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FINAL REPORT OF THE MANAGEMENT SUPPORT CONTRACTOR
FOR THE
RESIDENTIAL SOLAR HEATING DEMONSTRATION

VOLUME I. MANAGEMENT SUPPORT ACTIVITY

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by

BE&C Engineers, Inc.

(A Boeing Subsidiary)

for

Office of

Policy Development & Research

Department of Housing and

Urban Development

The research and studies forming the basis for this report were conducted pursuant to a contract with the Department of Housing and Urban Development (HUD). The statements and conclusions contained herein are those of the contractor and do not necessarily reflect the views of the U.S. Government in general or HUD in particular. Neither the United States nor HUD makes any warranty, expressed or implied, or assumes responsibility for the accuracy or completeness of the information herein.

PREFACE

This volume is one of five composing the final report written by BE&C Engineers, a Boeing subsidiary. Under contract to the U.S. Department of Housing & Urban Development (HUD), Boeing provided management support for the Residential Solar Heating Demonstration. The demonstration, part of the National Program for Solar Heating and Cooling, began in 1975. During the next four years, HUD awarded over 900 grants to builders/developers who were to install solar systems on dwellings new or retrofitted; 497 grants actually resulted in construction.

Volume I gives the general history of the demonstration from the contractor's viewpoint. The other volumes cover specific technical issues:

Volume II--Solar Repair Program
Volume III--High Temperature Exposure of Wood Structures in Solar Systems
Volume IV--Corrosion Problems
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ABSTRACT

This report details Boeing Company activities as management support contractor for the Residential Solar Heating and Cooling Demonstration program administered by the U.S. Department of Housing and Urban Development (HUD). HUD, under direction of laws established to encourage solar energy, awarded grants for the purchase and installation of solar heating and cooling equipment. Boeing assisted HUD in the award of 943 grants by making technical and feasibility reviews of the 3,837 applications and by providing administrative and planning support. Boeing field representatives provided liaison for the installation of solar systems in over 10,000 residences throughout the 50 states.

Boeing and its subcontractors gathered data about the solar installations, grantee experiences, utility consumption, consumer acceptance, and operating problems. These data were computerized for use and analysis. Boeing also designed and installed instrumentation, connected to the National Solar Data Network, that measured performance in 83 solar systems. Finally, Boeing carried out repair or removal of solar systems in over half the grant projects.

Many active space-heating systems experienced degradation or failure. Few active systems showed the reliability that consumers expect of heating plants. Domestic hot water and passive systems were better.

EXECUTIVE SUMMARY

Public Law 93-409, "Solar Heating and Cooling Demonstration Act of 1974," created a vigorous Federal program of research, development, and demonstration to establish solar energy as a viable resource for the nation. In the course of hearings and debate while this law was being formulated, proponents maintained that solar technology was developed, available, and suitable for use in both residential and commercial applications. Others maintained that the state of the art was not suitable for widespread use and that the solar "industry" lacked adequate system testing and standards for other than individual components and also lacked the production, installation, and service infrastructure needed. The U.S. Department of Housing and Urban Development (HUD) expressed concern that a large-scale residential demonstration posed a significant risk to unsuspecting and unknowledgeable consumers who would be encouraged to purchase solar-heated homes relying only on the Federal government's "involvement and sponsorship."

The program was implemented, however, with the basic goal of creating a self-sustaining residential solar industry, if possible, upon completion of the five years of demonstration. Objectives were to encourage the use of solar energy, identify potential constraints to its use, and develop approaches to remove these constraints. The Department of Energy (DOE) and HUD shared responsibility for accomplishing these goals and objectives. HUD managed and coordinated the residential demonstration program while DOE maintained an overview. HUD's responsibility involved four major tasks: 1) conducting the demonstration, including data collection, 2) developing industry standards, 3) developing the market, and 4) disseminating information.

HUD selected the Boeing Aerospace Company (now BE&C Engineers) in January, 1976 to assist in conducting the program. This document is the final report, submitted as required in the HUD-Boeing contract, detailing the work performed for HUD. Other contractors and government agencies provided prime support to HUD in such areas as information dissemination and development of industry standards.

Boeing subcontracted with three firms to provide supplemental capabilities in specialty areas. Dubin-Bloome Associates provided technical expertise on solar technology and applications, AIA Research Corporation provided architectural expertise, and Real Estate Research Corporation provided non-technical data collection and marketing analysis services. The management support contractor role embraced three general task areas: grant management support, data collection and analysis support, and solar repair support. Major activity by Boeing under the management support contract ended in 1983.

GRANT MANAGEMENT

HUD awarded grants through eight formal, national, competitive solicitations. Grants provided funds for the purchase and installation and, in some cases, the design of solar heating and cooling equipment in residences. The grants were given to builders/developers, housing authorities, universities, local governmental agencies, and similar organizations throughout the United States and its territories.

Individuals or firms agreed to install solar equipment in dwellings that were to be sold or rented on the open market. Grants were awarded in cycles starting in early 1976 and running through late 1979, to allow new technologies to be included in the program as they were developed. Table S-1 gives the summary statistics for each grant cycle. It includes the number of applications received, number of grants awarded, and other important program indicators.

HUD's basic approach was to maintain a hands-off position with respect to the grantee's decision-making processes. HUD deliberately did not become involved in the selection of the solar system and the attendant design relative to the house and solar system integration. When potential problems were noted in the review of grantee proposals, HUD prepared a list of "technical concerns" for the grantee's consideration. Once the grants were awarded, Boeing field representatives throughout the U.S. provided on-site grant management assistance for HUD. They maintained continuous liaison with the individual grantees, reported project status, and assisted the grantees as requested, in a strictly advisory posture. They also kept a record of each project, took photographs at the various sites, reviewed and approved progress reports and grantee invoices for further processing by HUD, and were the primary point of contact between the grantee, HUD, and other program participants. Chapter 3 describes the grant award and administration process.

DATA COLLECTION AND ANALYSIS

Data collection, analysis, and dissemination was an important task in HUD's Residential Solar Heating Demonstration program. Data, both technical and non-technical, were gathered from a large number of projects on a national scale, processed, and analyzed. The results were disseminated by others to all parts of the residential "industry" as well as to residents, builders, lending agencies, and local government agencies.

Boeing collected data that described the solar systems and dwelling units included in the program and the people or firms responsible for design and construction. These data also described the experiences of the grantees in the areas of schedules, construction, testing, and marketing. Utility consumption data were collected from about one-quarter of the grants, affording an insight to the economics of solar heating.

Some grants were instrumented as part of the National Solar Data Network. A variety of sensors monitored system performance and operation. Boeing assisted in the selection of these projects, designed instrument installations, procured the instruments, and provided technical assistance during the installation. Land lines fed the instrumented data to a facility operated by a DOE contractor for processing and analysis. To aid in the analysis of the system performance and for future assessment of maintenance and repair trends, detailed technical descriptive data were collected on each instrumented system. To complete the data base on the instrumented systems, non-technical data were also collected on most of the instrumented residences, the exceptions being those projects that would not produce pertinent non-technical data.

Other projects were chosen for non-technical data collection too. Non-technical data, collected by means of interviews and surveys, covered market activities,

TABLE S-1
SOLAR PROGRAM INFORMATION

CYCLE (GRANT NO.)	RFGA AVAIL. (RELEASE DATE) (NUMBER RELEASED)	APPLICATION DUE DATE (NO. APPL. REC'D)	AWARD ANNOUNCED DATE	SELECTED FOR AWARD			AWARDED			DELETED OR MODIFIED			CONSTRUCTED OR IN PROGRESS		
				NO. OF GRANTS	NO. OF UNITS	NO. OF SYSTEMS	NO. OF GRANTS	NO. OF UNITS	NO. OF SYSTEMS	NO. OF GRANTS	NO. OF UNITS	NO. OF SYSTEMS	NO. OF GRANTS	NO. OF UNITS	NO. OF SYSTEMS
CYCLE 1 H-2423 - H-2477	SEP. 26, 1975 5,000	NOV. 10, 1975 250	JAN. 19, 1976	55	142	106	49	136	100	9	23	11	40	113	89
CYCLE 1 SITE-SYSTEM H-2593 - H-2604	MAY 14, 1976 IDENTIFIED 170 CANDIDATE BLDR.	JAN. 15, 1976 25	JUL. 26, 1976	12	44	46	12	44	46	4/2**	22	22	8/10**	22	24
CYCLE 2 H-2701 - H-2801	JUL. 14, 1976 (JUL. 1, 1976) 8,000	SEP. 11, 1976 308	OCT. 15, 1976	102	1,411	338	95	1,400	331	25	110	78	70	1,290	253
CYCLE 3 H-8015 - H-8212	JAN. 24, 1977 (JAN. 3, 1977) 17,000	MAR. 29, 1977 707	MAY 31, 1977	169	3,475	502	167	3,444	498	22	351	83	145	3,093	415
CYCLE 4 H-8301 - H-8348	NOV. 1, 1977 OCT. 26, 1977 15,000	JAN. 16, 1978 525	MAR. 31, 1978	48	2,002	81	48	2,002	81	12	293	23	36	1,709	58
CYCLE 4A H-8350 - H-8445	MAR. 31, 1978 (MAR. 31, 1978) 25,000	AUG. 1, 1978 457	SEP. 30, 1978	96	4,848	300	95	4,408	299	20	791	63	75	3,617	236
PASSIVE DESIGN COMPETITION H-8601 - H-8762	MAY 15, 1978 (MAY 1, 1978) 5,000	AUG. 8, 1978 555	DEC. 20, 1978	162	262*	262	162	262*	262	0	0	0	162	262*	262*
PASSIVE DEMO. H-8601A - H-8762A	MAY 15, 1978 (MAY 1, 1978)	AUG. 8, 1978 555	DEC. 20, 1978	80	126	126	79	125	125	25	46	46	54	79	79
CYCLE 5, STEP ONE HG-8801 - HG-8939	FEB. 7, 1979	APR. 26, 1979 880	MAY 17, 1979	139	550*	221	136	547*	218	6	14*	8	130	533*	21
CYCLE 5, STEP TWO HG-9201 - HG-9339	-	AUG. 21, 1979 130	SEP. 28, 1979 NOV. 16, 1979	105	321	165	100	316	159	31	141	58	69	175	101
GRAND TOTALS		3,837		968	12,369	2,147	943	11,875	2,119	154	1,777	392	791 ***	10,098	1,255

