by the National Oceanic Atmospheric Administration (NOAA) in cooperation with DOE. The University of Alabama in Huntsville is collecting non-NOAA data for the National Climatic Center. It was pointed out that the solar data program was not intended to be a primary means of collecting climatological data. However, it turns out that a great deal of such data is accumulating, and it will be made available as soon as possible.

"Larry Murphy, of IBM, pulled together something he calls "gee-whiz" numbers. There were 30,000 data plots of various types provided to the sites that are either operational or in the start-up phase. That is a considerable amount of data, involving the reduction of at least 12 million data points. DOE will continue to feed data back to the demonstration sites, as necessary, to expedite the start-up of these projects. There was a question as to which of the demonstration sites are instrumented. There is an internal document on the entire solar data network that identified those sites which are instrumented and are operational and transmitting data. What is really needed in view of the questions raised is a bulletin which identifies the operational, instrumented sites. DOE intends to do this right away.

"The next area discussed was the Control System Evaluation. One question raised: Can control system problems be avoided? DOE has pointed out some of them and feels that the information on control system problems will be available through conferences such as this and through reports that will be issued in the near future. DOE also expects to include critical problems concerning control systems in bulletins. These bulletins can be issued in much less time that is required for areport. Any questions concerning information from the data programs should be addressed to the National Solar Heating and Cooling Information Center. The toll free numbers are 800-523-2929 nationally, and 800-462-4983 in Pennsylvania. The address is P.O. Box 1607 Rockville, MD., 20850.

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"The next question: Is the instrumentation program used to optimize the control system? That was not the initial purpose of the instrumentation program nor is it an objective of the IBM contract. However, the IBM people have been working very closely with the project people and assisting in this area.

"Are there any recommendations for control sensor locations? Again that is not the responsibility of the instrumentation program. DOE feels that is the responsibility of the designer of the control system and the contractor, although the IBM people have made some interactive recommendations at a number of sites and probably will continue to do so. The question was raised as to what unique control applications, such as absorption chillers, hybrid solar systems, heat pumps, etc., are included in the program. Again, based on the interest by participants on this, DOE intends to put out solar bulletins that will document the various types of instrument sites. Next was the area of Analysis of Collector Arrays. The question was asked: How does DOE plan to follow collector performance degradation? This issue has been raised several times. The DOE contracts for the demonstration sites allow data collection for a period of up to five years. That data is being stored so we know how systems performed at the beginning. DOE will know on a continuous basis how that performance shifts. Announcements will be made of these data and reports of trends.

"The next issue was collector performance reports. One question was: How is DOE going to report the performance of collectors? The way it intends to do that is to prepare comprehensive comparative reports of the collectors as they perform in the field. There was a question as to whether DOE would rank collectors according to performance. The answer to that was a definite no. DOE will report how they perform, but it will not rank them according to their performance.

"The question was raised: Will concentrating collectors be analyzed in the same way as flat-plate collectors? At the present time, the concentrating collector results will be presented in the same format, that is the Hottel-Whillier-Bliss equations.

"There was considerable discussion on criteria for collector certification. Concerns in this area should be sent to Dave Pellish at DOE, phone number (202) 376-9600. Dave is interested in the opinions of people from a wide variety of backgrounds.

"Some of the comments led to the need for reciprocity of certification criteria between states. It was pointed out that a number of states are establishing their own certification programs independent of the Federal government. It is going to become a burden on collector manufacturers to get their collectors certified in each of the states. It seemed that the attendees were divided into two groups. The sellers were concerned with over-regulation, and buyers with quality.

"Another interesting question was raised concerning the use of foreign manufactured collectors in the demonstration program. It seems that there has been some conflict in information disseminated in this particular area. The DOE

policy is that the "buy American" clause does apply throughout the demonstration program. Particular collectors will need to satisfy the "buy American" clause to meet the DOE policy.

"In the area of Architectural and Engineering Factors, the question raised: Can DOE help stimulate sales in the private solar market? It should be able to by providing performance, cost, aesthetics, and reliability data on successful projects. It seemed that the people who raised that question wanted a little better answer than that. It seemed they wanted more support from DOE in the marketing. Another question was: Can DOE provide examples of good aesthetic designs? The answer was affirmative. DOE has a number of demonstration projects that are very attractive; brief, descriptions of these and other projects are described in the Project Summaries Report (DOE/CS-0009, May 1978).

"The question was raised: Can DOE publish system descriptions ranked by cost? The answer was no; DOE will not do that. What it will do is give a project description and tell how much the project costs. It will not say one is better than another. It is similar to the situation with collectors. DOE will give the information from which can be drawn a valid conclusion, but it will not be making that decision. DOE will also be providing some design guidelines in the very near future.

"In the area of Reliability, Maintainability and Material Performance, quite a number of questions were raised concerning collector glazing and selective coating problems. DOE will address those in the reliability program. It will be recording any failure or degradation of those particular elements of the collector. There is a need for information on the aging and degrading of collectors and solar system components. This information is being collected and will be reported. There was considerable interest in receiving performance statistics, reliability data, and failure histories. This information is also being collected. It is in the preliminary stages right now, but this kind of information should be published in the next six months.

"A number of people also asked: How will reliability and materials data become available to the public? There are two primary methods by which that information can be obtained. One is the DOE Technical Information Center (TIC). Reliability information can also be obtained directly by writing to: The Solar Data Program, Argonne National Laboratory (ANL), 9700 South Cass Avenue, Argonne, IL, 60439.

"Another question that came up was: Will Argonne develop solutions to problems? It is not the intent of the data program nor the Argonne element of the program to develop solutions. It is obvious that as the demonstration programs progress, certain solutions are going to be discovered. DOE is going to make a very deliberate attempt to publish those known solutions. It is also going to try to identify prevalent problem areas. Once those problem areas are identified, it will turn that over to other groups such as the research and development activities to develop the proper solutions. The solar data program is trying to assess performance and to identify problem areas, but it does not get into the solutions. There was a final comment that was made that many of the failures are due to inadequate installation specifications or due to a lack of attention to installation

specifications. Many of the problems cannot be directly attributed to solar, they are more directly attributed to other factors.

"The final area was Cost of Solar Energy Systems. The first question was: Will the cost data be placed in a cost-estimating guide such as Means or the Dodge estimating guide? The answer is yes. The subsystem costs are being broken down into labor, overhead, etc. This will be used for cost-estimating purposes. DOE already has contacts with the Means and Dodge estimating guide people and they expressed interest in including these data in their estimates. The next issues of the Means and Dodge estimating guides will include some of the data that have been gathered.

"The next question was: Will regional labor cost variations be accurate? The answer is yes. The labor estimates that DOE established nationwide can be applied to the cost data that it is collecting.

"The question was asked: Will labor types and hours required be included in cost-breakdown reports? These data will be provided where they are available. There are difficulties in obtaining this kind of information because of the type of bookkeeping system that the individual site personnel keep. Whenever this information can be obtained, it will be made available.

"Another question was: Will cost reduction recommendations be provided? Yes, these types of data show up on just about every project and also become apparent during cost breakdown comparisons for several projects and we will try to duplicate.

"The question was asked: Will maintenance costs be included in the data collection program? The answer to that was also yes. Under the ANL task, data will be collected and be utilized in the determination of cost performance ratios.

"The next question was: Will the project configuration, personnel relations, and problems be included in the cost reports? The answer to that is yes when it appears to help clarify project cost. An attempt will be made to formalize the costs so that they will be translatable to future projects.

"The final question regarding costs was: Will individual project description cost and performance reports be summarized in a single report? The answer to that is also yes. One of the major objectives of the National Solar Data Program is to establish how well the projects perform, how much they cost, and, ultimately, what are the benefits of solar energy.

"There were some additional questions that were of a general nature. One was: How is the existence of available reports made known to the public? In the near future a series of solar bulletins will be available through the Solar Heating and Cooling Information Center. One of these solar bulletins is available here at this conference, and subsequent editions will be issued periodically. This solar bulletin provides the title and the number of each of the reports published under particular programs. They can be ordered directly from the DOE Technical Information Center.

"There were also questions raised concerning the availability of the reports at this conference. DOE apologized for not having enough copies of the reports

to hand out to everyone. It simply does not have enough reports to hand out.

Another question that was: How does one get on the mailing list for solar bulletins? At the present time the best way to do that is to contact the National Solar Heating and Cooling Information Center. Their toll-free number is 800-523-2929.

Another question that came up was: Can data from non-DOE projects be included in the data program and made available through the data program? This is something that DOE has not addressed but needs to look at.

One important comment made was that caution should be exercised when taking the results from an individual site and extrapolating them to another site. Care should be taken because of different kinds of situations or climatic conditions.

"I would like to close by listing the type of people who participated in this National Solar Data Workshop. The categories of participants are shown in viewgraph 10. That is all the comments that I have. I would like to express my appreciation to all of you who participated in the workshops. We feel that these are valuable exchanges of information to increase the use of solar energy to replace fossil fuels," said Hale in closing.

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SUMMARY OF SOLAR DATA PROGRAM WORKSHOP
CHICAGO

The following information is a summary that was prepared by the Session Chairman, H. Jackson Hale, based on inputs that were given to him by panel members after each workshop.

"The second workshop dealt with the National Solar Data program. The workshop was structured quite similar to the discussions held yesterday afternoon. The National Solar Data Network and the Thermal Performance Reports were combined in the first session, then the Control Systems Evaluation was followed by the Analysis of Collector Arrays. Next was a discussion of the Architectural and Engineering Factors followed by the Reliability, Maintainability and Materials Performance and finally, the Costs of Solar Energy Systems.

"The participants by type in this workshop consisted of designers - 35 percent; installers and contractors - 15 percent; government including local, state and federal - 10 percent; solar manufacturers and representatives - 8 percent; university and education - 10 percent; testing agencies - 12 percent. The utilities were represented by 5 percent. It is also interesting to note that approximately 8 percent of the people attending the workshop have a personal residence with solar energy.

"The first area of discussion was the National Solar Data Network.

"There was some discussion of the site-selection criteria. The comment was made that it seems that relatively little information on passive systems is presented. The attendees felt passive systems deserved more attention than given. DOE has nothing against passive systems. It turns out that in the selection of the demonstration projects, there have been a relatively small number of passive systems proposed. That is the reason why there is relatively little data on them. Six sites with passive systems are currently under evaluation; one of those is the Kalwall site. One of the performance reports handed out at this conference represents Kalwall, and its performance is very good.

"There was also a considerable discussion of the climatological data. It was pointed out that the insolation data that is being gathered is useful, but it was not a primary objective of the program. The climatological data was needed to do a performance evaluation. There is another activity within DOE that concentrates more in this particular area and all the data gathered will be turned over to it. It is working with the SOLMET format and some other aspects of analysis of the insolation data.

"Another question was raised concerning the subsystems efficiency reporting. It was emphasized that DOE reports on the overall system as well as the subsystems. The monthly performance reports not only go into the system but also into the collector array, the storage tanks, and some of the heat exchange systems and cooling systems.

"A rather common question was: What data are available to the site contractor? DOE has given a considerable amount of information directly to the site contractor and expects to continue doing so. Frequently, during the start-up period, people prefer data plots of a particular parameter such as a temperature or flow

rate as the result of certain modifications or changes made to the system. To date, 30 thousand data plots, which represent 12 million data points, have been given out. There is not any reluctance to hand out these data. Any site personnel who need such data can obtain it by contacting IBM.