* DESIGNED BUT NOT NECESSARILY BUILT AND NOT INCLUDED IN GRAND TOTAL

** SITE SYSTEMS, 2 GRANTS RECEIVED DESIGN-ONLY AWARDS

*** INCLUDES 497 GRANTS THAT WERE BUILT AND 294 DESIGN-ONLY COMPLETIONS public acceptance, financing, utility costs, repair and maintenance, and various other subjects. For these additional projects, technical descriptive data were also collected.

The above data (excluding the instrumented data) were collected by Boeing and loaded into the Solar Data Center Database operated by the National Bureau of Standards (NBS). The Database comprised a system of computerized records that were accessible via on-line interactive request or by printouts. These data were used to establish a record of performance and cost; for development of design manuals and criteria, property standards, and regulations; and for other related purposes. In addition, the data aided in program decisions, inductive analysis, design studies, market promotion, financial studies, and responding to consumer questions. Chapter 4 presents a complete description of the data acquisition and analysis tasks.

PROGRAM MANAGEMENT

As more fully set forth in Chapter 2, Introduction, Boeing also provided HUD with program management services. Schedules were prepared for each cycle of the program. A target number of projects per cycle was established. A substantial effort was expended in supporting HUD with the grant award process, including preparing Request for Grant Application packages, distributing over 80,000 copies to potential applicants, receiving and evaluating 3,837 applications submitted, and preparing the 943 grants. HUD awarded nearly $23 million in grants, representing over 12,500 solar-heated homes.

Boeing assisted HUD with a program-wide system of communications between grantees, field representatives, and HUD. We supported HUD in planning periodic program reviews with all program participants, and in planning and executing presentations made for the program. We provided program information and visibility services. A program control center in Seattle and a solar work room in Washington, D.C., were established to receive, post, and retain program status. Program schedules, configuration, and progress were evaluated to identify problems, and recommendations made for their resolution.

In addition, Boeing coordinated, as directed by HUD, the residential program activities with the commercial DOE and residential Defense Department programs as well as with NBS and other DOE contractors that were undertaking special studies or supporting the instrumentation activity.

SOLAR REPAIRS

Perhaps the most significant program task was the effort ultimately expended in making solar repairs. There was no specific plan in the demonstration program for a repair activity, though HUD did establish a contingency fund for catastrophic situations. The original idea was to conduct and complete the demonstration and leave a residential solar industry in place which could respond to free market demands. However, before the demonstration could be completed, significant information regarding system failures began to reach HUD and a formal program for investigation and repair was started.

An inordinately high percentage of the total number of solar systems in the demonstration program required significant repair, replacement, or removal action due to serious operating problems. Of a total of 1,255 systems in the program, 599 (48%) have been the subject of one or more System Operating Problem Reports. All of these systems required at least some technical assistance; most required major repair. These problems primarily arose "out of warranty," when the manufacturer/installer could not respond to a remaining warranty obligation because of business failure, or refused to respond because of claimed shifting of the problem responsibility.

Collectively, these systems depict a horrendous consumer problem. We have no reason to believe that this experience was limited to those systems supported by HUD grants. The probability is that most residential systems delivered in the open market area during this period are in a similar circumstance (or worse, not having had the degree of technical support that the grant systems had). Furthermore, HUD consumer surveys conducted by Real Estate Research Corporation during the course of the demonstration indicate a general lack of problem perception by the consumer until a major failure occurs.

In assessing the severity of this problem, the reader should be aware that <u>no</u> performance survey was made of <u>all</u> of the systems in the program. Initially, the problem reports emanated from grantee/consumer complaints or from indications in instrumentation records of operating anomalies. Most complaints concerned active space-heating systems. Because of the growing number of these complaints, HUD directed Boeing/Dubin-Bloome to make surveys of all active space-heating systems that might have one or more of three potential deficiencies:

1. hazardous collector materials (foam insulation in contact with absorber plates, flammable structural materials such as redwood frames, or plywood backing)
2. solar attics (a portion of the attic serving as an air collector box and thus subject to severe overheating)
3. liquid space-heating systems that showed serious corrosion potential (dissimilar metals, open-to-atmosphere piping loops, or steel tanks)

No general survey was made of passive systems, air heating systems, or large domestic hot water-only systems. Such systems were included in the repair program only if grantee/consumer complaints reached us or if instrumentation anomalies indicated a problem. On that basis also, there was significant repair/removal activity. Chapter 5 sets forth a complete summary of the solar repair program.

PROGRAM PHASING

Figure S-1 shows the general phasing of the management support contractor's tasks. The intense activity required to plan each grant cycle and evaluate the applications was accomplished in the first four years of the contract, 1976-79. Over 90% of the grantees had completed construction within approximately two years after grant award. The data collection task was largely accomplished from 1977 through 1980. By 1980, the repair program had become the most important activity and was, by 1982, virtually the only activity.

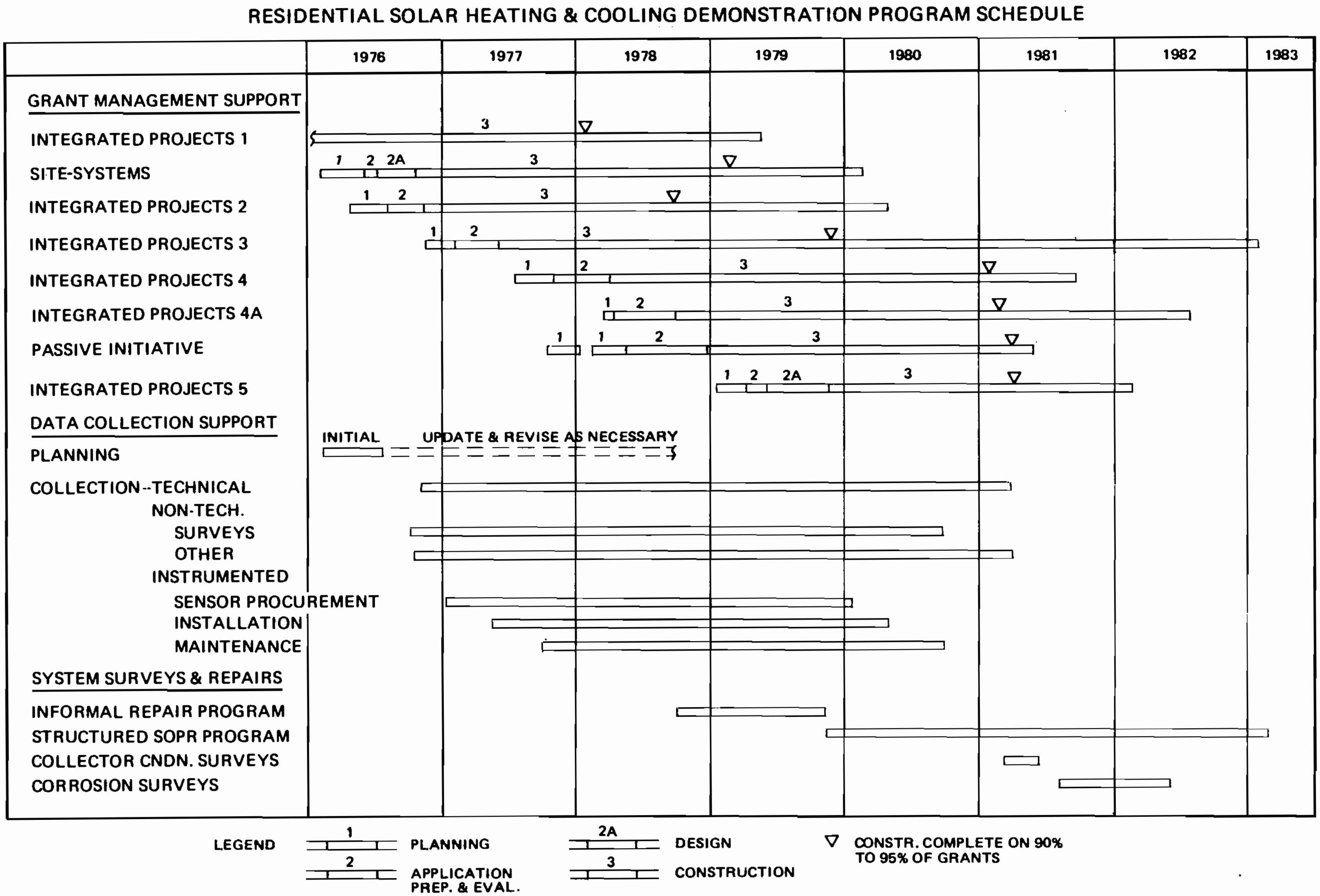


Figure S-1. Phasing of Management Support Contractor's Tasks

CHAPTER 1. BACKGROUND

In order to place into perspective the origin of the Residential Solar Heating Demonstration program and its goals and objectives, it is necessary to refer back to 1973. At that time, in response to the Arab oil embargo and the resultant shortages and rapid price increases, various strategies began to develop which would reduce our dependence as a nation on the use of non-renewable energy resources. The primary emphasis was on reducing oil consumption, with particular attention to imported oil.