"The data program duration was questioned. All DOE contracts with the demonstration sites allow data collection for a period of up to five years from the operational date.

"The calibration of the data system was also questioned. DOE has an initial calibration of all the sensors that are used. That is followed by a periodic spot check at the site by pulling the sensors out and recalibrating them, or at least, checking their calibration. The site analysts also have access to the data at all times. They look at the trends of the data. If they see something that looks a little bit odd, they can request additional calibration. DOE is trying to stay on top of the calibration and any drift that may occur.

"The next topic was the Control Systems Evaluation.

"One of the questions was: Where can more information on control problem solutions be found? Obviously at a conference of this type, solutions to some of the control problems that have been discovered were discussed. Others will be published in solar bulletins. This is a one page bulletin that gets wide distribution. Since it is rather small and easy to prepare, it is more useful to expediently disseminate more information than the comprehensive technical reports, which take a while to go through the preparation and publication cycle.

"The question was raised: Are specific components such as air handlers being evaluated? There is no specific element of the program directed at air handlers, except for the evaluation that is done as a part of the normal evaluation of the overall solar demonstration system.

"The next question was: Is the design of the control systems being evaluated by the Data Program? It was pointed out that the purpose of the Data Program evaluation is to insure that the system is performing as expected. Site analysts work very closely with the site personnel so indirectly there is an evaluation of the control system. It is a by-product and is simply a matter of support that the site people are getting from the data program. It was pointed out that the DOE R & D Branch has an active program in evaluating the control system strategies.

"The next question was: How can designers without sophisticated tools evaluate the performance of their control systems? That is a pretty difficult thing to do. DOE is trying to furnish the data to these people, identify problems, and identify the areas that should be looked at. Hopefully, people will be able to extrapolate from that information. It was also pointed out that some useful but limited information can be obtained by much less expensive instrumentation than currently being used. DOE will be publishing some documents in this area very shortly.

"Will design guidelines for control systems be made available? DOE is going to try to publish most of the information that is gained in the data program in the form of guidelines as well as other techical documents.

"The next area had to do with the Collector Array Analysis.

"The first item was the collector array definition. The results that were presented in the paper on the subject reflect the effects of manifolding, headers, piping, etc., located between the inlet and outlet temperature sensors. In the workshop, the attendees were cautioned to pay close attention to the particular array for which the results were presented. The way that an array is connected can have a significant effect on the performance of the collectors. It depends on whether it is a series or parallel arrangement, what type of insulation is being used, etc.

"The question was raised concerning transient effects. Computation of collector transient dynamics is possible but the objective is to present a simple model with an acceptable error for the industry. The answer was yes, it can be done to a limited extent from the data being gathered but right now that is now going to be a principle objective.

"Degradation of performance has been questioned several times. It was pointed out that performance will be continuously monitored and evaluated over a five year period. Therefore, it will be possible to identify trends and correlate that information with the Argonne materials program. IBM and Argonne are very familiar with what the other is doing; and when either one of them finds something that needs a close correlation, DOE will probably sponsor such work.

"Questions also were raised concerning solar insolation analysis. Solar insolation data are only a by-product of the solar data program. However, DOE does expect to do further analysis of the reflection, the tilt angle, and beam-versus-diffuse radiation. There seemed to be a considerable lack of agreement on the proper techniques to use in converting from horizontal to the tilted angle and vice-versa. That was not one of the objectives in this program; however, data is being gathered that will make it possible for someone to do this kind of study.

"The next area covered was the collector array analysis report format. Here the attendees were questioned as to whether the format that was proposed is satisfactory. There were some inputs that would increase the scope of the report. It was suggested that it include such things as the angle of incidence, morning-versus-afternoon data, clear-versus-cloudy data, and a number of other parameters that people identified. It was felt that if additional data were included in the collector array performance, it would make the data more meaningful.

"In that same discussion one of the attendees asked for some of the raw data to be included in the reports. There is no problem with including the raw data in the report; it is a matter of degree. How much raw data to include? Data are taken every five minutes. Is an hour of data needed? Is a day of data needed? Are several days of data needed? Unfortunately, a good answer from the attendees was not forthcoming. DOE will be looking at that some more and probably will include some raw data.

"The next area concerned Architectural and Engineering Factors.

"The question was: What sort of information would you like to see? The response was: easily usable data that can be directly applied on a practical level. That is a general response, but DOE will try to respond to it.

"Again, in this area people wanted the basic raw data, so that the designer can draw his own conclusions. DOE will probably be shifting its program some to provide more raw data. It is a serious matter. How far should DOE go with the release of raw, unanalyzed data?

"The second question was: Will Stephen Weinstein's paper, including the graphics, be available? That is something that has been asked at all conferences to date. People would like to see the hard copy of the material that Weinstein presented. The answer to that is yes. It will be available in the near future.

"Another question was: Would a publication providing examples of good aesthetic designs be of value? The attedees responded yes, and DOE is going to try to put together something that shows the public some of the more attractive solar designs. DOE has some very attractive projects and the workshop participants felt that it would be worthwhile to publicize them.

"Then, the discussion turned to Reliability, Maintainability and Materials Performance.

"In the area of material deposition and its influence on performance, there was a discussion on the build-up of scale on heat exchangers and other components and how it affects system performance. It was pointed out that Argonne National Laboratories (ANL) is evaluating scaling potential in aqueous solutions in some of the solar systems that are in the demonstration program. A report on that activity is scheduled for this December.

"A question was raised concerning system aging and degradation. That will also be addressed in the Reliability and Materials Performance program. The data will be collected over five years. Any degradation and aging will be evaluated and published. The activity at ANL pertains more particularly to materials. IBM concurrently evaluates degradation in performance. DOE will be tying these two together to see if ti can draw any conclusion from those data.