Committees in the Congress began hearings on the subject of energy independence. One of the results was a national program to encourage the use of solar energy to a point where, by the year 2000, solar energy applications could provide a significant part (at least 10%) of the energy consumed in heating and cooling an estimated 75 million commercial and residential buildings. By that time, such consumption was estimated to account for 20% of the total energy used in this country.

PUBLIC LAW 93-409

To implement the program, the Congress passed several legislative acts which the President signed into law. Among those, and of particular relevance to this report, was Public Law 93-409, "Solar Heating and Cooling Demonstration Act of 1974." This law, signed on September 3, provided for a number of research and demonstration programs dealing with solar energy and gave overall authority for such activity to the Energy Research and Development Administration (ERDA), which has since became the Department of Energy (DOE). ERDA was named as the lead agency to authorize and conduct various research, development, and demonstration activities either directly or in cooperation with other Federal agencies. The legislation gave the Department of Housing and Urban Development (HUD) the direct responsibility to plan and conduct the residential demonstration that had been mandated.

In the course of the hearings and debate, as Public Law 93-409 was being developed, proponents of the commercial and residential demonstration programs, both in the Congress and the fledgling "solar industry," maintained that the time for a marketplace demonstration was at hand. They claimed that the technology for commercial and residential solar systems was known to the "industry," that the products of this technology were in manufacture and were available, and that the advent of a significant and large demonstration program would provide the impetus for the solar industry to move quickly to the point where it could provide economically viable and technically reliable solar systems on a large-scale production basis.

During the hearings, there were those whose testimony questioned the advisability of such a large demonstration, as compared to additional research and development activities and a much smaller, more controlled demonstration program. HUD was a principal spokesman for this point of view, questioning not only the state of the art, but the state of the industry and its apparent lack of a reliable design, production, installation, and service infrastructure.

HUD pointed out that there were few among the current manufacturers who were approaching the marketplace with a system-delivery approach, preferring rather to sell glazings only, absorber plates only, manufactured collectors only, or various and sundry system parts such as pumps, piping, tanks, and controls. There was then little or no involvement by these manufacturers with the design of systems in which their products would be used or the manner in which they would be installed. For the most part, the only formal ties to the installation community were loosely drawn distributorship arrangements, primarily with established local residential and commercial HVAC (heating-ventilating-air conditioning) contractors. These contractors, despite their otherwise deserved reputations for capability, lacked solar understanding and expertise.

As for system components (collectors, pumps, tanks, etc.), there had been little or no developmental testing or concerted design evaluation of the propriety, relationship, and compatibility of the various products within a given solar-system environment. Certainly, various manufacturers performed design evaluations and performance tests of their particular products, but such evaluations and tests were of the individual manufacturer's concept. There were no developed industry standards, not even of an interim nature, for evaluating and testing solar components or systems, and therefore no basis for meaningful component or system comparison that would determine product reliability and suitability.

Lastly, in its concern over a large-scale marketplace demonstration, HUD cited the problem which the fractionated posture of the "solar industry" posed with respect to reasonable and enforceable purchaser warranties and the availability of knowledgable maintenance and repair organizations to provide services both during and after warranty expiration. In short, HUD felt that all of the foregoing concerns constituted a significant risk, of possible catastrophic proportion, to unsuspecting and unknowledgable consumers who would be encouraged to purchase homes with demonstration systems, simply relying on the Federal government's "involvement" in and "sponsorship" of the proposed demonstration projects as an assurance of reasonable consumer choice. Such reliance would place HUD and the Federal government in an unwarranted position of having at least a moral liability for faulty consumer choices.

The Congress opted for a large-scale demonstration, however, and passed Public Law 93-409, which mandated major commercial and residential demonstration programs. In recognition of the various concerns that had been expressed, the law provided for concurrent activity by various Federal agencies in further research and development. Interim performance criteria were to be developed and published. Test procedures were to be developed, and a contingency fund set aside for maintenance and repair of delivered systems. Other work included industry coordination and monitoring, data collection and dissemination, training programs for design and installation, and performance monitoring.

PROGRAM GOALS AND OBJECTIVES

The primary goal of the residential demonstration program, in response to Public Law 93-409, was to provide for the growth of residential use of solar energy, in both new and retrofit construction, to the point where upon completion of the program, there would be a viable, competitive solar industry in place which could respond to increasing demand for reliable solar products in the marketplace. The main objectives to be met in reaching that goal were as follows:

- o encourage industry to develop improved and lower cost equipment
- o identify the potential institutional barriers to the widespread use of solar heating and cooling in residential applications, and recommend potential solutions to removing these barriers
- o provide a data base of technical information about hardware characteristics, in-use performance, and acceptability
- o provide industry and regulatory bodies with some of the experience necessary to enable them to continue use of solar energy in residential buildings after the program's end
- o identify solar equipment available to be incorporated into new dwelling units and retrofitted into existing ones
- o demonstrate available solar hardware through incorporation in new dwelling units and retrofitting into existing ones

This report will discuss the manner in which the residential demonstration program addressed these goals and objectives.

CHAPTER 2. INTRODUCTION

This report documents the activities, findings, and conclusions of the management support contractor for HUD's Residential Solar Heating Demonstration program. It discusses the experiences of the support contractor and its subcontractor team pertaining to a) grant management support activities, b) data collection and analysis, c) solar system repair activities, and d) conclusions. The report has been prepared by BE&C Engineers, Inc., a Boeing subsidiary, which is the successor to Boeing Aerospace Company for HUD contract H-2372 awarded in January 1976. The succession resulted from an administrative change and did not affect the personnel makeup of the organization that performed the contract work from inception through to completion.

PROGRAM METHODOLOGY

Development of a viable solar industry with established marketing ties to the builder/developer community was an absolute necessity for the ready acceptance of solar products in the marketplace. Such acceptance was the key to meeting the program goals. Therefore the program had to be structured in a manner that would stimulate direct interaction of the two "industries," both of which are highly fractionated and diverse, with encouragement and overview from the Federal establishment. However, there were certain demonstration concerns which suggested that particular system concepts should be demonstrated in prescribed locations where given systems were most suitable for reasons of technical performance. These considerations led to a program plan based on two types of demonstrations—Integrated Projects and Site-Systems Projects—which are briefly summarized below.

Integrated Projects involved soliciting applications from builder/developers, in any location, that proposed to build projects with solar-energy systems. In each case, the builder had selected a particular system and incorporated it into the proposed project design.

Site-Systems Projects involved soliciting applications from builders in specific areas of the country determined by a system/location matrix. These applications were expected to propose projects on which the builders were willing to include solar systems prescribed by HUD and would, following project awards, integrate the design of those systems into the building plans and proceed with construction.

HUD elected to use a grant program for both project types. Successful builder applicants were awarded lump-sum grants for all or a portion of the added project costs directly attributable to the design and installation of the solar system. In choosing the grant approach, as opposed to contracting for the construction of the project or the solar system, HUD was able to avoid direct involvement in the market process and the construction. The designer, builder, and solar equipment contractor functioned in a normal private-market atmosphere. HUD provided a stimulus to both the solar and homebuilding communities without interrupting the normal relationship between supplier and builder. In this way, the department could oversee project status and give technical assistance, when requested, on a more-or-less hands-off basis. The developing market forces were left to work in the manner that would be required of a future self-sustaining industry, which was the goal of the demonstration program.

The mechanics of the entire grant process are discussed in Chapter 3, Grant Management. HUD awarded 943 grants during the residential demonstration. When adjustment is made for those grants that were for design only and grants that were annulled or terminated, 497 grants actually resulted in construction. Figures 2-1, 2-2, and 2-3 recapitulate, graphically, the construction grants by cycle. They show that the 497 grants resulted in the construction of 10,098 living units, using 1,255 solar systems.

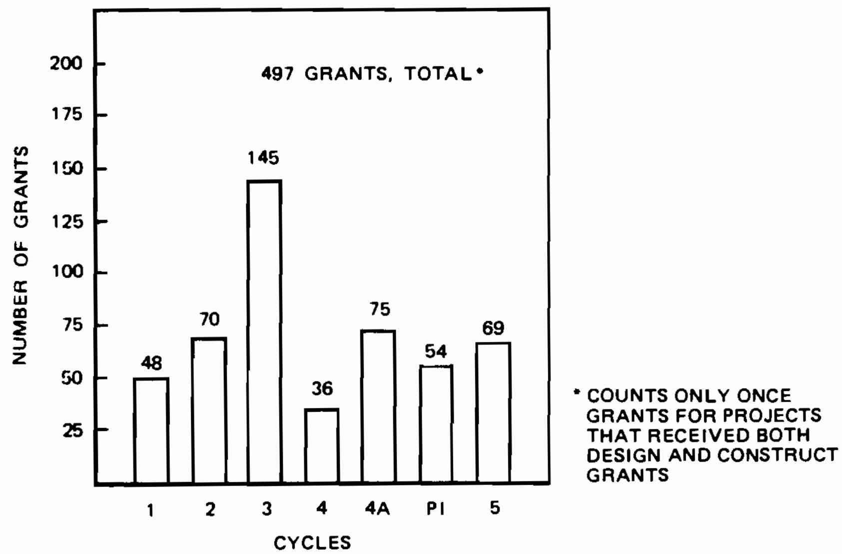


Figure 2-1. Number of Grants Constructed per Cycle

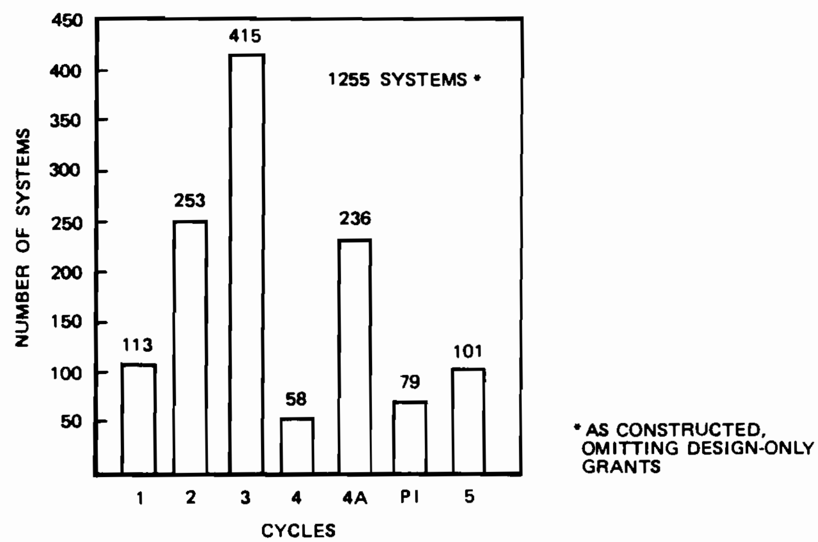


Figure 2-2. Number of Systems Constructed per Cycle

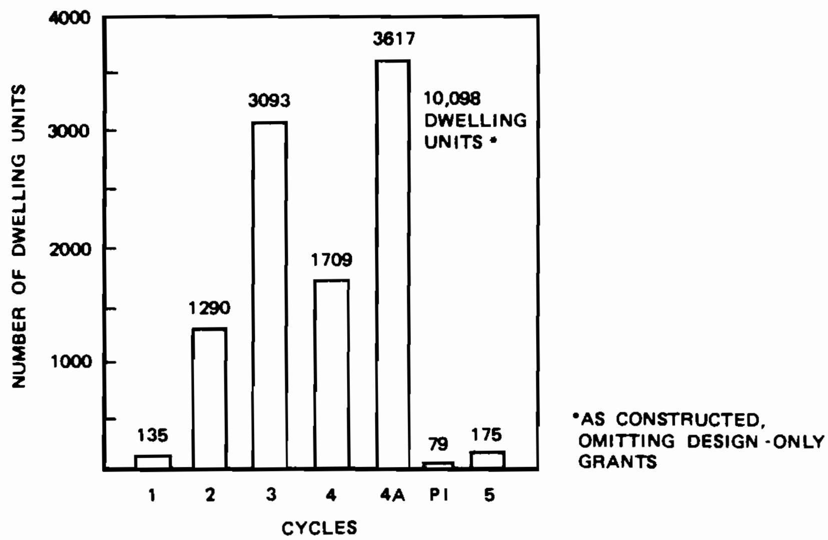


Figure 2-3. Number of Units Constructed per Cycle

PROGRAM MANAGEMENT

HUD managed the demonstration program through the office of the Assistant Secretary for Policy Development and Research, Division of Energy, Building Technology and Standards Research. To assist the HUD staff, a management support contractor, now BE&C Engineers, Inc., was engaged to provide support services including:

- o establish and maintain a program control center to receive, post, and retain program status reports, and establish procedures for analysis of program status versus schedules
- o provide advice and professional expertise in the evaluation of solar project applications and assist in developing program plans and scopes of work and in preparing project grants
- o maintain continuous liaison with individual local grantees/contractors on project status and reports, and assist in the resolution of local project problems as directed by HUD
- o provide support to local project developers during project construction, solar-system installation, and project marketing, and arrange for local system testing, maintenance, and services as directed by HUD
- o establish procedures and coordinate with all agencies and contractor organizations that interacted with the residential demonstration program, including the National Bureau of Standards (NBS) for collecting project data and developing performance standards and the National Aeronautics and Space Administration (NASA) and DOE for installating instrumentation and other related project activities
- o assist in the selection and use of design integration consultants
- o monitor the design integration process, and provide contractual support and direction
- o provide for instrumentation design, and furnish instrumentation packages to

selected local grant projects

- o carry out various technical and non-technical data collection and analysis activities, and assist in the development of a solar data base
- o develop survey instruments and procedures to obtain data on consumer acceptance, financing practices, building code approvals, operating experiences, and similar non-technical issues
- o recommend procedures for and manage a repair program for solar systems that affected grantees or consumers reported as problem systems, conduct surveys and inspections to identify such problem systems, provide repair designs, and contract for the necessary corrective effort as directed by HUD.

In performing these services, Boeing was supported by three major subcontractors.

Dubin-Bloome Associates, P.C., of New York City and Hartford, Connecticut, provided the basic expertise in solar-system evaluation and application. DBA participated in all technical reviews, including post-award grantee reports and provided support to field personnel in the checkout, problem evaluation, and repair/removal of problem systems.

Real Estate Research Corporation of Chicago and Washington, D.C., (and other locales not involved in this contract) assisted with the non-technical evaluation of grant requests and with the development of survey instruments primarily for marketing data and consumer acceptance. In the post-award period RERC conducted various planned surveys, prepared interim reports, and provided general assistance in the area of non-technical data collection and analysis.

AIA Research Corporation, in Washington, D.C., is the research adjunct of the American Institute of Architects. Its program responsibility was to provide basic expertise in solar-system evaluation and application from the architectural point of view. AIARC participated in all technical reviews, including post-award grantee reports for passive systems, provided occasional support to field personnel, and prepared descriptive documents for each project cycle. It identified and engaged design integration consultants and furnished related descriptive material. It provided a conduit to the solar community for assistance in engaging consultants to help with grant application reviews .

In addition to the foregoing, Boeing retained a number of other small contractors and individual consultants. HUD made a conscious effort to provide a maximum involvement of the solar design community and others in finance, law, and building construction. The purpose was to maximize the learning experience and business opportunity, thereby fostering the industry's maturation. Manufacturers and designers whose products were used in the various grants were not involved in the evaluation processes for obvious conflict-of-interest reasons.

Following chapters of this report set forth the program operations in subjective detail. Figure 2-4 is an illustration of the overall schedule, task activities, and phasing.