"A question was raised concerning the frequency of reports on atmospheric corrosion. At the present time monitors are being installed in a number of sites and it is expected that this kind of information will be reported aproximately every six months.

"The attendees also wanted to know how detailed the material performance information would be. That is hard to answer except to say that ANL will publish data on atmospheric corrosion, solar-fluid corrosion and property changes and scaling. DOE will be publishing this in sufficient detail to answer most questions. It was also pointed out that under the ANL program, DOE does not intend to do metallurgical studies. In the event of a problem. DOE will not go

into it to that extent unless it has a very outstanding problem with wide-ranging implications.

"In general, the national solar data program, is trying to identify how these systems work under real operating conditions. If there are significant problems, the data program will report them, but it does not intend to get into the solution of such problems. The information will be turned over to groups such as DOE R & D Branch or contractors to solve.

"Finally, the area of Costs of Solar Energy Systems was discussed. The workshop attendees agreed that the type of data being collected and presented is going to be useful to the designers.

"They also identified the need for two levels of cost data, one of them being preliminary estimates. Here they were referring to the kind of information that a contractor needs to give to his client when the design is in a very early stage. At that time, the drawings have not been completed; but he has to give the client some indication of how much the system will cost before they go too far with it. Of course, the attendees also recognize the need for more precise data for estimating final construction. DOE is trying to address these items and make that information available. Some of it is included in the reports that were handed out at this conference.

"The comment was also made that the cost per unit of energy is very valuable and should be based on life-cycle cost. DOE agreed with that. One of the principle objectives is to take this performance and cost data and tie it together in terms of dollars per unit of energy delivered.

"Another comment was that the cost per square foot of building, by building type and solar application, is desirable. Here attendees were asking DOE to take cost information and categorize it into the building type and solar application and make that available. DOE will try to do that; however, at this stage it cannot arrive at those kinds of conclusions because it has a relatively limited amount of information. The program is such that DOE will be able to do something like that in the future.

"Everyone would like to be able to extrapolate the demonstration program data into both larger and smaller systems, to other geographical regions, and to other loads. There was some discussion on that and it was concluded that it is a rather difficult task. DOE stressed that with the information it has now, one should be very careful in extrapolating it very far. When one starts switching from a large system to a small system or to another climatological region or to another geographical region where the labor rates change and so forth, he must be careful. DOE recognizes the need for this ability and is headed in that direction.

"Also, one attendee made the comment that there is a need for general non-technical data for the public sector. What he was saying was that it would be good to tell the public that solar systems for a house of a certain type will cost you so much and it is going to save so many dollars for a heating season.

It would be nice to be able to do that but it is extremely difficult to do. Many people ask how much is solar going to cost; how does it complete with gas; does it work well for hot water and does it work well for heating? There is not a single answer. If one is ever found, DOE will be sure to broadcast it on all the networks.

"Another question concerned the charts showing cost breakdown data that were presented by Bob Hedden. Bob's charts are included in the final proceedings.

"There also were several general comments and questions.

"One was: How are sites selected for the data program? At the present time, DOE has a matrix that includes all the basic system types in all the geographic locations. Up to this point, there are certain holes in that matrix. There are also some areas where it has a concentration of projects. What DOE tries to do in reviewing new projects is to see if they fit into the areas of the matrix where there are no projects.

"Sometimes that means that DOE does not instrument really good solar systems, but DOE does have limited funds. It tries to cover all the basic system types, the passive systems, the air systems, liquid systems, heating, cooling, hot water, in all the climatological regions. It certainly cannot cover everything but is trying to do it in a matrix manner and fill out the matrix completely.

"It was pointed out that presently the data program includes only Federally funded projects due to limited budget. A number of people asked if they can have their project included in the data network. DOE would like to, but right now it does not have enough money to instrument all of the Federally funded ones; thus, it is hard to justify going outside the program.

"Another question was: Is the data program used to recommend methods for performance improvements? The response was that the systems are evaluated as they are performing, and the system improvements are the responsibility of the site owner or the grantee. It was pointed out that there has been a considerable amount of discussion between the site analyst and the site owner. DOE encourages this discussion, but does not get in the position of making a firm recommendation to the site people. It is their project, and they have the responsibility. The solar data program can only bring certain options to their attention. It does not make any recommendations.

"The final question was: Is government funding available to fix systems after the contracts are completed? The answer to that is DOE cannot make a hard and fast rule regarding that. It has to review each one on a case-by-case basis.

"In closing, I would like to say one further thing. We're going to have another conference this fall that will go into greater detail than we have at these conferences concerning the various aspects of the data program. The title of the conference is Solar Heating and Cooling Systems Operational Results. At that conference we will restrict the information to operational results. We're not going to make any predictions or simulations. It is based on projects that

are working and will represent the information that has been gained from those projects. It will be held at the Broadmoor Hotel in Colorado Springs November 28 through December 1. If you would like to attend, you can get additional information from Miss Vickie Curry at the Solar Energy Research Institute."

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SUMMARY OF SOLAR DATA PROGRAM WORKSHOP
BOSTON

The following information is a summary that was prepared by the Session Chairman, H. Jackson Hale, based on inputs that were given to him by panel members after each workshop.

"The workshop on the National Solar Data Program was structured after the order of the earlier presentations. These included the National Solar Data Network and Thermal Performance reports, Control Systems Evaluation, Analysis of the Collector arrays, Architectural and Engineering Factors, Reliability, Maintainability and Materials Performance and Cost of Solar Energy Systems.

In Solar Data Workshop, about 20 percent of the attendees were designers. That is a little bit less than we had in the two previous conferences, San Francisco being 50 percent and Chicago 35 percent. Installers and contractors represented 5 percent of the participants here, contrasted with 15 percent at the other conferences. Representation of the local, state and Federal government at this conference was higher than the others. In this workshop, it was 40 percent. The number of solar manufacturing representatives was essentially the same, 10 percent. It is surprising that there were no testing agencies represented in the particular workshop. Owners were 5 percent and general solar interest people about 5 percent. The percentage of solar people having solar energy systems in their personal residence was 8 percent.