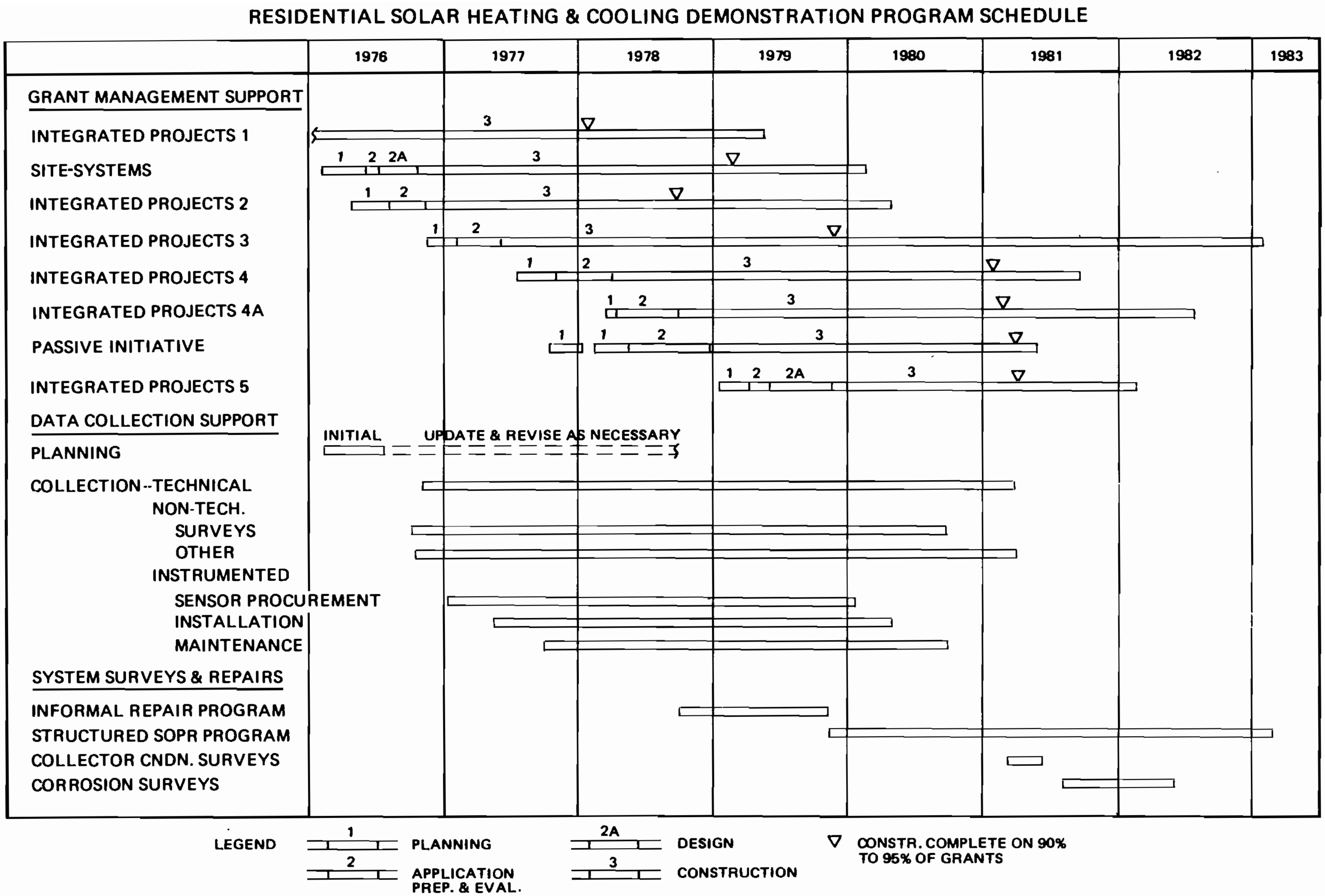


Figure 2-4. Phasing of Management Support Contractor's Tasks

CHAPTER 3. GRANT MANAGEMENT

As previously indicated, HUD's primary goal in the program was to help to create a self-sustaining residential solar industry by the end of the five-year demonstration period. The implication of a self-sustaining industry is one that could respond to market forces and consumer demands without interference or direct support from the government sector. In order to encourage that mode of growth and development from the start, HUD elected to use a system of grants, for partial project sponsorship. The grant mechanism provided a means of furnishing financial and technical incentives for the demonstration of solar hardware, without involving HUD in a direct contractual responsibility for the choice of equipment, its integration in a project design, or the construction of the project. Except for the financial incentive, the solar supplier-builder/developer relationship was allowed to function as it would in a free-market situation. Grants were awarded which generally provided the applicant with all or a part of the cost for the solar aspects of his project.

This chapter will discuss the nature of the grants and, in some detail, various aspects of the grant management task performed by Boeing.

DESCRIPTION OF GRANTS

Basically, there were three categories of grants.

Site-Systems Projects—involving applicants from specific locations, determined by HUD, who were willing to build a project using a HUD-prescribed system that the applicant would integrate into the design.

Integrated Projects--involving applicants from any locale who wished to build a project for which they had chosen a particular solar system and had incorporated such system design into the proposed construction project.

Design-Only Projects—involving applicants who were willing to produce a design for a passive residence and allow HUD to publish the design for use by others.

There were eight separate series of grant awards: Cycles 1 through 4, 4A, and 5 for Integrated Projects, a Passive Design Competition, and one series of Site-Systems Projects. (Figure 2-4 showed the phasing and time periods of the various cycles.)

With the exception of the Site-Systems series, all of the competitive solicitations were open to applicants from any place in the United States, its territories, and possessions. Site-Systems awards, because of the program design described in this chapter, were limited to 10 of the 510 State Economic Areas (SEA)* in the country and were intended to be competitive only within the SEA.

In all, HUD awarded a total of 943 grants. However, due to changing housing market conditions, pricing increases, business failures, and various other circum-

*as defined in the Bureau of the Census publication PC(2)-10B stances beyond control, some grants were not accepted when tendered, or were later annulled or terminated. When the above total is refined for those actions, and for the grants that covered design only, 497 of the grants actually resulted in construction. The 497 grants produced 10,098 living units, using 1,255 individual solar systems.

GRANT APPLICATIONS AND AWARDS

Grant procurement was handled under three format variations.

Site-Systems Projects

The original plan for Site-Systems (SS) demonstration projects called for a once-a-year cycle of awards, involving 50 sites over a five-year period. Each of the sites was chosen from a pre-selected group of SEAs. The various types of systems to be demonstrated at each site were pre-determined. The basis for site and equipment selection is defined in a report prepared for HUD by Arthur D. Little, Inc. (Reference 1, on the list that follows Chapter 5 of this volume). Essentially, the purpose of the matrix plan for the demonstration was to match comparative types of systems to areas of the country where optimum system performance could be expected, thereby allowing a realistic cross-evaluation, by area, of system suitability. It was also originally intended that virtually all these grant projects would be instrumented for purposes of data acquisition.

To initiate the SS program, contractor personnel visited Boston, Atlanta, Albany (N.Y.), Richmond (Va.), Des Moines, Columbus (Ohio), Los Angeles, Denver, Tucson, and Honolulu in March 1976. They interviewed prospective applicants and explained the plan and intent of the program. Advance notification to builders was provided by a solicitation notice in key editions of the local newspapers and by publicity through local homebuilders associations (HBA). The National Homebuilders Association also provided advance publicity through its monthly newsletter and a bulletin to all affected local member organizations. The advance notices gave a series of dates and times that interviewers would be in a certain location and provided a phone contact and location for a personal interview if desired. Group meetings were also held at the local HBA offices where response to the local publicity had been sufficient to warrant such a session. In any case, the interviewers talked with each of the local HBAs to solicit help in identifying potential builder participants.

The response to the solicitation was disappointing, at best. In several locations no builders answered it. The only candidates there were gained by contacts that the interviewers initiated, working from source lists furnished by the local HBAs. When the Request for Grant Application (RFGA) was ready for issue in May 1976, only 180 potentially qualified applicants, in all 10 cities, had expressed an interest in receiving it. Among the 180 was a significant group whose interest, from impressions gained in the interviews or subsequent conversations, seemed marginal.

The negative impressions of builder interest were rudely confirmed in June 1976, when only 11 project applications were received at the closing time for the solicitation. This lack of response was even more striking if the ease of responding is considered. Basically, the RFGA required an expression of interest in a single- or multi-family project which the applicant intended to build, along with a builder qualification statement. There was no technical effort required of the builder and the cost of a response was negligible.

If successful, the applicant could expect a fixed-price grant to integrate the solar equipment into his project design and to prepare a cost estimate for the solar construction costs. Upon completion of this phase, the applicant was expected to negotiate with HUD for a lump-sum addition to his grant, covering the solar portion of his construction costs. Additionally, those applicants whose projects were selected for instrumentation could expect a further negotiated increase in their grants for instrumentation design and installation.

It was anticipated that the phased, negotiated grant would negate any feelings of risk which potential applicants might have, in view of the fact that the type of system would not be known until after grant award. However, when recipients of the RFGA who did not respond were polled, they gave a myriad of reasons, but consistently stated that:

- o Builders were unwilling to accept responsibility for a system type and manufacture not of their choosing.

- o Without an experience base, the builders felt that a fixed-price design grant exposed them to an unknown risk.

- o The solicitation indicated that most of the systems awarded would be for only domestic hot-water systems and the significance of such a project did not justify the effort to many builders.

As a result of the poor response and the nature of the above comments, it was obvious that future SS solicitations were in question and that further study and evaluation of this portion of the program would be required in the year before the next scheduled solicitation. Such study activities were initiated immediately while evaluation and award of the SS Cycle 1 projects moved ahead.

HUD's Grant Application Review Panel (GARP) approved all of the applicants for the first group of SS projects. In July 1976, 12 grants were issued for seven of the 10 SEAs that had been solicited. Projects were awarded in Boston, Atlanta, Columbus, Denver, Tucson, Los Angeles, and Honolulu. There were no responses from Richmond, Des Moines, and Albany.