One of the issues that was raised concerns the selection of the sites scheduled to get instrumentation and become a part of the National Solar Data Network. DOE has developed a matrix for demonstration sites and is trying to select sites that will completely fill that matrix. It looks at such things as the climatic zones of the projects, the type of solar system (e.g., passive or active), the type of storage, the type of collector (e.g., flat plate, concentrated, evacuated tube) and so forth. There are some holes in the matrix, and DOE will try to fill them from the PON 3 projects.

The next issue was data availability. DOE makes data available immediately to all the site contractor personnel upon request to IBM, which has had a number of requests for individual plots of temperatures, flow rates and similar information. The people who have sites and who would like to have information of a specific nature can contact their representative at IBM. There is a site analyst that is responsible for each site, and the site people are encouraged to talk to him and ask him for specific information that they need. If difficulties arise, contact with DOE should clear things up. There is probably a reason why IBM cannot release the data requested and DOE will try to respond.

A lot of interest was expressed for weather data. DOE pointed out that all weather data collected in the demonstration program will be made available in the SOLMET format. There are 200 sites planned for National Data Network. Every one of those sites has climatological instrumentation and information will be made available.

The next issue was "lessons learned" availability. In effect, what was sked: "How can the information gained from the data program be made available?" DOE is beginning to publish solar bulletins. One that identifies all of the reports that have been prepared to date was handed out at this conference.

Copies of these are available from the DOE Technical Information Center.

"Also, DOE is in the process of preparing a number of conference papers of the type that were presented here. Most of the available reports have been taken by this time, but DOE has turned out thousands of documents in this series of conferences and expects to continue to do so.

"Another area concerned program-wide analysis. Attendees wanted to know whether DOE is going to compare collectors from one site to another. It certainly is and that information will be available this fall.

"With regard to the air-versus liquid systems, DOE will be publishing the performance of both types, using standardized reporting procedures that will allow comparison of air-versus-liquid. It was pointed out that the DOE does not take sides or say which one is best. It is going to publish the results and let the user draw his own conclusions.

"The next area was climatic regions. The question was asked: "Will we compare sites in one climatic zone versus another?" The answer was definitely yes. That was the intent in putting together the matrix of the type that was just discussed.

"The next area was passive systems. There seemed to be a widespread feeling or implication that DOE is not doing enough in passive systems. This is not due to any deliberate intent on the part of the DOE. DOE has had a relatively small number of proposals within the demonstration program that are passive systems. At the present time, it has six passive systems which are going to produce instrumented data. People want more information from those, and DOE will try to make it available as fast as it can. DOE just developed a new evaluation technique that will allow evaluation of passive systems in a manner that will lead to reasonable comparison between passive and active systems. That technique is reflected in the Kalwall report handed out at the conference. DOE expects to be making additional presentations on passive systems in upcoming conferences.

"There were some questions concerning the inclusion of multi-family residences in the program. As indicated earlier, DOE uses the same national data network to collect data from the residential projects as it does for the commercial projects. There are a number of multi-family residences and, based on the memory of the workshop panel members, the greater number of those residences include heating and hot water only. That is not through any deliberate action on our part, it is just the way the demonstration sites have become available.

"Control system evaluation was discussed next. The question was raised: "Are modulated system flow rates being evaluated?" This has to do with the dynamic-versus-static evaluation of solar energy systems. It was pointed out that currently there are no instrumented operational sites which have variable flow rates; and, therefore, DOE is not doing an evaluation of them. It would certainly welcome an opportunity to evaluate variable flow rates as such sites become available in the future demonstration projects.

"Another question was: "Are results being coordinated with controller manufacturers?" At the present time, principal discussions are held directly between the solar data program personnel and the site personnel. If DOE runs into a major problem, it certainly will go to the manufacturer and have some discussions of the problem; but DOE is principally interfacing with the site personnel and not the controller manufacturers. The DOE R&D Branch has a control system evaluation program underway at this time, so there is an active effort in the development and evaluation of control systems within DOE.

"The question was raised: "How will the results be disseminated?" Again, the answer is the same. DOE will be putting out solar bulletins and will be having additional conferences. It expects to publish a report on the control systems evaluations by the end of this year.

"A discussion of the analysis of collector arrays followed. A question was raised concerning collector performance as a function of geographic regions. It was pointed out that the curves that are derived from the filtered data are supposedly independent of geography. However, it was also pointed out that if there is any difference from one climatic region to another, it can be determined because DOE knows where each of the collector arrays is located.

"A question was raised concerning the availability of collector analysis software. At the present time the programs, that DOE has, exist as undocumented engineering tools subject to revision and expansion. They were developed as internal working tools. It is believed that the individuals who need such programs can develop them in a relatively expedient manner based on the equations that are given in the proceedings. The software that DOE developed is of course principally compatible with the particular computer system that its contractors use.

"There was a question concerning the evaluation of steady-state versus dynamic performance of collector arrays. DOE will be doing such an evaluation. That was discussed by Bill McCumber, and he indicated that the first results are scheduled to be published in November. The attendees were asked for suggestions for additional collector array data output. There were a couple of responses which were very worthwhile and DOE will consider them. One attendee suggested that DOE include a percentage of the time in each of the operating ranges, in other words, a histogram of the operating times at each of the operating points. This can be done from the data that are available and DOE will try to do so. It was also indicated that the collector array reports would be meaningful if DOE could give some of the collector design parameters; such as the absortivity, emissivity, the transmitivity of the glazings, and the insulating characteristics of the insulation. DOE will try to do that to the extent that it can. In many cases, it does not have all the information. That is information that the collector manufacturer has, and it is not always published. Many designers would like to design their own collectors or make their own assessment of other collectors and, therefore, need the parameters of particular collector design.