The disappointment with the SS approach was not limited to the meager response. Design integration efforts by the builders were crude and difficult and communication between the builders and the assigned manufacturers was, at times, strained and contentious. The entire interaction of supplier-installer-builder showed the result of a lack of choice by the parties. If the goal of the program was to create a free-standing industry, it became obvious that the forced relationship of the SS approach was not the way toward that result. Most builders found it difficult to cope with the design involvement required of them. They seemed more comfortable in the normal role of coming up with a complete housing design package and proceeding, in the field, to construct the project. Usually the builders were heavily involved in their various field activities and found it difficult to make time for the design coordination that was necessary. Further, the concurrent design and construction activities interrupted their normal building practices. When projects were chosen for instrumentation, the difficulties were substantially compounded, as virtually none of the builders or their designers had any background in instrumentation design. It seemed to be looked upon by the builders as an intrusion into their project activities, and the modifications were very difficult to negotiate and administer.

Originally, 12 grants were awarded for 44 solar systems, all of which were for single-family detached (SFD) houses. Only nine of the grantees made it through the Phase I design review before withdrawing. One of the nine withdrew after award of the Phase II construction modification but before construction start. Six of the remaining eight grantees chose to proceed with fewer units than originally intended. The eight grantees completed projects that accounted for 22 systems on 22 SFD units.

While the intent was to instrument all of the SS projects, the difficulties encountered in trying to provide an effective design and a reliable installation plan forced reconsideration. Ultimately, only four grantees went through with the instrumentation of seven systems.

Despite the small number of SS grants, the progress of those that were ultimately completed was very slow. These grants required a good deal more day-to-day administrative support than was necessary for other cycles. The grants were awarded in July 1976, and it was not until the first quarter of 1979 that 90-95% were completed. The others were not completed until the end of the first quarter, 1980. Total elapsed time from the date of award was 3 3/4 years.

The study begun upon receipt of the Cycle 1 applications culminated in December 1976, when HUD decided to cancel all future SS solicitations. It was clear that builders were much more interested in the approach. Their response to Integrated Projects Cycles 1 and 2 and the interest expressed in the soon-to-be-released RFGA for Cycle 3 proved this.

For the data acquisition activities planned at the SS projects, it would be possible to choose Integrated Projects grants, after award. The two previous Integrated Projects cycles had had a good mix of projects. System types and locations could be matched reasonably well to the matrix requirements. More important, perhaps, was the fact that grants for instrumentation could be chosen from a wider range of designer-builder teams whose qualifications and capabilities were more tangibly known, by reasons of their technical submittal for the grant application. HUD also avoided becoming involved between the industry and the builders in the issues of system choice and project integration design.

Day-to-day field support for SS projects, surveillance, and grantee assistance was accomplished in essentially the same manner as it was for the Integrated Projects series. The methodology can be found in a later section of this chapter dealing with grant administration.

Summary statistics pertinent to the Site-System Cycle 1 awards are presented in Table 3-1. Figure 3-1 shows the geographical dispersion by state, of the grant awards.

TABLE 3-1
SUMMARY OF GRANTS IN SITE-SYSTEMS CYCLE 1

	Grants Awarded	Grants Annulled	Designs Completed	Construction Completed
New SFD Dwelling Units	12	4	10	8
Solar Systems	44	22	0	22

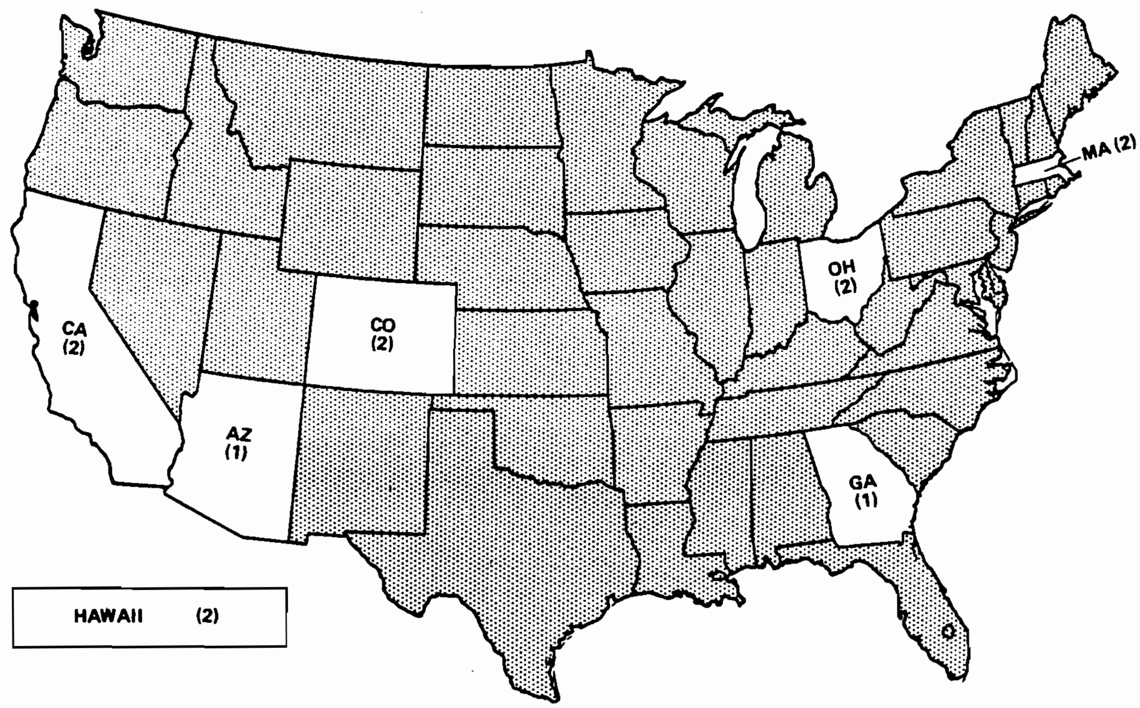


Figure 3-1. Location of Grants, Site-Systems Cycle 1

Integrated Projects

There were six cycles of Integrated Projects (IP) awards. The first awards in Cycle 1 were made in December 1975, a few weeks before the effective date of the management support contract under which this report is furnished. The last awards, those for Step Two of Cycle 5 were made in October and November 1979. During that four-year course, there was considerable evolution in the RFGA instructions and submittal requirements. As each successive cycle came before HUD's review panel and its consultants, experience with proposal deficiencies and knowledge of problems with systems in the field were translated into the application instructions and the application form and submittal requirements for the next cycle.

By encouraging a higher awareness of the need for a detailed and deliberate discipline in the design and selection of solar products, HUD sought to improve both the quality of projects proposed and the understanding of solar requirements by the building designer, developer, and contractor community. The goal of a viable solar industry at the end of the program required that much be done to further the relationship and mutual understanding of residential solar applications by solar producers and builders.

This progressive development of a better designed, more reliable solar product was not limited to technical information and design calculations. While Cycle 1 required a warranty to the purchaser, Cycle 2 applicants were obliged to furnish a written solar-product warranty with their submittals. In Cycle 3, the evaluation factors were improved, so applicants submitted a greater number of pertinent technical details. For Cycle 4, all solar systems had to be manufactured, designed, and installed in accordance with the HUD Intermediate Minimum Property Standards (IMPS). Evaluation criteria were further enhanced, and submittals again upgraded. Applicants were also required to offer an acceptable warranty of not less than five years for collectors and one year for the installation of the system.

The improved grant-award process caused a program change during Cycle 4. By January 1978, when submittals were due, many collector manufacturers had not completed the efficiency and stagnation tests required by IMPS (Reference 2). They failed to allow enough lead time at the two testing facilities, where capacity was limited. Therefore, some applicants could not present the necessary certifications that tests were passed. In March, HUD awarded grants to 48 qualified applicants. The panel rejected submittals that did not include test certifications; a new cycle, 4A, was scheduled for submittal in August 1978, allowing sufficient time for completing the tests. The revised RFGA document was mailed to approximately 12,000 potential applicants. Those applicants whose earlier Cycle 4 applications were rejected were eligible to resubmit in competition with any new applicant who chose to apply for a Cycle 4A grant.

The increasing sophistication of the grant applications and the effort required of applicants is too detailed to elaborate here. There was a significant difference with respect to the thought process in which a successful applicant had to become involved. A nominal qualifier for a Cycle 2 award could not have attained the same position in Cycle 4 without having become better qualified and having shown more understanding of the residential solar application process.

All the various IP cycle awards, as well as the SS and Design-Only projects, were judged finally by the GARP after having been evaluated by panels of experts in the areas of applicant qualifications, project development, project opportunity, and technical acceptability. Through the management support contractor, HUD had the services of most of the foremost experts in the field of solar design and application. There were also specialists in the evaluation and marketing of residential projects and personnel skilled in assessing contractor organizations and the relative responsiveness of each of the applications vis-a-vis the mandatory and optional factors for award.

Two reviewers in each evaluation category independently graded each application. Projects that were graded satisfactory proceeded to the next segment of reviewers. Those that were rejected by one or more of the reviewers were referred to an audit team, which evaluated the grading and attempted to resolve any rejections. Those applications that were confirmed by audit to be unsatisfactory were referred to the GARP for a decision as to whether to reject the application or return it to the remaining review process. When all of the applications had been through the full review process, they were graded and presented to the GARP in rank order for award consideration. The presentations were made by a team of reviewers who acted as advocates for the project. They explained the details of each application to the GARP and answered both technical and non-technical questions that arose.