"The next area concerned Architectural and Engineering Factors. The question was: "Should the solar systems be specified separately from the remain-

der of the HVAC work?" It was a feeling of Steve Weinstein and Andy Parker that this should not be done. They recognized that many approaches are being used at the present, but they felt the solar piping should be specified with the rest of the piping. In other words, solar should not be separated from the remainder of the HVAC system with the exception that the specific solar equipment could be included in a separate specification.

"The next question was: "Is prebidding of collectors a viable approach for selection of collectors?" The answer was yes. However, attendees were cautioned that they should be careful that the cost per Btu includes the estimates for the entire collector installation, or they may not end up with the most cost effective system. The point is that they should consider prebidding, but consider the total installed cost of the collector, not just the collector itself.

"The next question was raised at every one of the conferences. "Will the information presented in yesterday's talk be available?" The audience was referring to the material that was presented by Steve Weinstein; the do's and don't's of the architectural and engineering aspects. The answer is yes. This information will be available partially in the proceedings that will be distributed. DOE also expects to publish a more comprehensive document by the end of the year.

"The question was raised: "Would a publication providing examples of good aesthetic design be of value?" The general consensus was that it would be of value to everybody. Therefore, DOE will try and pull together some of the projects that are aesthetically pleasing and publish this information.

"The next area was Reliability, Maintainability, and Materials Performance.

"A question was raised concerning availability of materials data on storage systems. The ANL data program will collect and publish this information as it becomes available from the demonstration sites. It was pointed out that throughout this program the information gathered comes directly from the demonstration sites. The Solar Data Program does not attempt to determine which materials would be better or worse. It merely tries to assess how well they perform in specific demonstration sites.

"Another question was raised concerning solar fluid corrosion inhibitors. It was pointed out that the ANL program includes in situ monitoring of the heat transfer fluid properties at a number of demonstration sites.

"Another question was asked concerning problems with solar collector absorbers and selective coatings. ANL is currently reviewing collector problems in addition to other system problems. Following that review, the most pressing problems will be given immediate attention. If DOE needs to look more closely at the absorber materials or the coatings, it will do so. Plans have not been developed as to specifically which part of the collectors need to be looked at in detail.

"The cost of maintenance was of interest to the attendees. It was pointed out that ANL is collecting the cost of maintenance data and this information will

be evaluated.

"There was considerable concern on control system reliability. ANL is evaluating this problem, and DOE anticipates publishing a report on its findings by March, 1979.

"Finally, we got into the area of Cost of Solar Energy Systems.

"There were two questions: "Will cost for operations, repairs and maintenance be determined?" and "Will the impact on fuel displaced in dollars be determined?" The same response applies to both. The system life cycle cost data will be determined and disseminated as it becomes available. DOE recognizes the need for this kind of information. It is one of the key goals for the program, and DOE will try to make it available as soon as it can. It is beginning to get information in terms of performance and in terms of cost. Of course, the maintenance cost information cannot be obtained until more experience with these systems accrues, but DOE will pull this together to the extent that it can and perform some life cycle cost studies.

"Another question was: "How will labor cost be identified?" DOE will identify labor cost in terms of time to install the system items and also by labor types. The specific labor rates will not be presented. The area labor rates can be applied so that they will be more meaningful. Labor rates vary significantly from one region to another and for that reason, DOE is electing not to put in the specific rates, but instead the time required to do a certain job and the type of labor to do it.

"The next question was: "Will cost trend data be provided?" The trend data by systems area will be available soon, and the trend data for system type-versus-time. DOE will have to collect these data over an extended period of time before it can do the latter type of trend analysis.

"The next question was: "How are costs developed?" That is, how does DOE build up cost data of the type that was presented by Bob Hedden? DOE builds it up in terms of raw cost for each item and for each region. It also builds it up with and without contractor overhead and profit. They indicate that the average values are used. Local values can be applied for each of these raw cost items.

"Another question was: "How will cost data be presented?" This information will be summarized in a design guideline format, and the cost data will be made available to sources such as the Dodge and Means estimating guides. They have indicated that this information will be included in one of their next publications. It should be of value to those who estimate solar systems cost.

"Another question was: "Are we going to be able to more closely identify where that knee occurs in the curve?" At the present time we don't have enough information to do that. We would like to be able to and as the information becomes available, we are going to try. We recognize the need for it. Almost every designer that I talk to points out that you don't squeeze every Btu you can get out of a system. It's not cost effective. Right now we

don't have enough information and we don't know in what form we should present the information when we get it. We recongize the need and we have a data base that will allow us to do that. When we can, we will.

"Another question was: "How are the results of the data program made available?" The attendees were encouraged to contact the National Solar Heating and Cooling Information Center in Rockville, MD. Their toll free number is (800) 523-2929. DOE tries to keep them posted on all the reports that are available. They can pass that information along as well as the information on how to get specific documents. In general, this information center does not hand out reports, but they have a listing on how to obtain them.

"I should also point out that we will use the "Solar Bulletins" more actively than we have in the past. They will be given a wide distribution and, as we prepare additional reports, those bulletins will be expanded. At the present time, our principal means of disseminating this information in the form of hard copies is the DOE Technical Information Center at Oak Ridge. As indicated in our workshop, all the reports that are developed under the demonstration program are given to the Technical Information Center for dissemination. At the present time we have a number of mailing lists, but they were developed for reasons other than just the Solar Bulletin. I have had a number of requests to be added to this mailing list and I have been telling people to contact the Solar Heating and Cooling Information Center to make sure that their name gets added to the mailing list."

APPENDIX A

ANALYSIS AND COMMENTS

ANALYSIS OF RESPONSES

An information sheet was developed for the Solar Update meetings to provide insights and information concerning the attendees and their interests. Among the areas sampled were the professions and technical interests of the attendees, their attitudes toward solar energy and various concerns and comments which they wished to relate. The following discussion provides an analysis of the information made available from the participant's responses.

General

The responses provided a wide diversity of opinions, attitudes, and interests. This was somewhat a reflection of the varied audience which attended the meetings and completed the information sheets.

Approximately one attendee in four completed the information form with over one-half (61 percent) of the participants having a background in engineering or architecture. Most of the comments received (about one-third) pertained to government policies toward solar energy. Additional interest (about one-third) was related to the Commercial Demonstration Program and the National Data Program and to the need for improved information and communication activities. The balance of the comments were divided between technical and hardware interests, concerns over cost effectiveness of solar energy, and institutional concerns including small business needs and regulatory issues.

The sample of interests related to solar energy placed emphasis on the design (44 percent) and construction (24 percent) aspects. Manufacturing of solar products, consumer awareness, and other interests accounted for the balance (31 percent) of the responses.

A majority of the respondees indicated that the future of solar energy was very promising and one-third expressed a need for more government support in this field. Only a small percent questioned the feasibility or the potential for utilizing solar energy to help meet future energy demands.

Increasing fuel costs, improved system costs, and tax breaks were cited as the primary factors to be considered as incentives to expand the application of solar energy. Design factors and warranties were indicated to a lesser degree High system costs were scored as a major obstacle to the use of solar energy at this time.

Over one-half of the respondees had not seen a solar demonstration project although some had been to several. Many of the attendees in Atlanta and Chicago took advantage of site tours made available during the conference.

A majority of those sampled indicated that the meetings had fulfilled their expectations and the speakers, workshops, and facilities were classified as good to excellent. The overall DOE Solar Heating and Cooling Demonstration Program received good to very good ratings.

Basic Themes from Comments

The following general themes are presented as extracted from the general comments:

- Continued government involvement and support is needed until the solar industry can "stand on its own".
- More contracts and grants are needed for small businesses in addition to grants for large established companies.
- More emphasis is needed on the philosophical and moral issues concerning the development of solar energy.
- Government involvement in solar energy programs should place emphasis on solar tax credits and improved insulation and conservation programs.
- More information is needed concerning methods for becoming involved in Federally funded programs.
- There is concern over the methods and quality of data dissemination based on results of the Demonstration Program.
- More media coverage of solar projects and applications is needed (TV specials, etc.).
- More simplified information packages are needed including "how-to-do-it" design and construction methods, practical and cost effective applications, lessons learned, and passive techniques.
- More small, local, and practical solar energy projects should receive attention and funding to broaden the demonstration base.
- Economic constraints are based on duplications of solar and conventional systems which compound the cost. Improvements in the installation and maintenance costs must be developed.
- Concern was expressed over several PON awards to individuals using components which they sell or represent. It was felt that projects should be awarded to contractors who apply the most cost effective approach.
- More attention should be given to passive, smaller, and more innovative systems in the future.

The DOE is reviewing all of the comments and information made available during the four meetings and is incorporating and implementing the various suggestions into its programs where possible. The attached information sheet format provides additional details concerning the responses.

THE DEPARTMENT OF ENERGY'S SOLAR UPDATE INFORMATION

FOR REGIONAL CONFERENCE PARTICIPATION

(SUMMARY OF ALL SITES)

Please identify your home city and state:

_____

Name (optional):_____

_____

Please indicate conference location:

/ / Atlanta

/ / San Francisco

/ / Chicago

/ / Boston

1. What is your profession/occupation?

1.	/ /	Architect	17%
2.	/ /	Engineer	42%
3.	/ /	Builder/Contractor	9%
4.	/ /	Realtor/Developer	1%
5.	/ /	Financier/Lender	---
6.	/ /	Insurance Representative	.3%
7.	/ /	Elected or Appointed Public Official	1%
8.	/ /	Government Employee (Federal, State or Local)	15%
9.	/ /	Solar Manufacturer	5%
10.	/ /	Educator	8%
11.	/ /	Other _____	

2. What is your prime interest in solar energy?

1.	/ /	Design	44%
2.	/ /	Solar Products Manufacture	9%
3.	/ /	Construction	24%
4.	/ /	Consumer	12%
5.	/ /	Other	10%

Please comment: _____

_____

3. What is your opinion on the future of solar energy?

1.	/ /	Very promising	62%
2.	/ /	Need more government support	31%
3.	/ /	Not technically feasible yet	7%
4.	/ /	No promise	0.7%

Please comment: _____

4. In your opinion, what are and will be the major incentives for increased solar energy applications? (Please use numbers for priority.)

1. /__/ Tax breaks 20%
2. /__/ Decreased installation costs 20%
3. /__/ Better designs 14%
4. /__/ Guarantees 8%
5. /__/ Increasing fuel costs 29%
6. /__/ Other 9%

Please comment: _____

_____

5. In your opinion, what are the major obstacles to solar energy applications?

1. /__/ Costs 57%
2. /__/ Lack of understanding 22%
3. /__/ Inconsistent and confusing reports 12%
4. /__/ Technology not ready 9%

6. How many Solar Demonstration Projects have you seen? _____

Please name 3 representative sites that you have seen:

a. _____

b. _____

c. _____

0 - 57%
1- 5 - 35%
6-10 - 4%
11+ - 4%

7. What motivated you to attend this meeting?

1. /__/ General interest 14%
2. /__/ To learn more about solar energy 21%
3. /__/ To learn more about the Commercial Solar Heating and Cooling Demonstration Program 16%
4. /__/ Came as your supervisor's representative 4%
5. /__/ To learn more about residential solar energy products 9%
6. /__/ To learn how to become involved in commercial solar energy projects through the Solar Heating and Cooling Demonstration Program 10%
7. /__/ To learn how to become involved in residential solar energy projects through the HUD residential program . . 7%
8. /__/ To gather information on how to design and construct a private commerical solar building 10%
9. /__/ To gather information on how to design and construct a private residential solar building 9%