Upon completion of the evaluation, the projects were re-graded, where appropriate, and re-ranked in accordance with the GARP-approved score. The costs of the tentatively approved projects were then tallied and an award cutoff established to match the funds available for the particular grant cycle. An award notice was then prepared for release by the HUD Secretary. The individual grant documents were prepared for a mailing, timed to coincide with the Secretary's announcement.

Table 3-2 is a recapitulation of the Integrated Projects Series awards. Figure 3-2 shows the geographical dispersion, by state, of the grant awards.

TABLE 3-2
SUMMARY OF GRANTS IN INTEGRATED PROJECTS SERIES

Cycle	Grants Awarded	Grants Rejected	Grants Annulled	Grants Completed
1	55	6	9	40
2	102	7	25	70
3	169	2	22	145
4	48	0	12	36
4A	96	1	20	75
5 (Step Two)	105	5	31	69
Totals	575	21	119	435

Design-Only Projects
Three series of grant awards resulted in design-only projects. There were 108 such awards in the Passive Design Competition, 61 in Cycle 5, and 2 in Site-Systems Cycle 1. It was intended from the start that the Passive Design Competition and Cycle 5 would yield such grants. Those which came from the SS projects, however, are simply the effect of grantees unable or unwilling to proceed with construction. They are mentioned here only to clarify the numbers.

Passive Design Competition--An RFGA released in May 1978 advertised the Passive Design Competition, a result of the Passive Initiative prepared by HUD. The RFGA invited qualified parties to submit applications for a design award in one of two categories, either new construction (Category A) or retrofit (Category B). Both project categories were limited to single-family housing, attached or detached. Design awards for new construction were set at a lump sum of $5,000 and those for retrofit at $2,000. Additionally, those projects of new construction that were being planned for speculative, open-market sale were eligible to apply for a construction grant covering one to five units. The construction grants also were a fixed, lump sum for all grantees, $7,000 for the first unit and $2,000 each for up to four additional units. The number of units to be funded was set at the time of grant award.

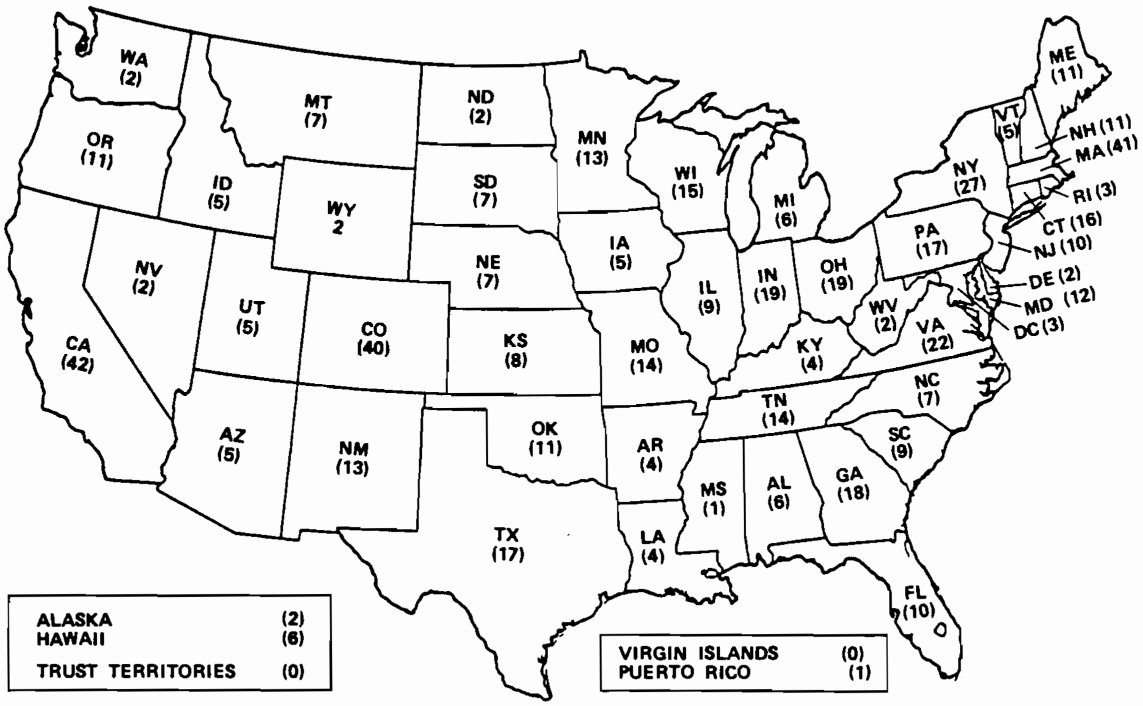


Figure 3-2. Location of Grants, Integrated Projects Series

All projects had to meet certain mandatory factors of award. These primarily established the applicant's eligibility to participate and determined the appropriate grant category. The awards jury also had a number of issues to consider relative to the acceptability of the proposed system design. For those applications that were considered technically acceptable, the jury engaged in further considerations of issues involved in project marketability and repeatability.

The Passive Design Competition RFGA was constructed in a workbook manner, like those for the IP series. Basically, the document provided terminology definitions, technical references, and general program facts. The application form required information about the project participant, schedules, and marketing. The applicant then had to complete a section on the technical approach. This section required the applicant to go through the logical and necessary design considerations and calculations for a proper passive solar design. Appropriate tables were furnished, complete with calculation formulas. The jury thus had a common set of design data from all applicants to aid the evaluation process.

The jury did not attempt to make design decisions for the applicants. The makeup of the application simply encouraged a deliberate, disciplined approach to the project design and allowed a common basis for evaluation. During the review, the jury identified any technical concerns that the review produced. The GARP evaluated these concerns and passed them along to the grantees for consideration at the time of grant award. In some cases, the applicants were invited to a design workshop before grant award. The workshop provided applicants with "hands-on" technical consultation to assist them in resolving design deficiencies or provide clarification of their design. Following the workshop, their applications were returned to the GARP for grant award action.

Grants for the Passive Design Competition (Table 3-3) were awarded in December 1978. Figure 3-3 shows the geographical dispersion, by state, of the awards.

Cycle 5 Projects--Cycle 5 was advertised by an RFGA released in March 1979. It was a two-step grant process in which applicants were required to apply for a project in either of two categories. Category 1 covered retrofit projects for low-to-moderate income, urban, multi-family buildings sponsored by neighborhood associations. Category 2 comprised new, single-family houses built for sale on the open market. Both categories of projects had to include significant energy-conservation features and a reasonable application of passive solar elements. A project could include active solar elements as well, in a manner which was complementary to the energy-conservation and passive-solar features.

TABLE 3-3
SUMMARY OF GRANTS IN PASSIVE DESIGN COMPETITION

	Grants Awarded	Grants Completed
Design Retrofit	17	17 (17)*
Design New Construction	145	145 (91)
Construction	80	54 (0)
Totals	242	216 (108)

*( ) portion of grants that were for design only

Application for a Step One design-assistance award required a relatively modest submission. It consisted of a one-page application summary form and four attachments. Three of the attachments described the qualifications of the applicant, the project designer, and the solar system designer. The fourth provided descriptive data on the proposed project, such as a general description of the project concept and style, proposed energy-conservation and solar features, a proposed project schedule, and information on funding sources over and above the grant amount involved.

To be eligible for future consideration for a Step Two construction award, applicants first had to be selected for a Step One design award. Applicants had to complete the Step One statement of work in order to receive payment for their effort. Payment for Step One was a lump sum of $5,000 for Category 1 projects and $2,000 for Category 2. The final product of the Step One work statement was the submission of a proposal for a Step Two construction award. These who met the Step One requirements were paid whether or not their Step Two proposal was judged worthy of a Step Two construction award.

Eight hundred-eighty applications were received by the closing date for Step One, April 26, 1979. An evaluation panel reviewed them on the basis of the information provided about the qualifications and experience of the applicant and the partici-