8. Did the meeting fulfill your expectations?

1.	/__/ Yes	50%
2.	/__/ No	6%
3.	/__/ Partially	44%

Please comment: _____

_____

9. How do you rate the success of this meeting?

a. Speakers:

1.	/__/ Excellent	15%
2.	/__/ Very good	42%
3.	/__/ Good	30%
4.	/__/ Fair	11%
5.	/__/ Poor	2%

b. Workshops:

1.	/__/ Excellent	12%
2.	/__/ Very good	37%
3.	/__/ Good	34%
4.	/__/ Fair	15%
5.	/__/ Poor	2%

c. Conference facilities:

1.	/__/ Excellent	45%
2.	/__/ Very good	37%
3.	/__/ Good	12%
4.	/__/ Fair	5%
5.	/__/ Poor	1%

10. How many solar conferences have you previously attended?

1.	/__/ None	42%
2.	/__/ 1-4	43%
3.	/__/ 4-8	11%
4.	/__/ 8-12	1%
5.	/__/ over 12	2%

11. Would you participate in a federal solar project, if offered?

1.	/__/ Yes	84%
2.	/__/ No	2%
3.	/__/ Undecided	14%

12. What is your evaluation of the DoE Commercial Solar Heating and Cooling Demonstration Program?

1.	/__/ Excellent	14%
2.	/__/ Very good	33%
3.	/__/ Good	30%
4.	/__/ Fair	9%
5.	/__/ Poor	2%
6.	/__/ Unfamiliar with the Solar Demonstration program .	12%

Please comment: _____

_____

13. Based on what you heard, please add your comments and recommendations about the DoE Commercial Heating and Cooling Demonstration program:

_____

_____

_____

_____

_____

_____

_____

_____

_____

APPENDIX B

LIST OF ATTENDEES

LIST OF PARTICIPANTS

A - Atlanta, July 12-14, 1978 C - Chicago, July 19-21, 1978

SF - San Francisco, July 16-18, 1978 B - Boston, July 23-25, 1978

4 - Attended all four conferences

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APPENDIX C

PUBLICATIONS DISSEMINATED

During the Solar Update Conferences, a number of reports and documents, including a preliminary copy of the Proceedings, were provided to the participants. This 266-page document included reports on the Federal program and invited papers given at the four regional meetings (DOE Conference No. 780701). This Final Proceedings includes additional materials which were developed as a result of the various workshops, summaries and other results.

Additional materials provided to all participants of the Solar Update Conference included the following:

Solar Demonstration Program Contractors' Review Part I:

This is a summary of the various papers relating to the specific solar projects involved. It also includes an analysis of the workshops conducted on installation, construction, hardware procurement, operation-performance and economic-environmental issues (Conference No. 771229-R1, December 5-7, 1977).

Solar Demonstration Program Contractors' Review Part II:

This 538-page volume includes transcripts of keynote papers and speeches, and provides highlight analyses of the various workshops (Conference No. 771229-P2, December 5-7, 1977).

Demonstration Project Summaries, Vol. I:

This is a 264-page book on commercial and residential projects summarizing the design and operating characteristics, with brief descriptions of the buildings involved (DOE/CS-0009, May 1978).

Research & Development Project Summaries, Vol. II:

This 276-page book describes research and development on collectors, thermal energy storage, heat exchangers, heat pumps, solar cooling, controls and systems (DOE/CS-0010, May 1978).

Solar Heating and Cooling Project Experiences Handbook (Preliminary Issue)

This 112-page book summarizes the "lessons learned" from other experiences from the Commercial Solar Heating and Cooling Demonstration Program, including "do's and don'ts" of design, installation and operation (DOE/CS-004510, July 1978).

Copies of these publications can be obtained from the U. S. Department of Energy Technical Information Center, Publications Department, P. O. Box 62, Oak Ridge, Tennessee 37830.

In addition, a number of documents resulting from the National Solar Data Program were distributed. Included were project descriptions and performance evaluations of various solar energy projects now being evaluated across the country.

APPENDIX D

PROGRAM AGENDA

PROGRAM AGENDA

THE DEPARTMENT OF ENERGY'S
SOLAR UPDATE

Atlanta, July 12-14; San Francisco, July 16-18;
Chicago, July 19-21; Boston, July 23-25, 1978

First day:
4:00 -
8:00 p.m. Registeration and Reception

Second day:
8:00 a.m. Introduction/Program Outline
8:15 a.m. Solar Demonstration Program Overview
8:45 a.m. Heating and Cooling Project Experiences from Contractors' Program Review
9:45 a.m. Coffe Break
10:00 a.m. Invited Papers
11:45 a.m. Lunch
1:15 p.m. Solar Data Program
3:10 p.m. Coffee Break
3:30 -
5:00 p.m. Solar Data Program (cont.)

Third day:
8:00 a.m. PON III Management Briefing
9:00 a.m. Workshop I: Demonstration Program Discussion/
Workshop II: Solar Data Program Discussions
9:45 a.m. Coffee Break
10:00 a.m. Workshop I (cont.)/
Workshop II (cont.)
12:00 p.m. Lunch
2:00 p.m. Workshop Summaries
3:00 -
3:30 p.m. Closing Remarks

Luncheon Speakers:

Atlanta -

Wayne Parker, Solar Energy Coordinator, Office of Energy Resources, State of Georgia.

Roy Pettit, Acting Regional Representative, U.S. Department of Energy, Atlanta, Georgia.

San Francisco -

John Yellott, visiting Professor in Architecture, Arizona State University.

Wilson Clark, Assistant to the Governor for Issues and Planning, State of California.

Chicago:

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