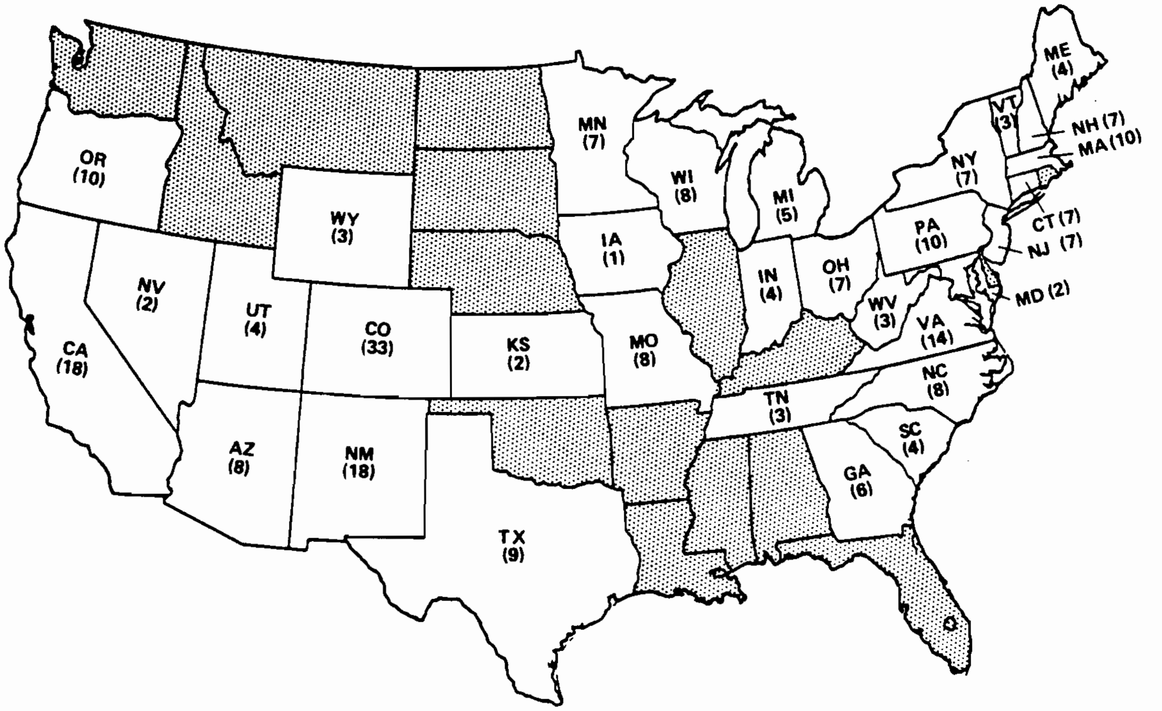


Figure 3-3. Location of Grants, Passive Design Competition

pating team, the apparent capacity of the team to successfully complete the proposed project, the type and quality of the proposed project, and the relative needs of the demonstration program for such a project. Following consideration by the GARP, HUD announced, on May 22, 1979, the award of 25 Category 1 and 114 Category 2 grants. The Category 1 participants were all neighborhood or community development groups with expertise in carrying out neighborhood revitalization projects for low-to-moderate income housing. The Category 2 participants were all established single-family home builders.

All the Step One grantees were invited to one of a series of kickoff meetings held in May and June 1979. The meetings acquainted the grantees with program procedures and provided an explanation of the grant process with respect to design reviews and the preparation of Step Two proposal documents.

A mid-course design workshop was held in Washington, D.C., for all grantees in July 1979. They were provided with "hands-on" architectural and engineering consultation. Details and calculations of their two proposals, in draft form, were reviewed. Upon completion of the workshops, grantees completed their final designs and submittals; in August 1979, HUD received 130 proposals for Step Two. As Table 3-3 showed, 105 awards were made.

The Step One (design only) Cycle 5 awards are recapitulated in Table 3-4. Figure 3-4 shows the geographical dispersion, by state, of the grant awards.

TABLE 3-4
SUMMARY OF GRANTS IN CYCLE 5, STEP ONE

Category	Grants Awarded	Grants Rejected	Grants Annulled	Grants Completed
1	25	0	1	24
2	114	3	5	106
Totals	139	3	6	130

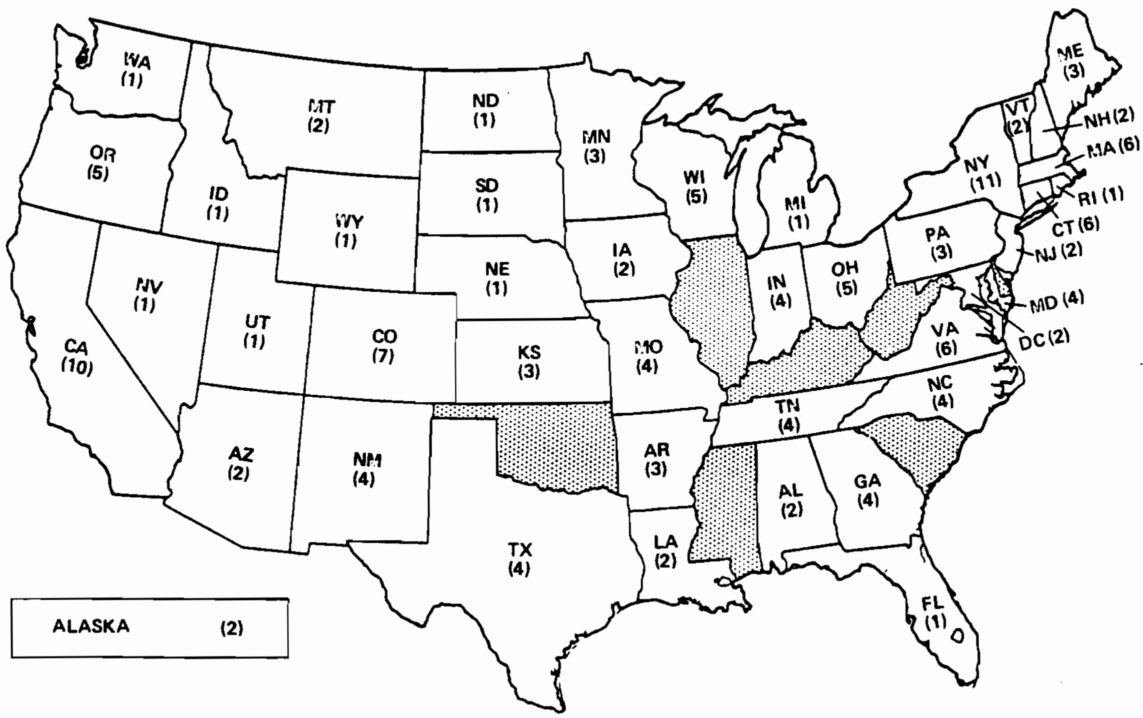


Figure 3-4. Location of Grants, Cycle 5, Step One

Day-to-day field support, surveillance, and grantee assistance were performed in much the same manner for all IP series. The details are discussed in the subsequent section.

GRANT ADMINISTRATION

Early in the administration of the Cycle 1 IP and SS awards, HUD recognized the need for a kick-off meeting with the grantees. Despite published instructions, various grantees did not understand the grant process, relationships, lines of communication, and reporting requirements. Given the total number of grants anticipated, it was imperative that all of the parties know the approach and conform to the established procedures.

GRANT MANAGEMENT CONTROL SHEET

Date: 10/1/82 CYCLE 5 58 of 67

GRANT NO.	GRANTEE NAME & PROJECT ADDRESS	CONTACT NAME, CONTRACTOR ADDRESS, & PHONE NO.	DESIGN Grant	DESIGN Appl'n	CONSTRUCTION Grant	Rpt 1	Rpt 2	Const	Rpt 3	Sold	Rpt 4	Site visits	NEW SFD	NEW SFA	RETRO MF	MANUFACTURER, MEDIA, & TYPE	COST TO GOV'T Design, Constr.
H-8849 H-9249 WM	HR RANSOM, INC. 2211 PICKET POST ROAD Upper Arlington, OH	H. R. Ransom 1525 Bethel Rd. Columbus, OH 43220 (614) 457-9874	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● S	● ●	2		H 1		Site-built Passive	2,000 10,000
H-8850 ~~H-9250~~ SW	GEORGE W. ROSENBARGER ~~Lot 431, Creekview Circle~~ ~~Woodfield Manor Subdivision~~ ~~New Albany, IN~~ 3/25/81	Jim Rosenbarger ~~2024 Pearl St.~~ ~~New Albany, IN 47150~~ ~~(812) 945-4634~~	● ●	● ●	● ●	● ●			ANNULLED				~~HC 1~~			~~Site-built Passive~~	2,000 10,000 (-10,000)
H-8851 H-9251 CO	MILES-RICHMOND, INC. 435½ South 6th Street South Park Alleyland Richmond, IN	Malcolm Miles S.R. 101 South Liberty, IN 47353 (317) 458-5111	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● S	● ●	3	HC 1			Site-built Passive	2,000 10,000
H-8852 ~~H-9252~~ SW	BARNARD BROTHERS, INC. ~~Lot 83, Lakeview Estates~~ ~~15 miles SE of Indianapolis~~ ~~Shelbyville, IN~~ 6/30/80	Dale Barnard 7721 Swails St. ~~Indianapolis, IN 46229~~ ~~(317) 862-3026~~	● ●	● ●	● ●	● ●							~~HW 1~~			~~Solaron Liquid A&P~~	2,000 10,000 (-10,000)
H-8853 WM	DON WHITNER BUILDERS & DEVELOPER Little Stream Village Bedford Township, MI	Don Whitner 2807 Barrington Drive Toledo, OH 43606 (419) 535-7240	● ●	● ●									HC 1			A&P	2,000
H-8854 H-9254 WM	HOLTZMAN & SILVERMAN 5326 (Lot #126), Indian Trail Hidden Heights Subdivision Ypsilanti Township, MI	Irwin T. Holtzman 24750 Lahser Southfield, MI 48034 (313) 353-4800	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● R	● ●	1	HC 1			Site-built Passive	2,000 10,000
H-8855 H-9255 WM	TRELLIS & WATKINS Lot #44, Block B Muncaster Manor Gaithersburg, MD	Allan Trellis 6565 Pennacook Court Columbia, MD 21045 (301) 596-6933	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● S	● ●	4	HC 1			Site-built Passive	2,000 10,000
H-8856 ~~H-9256~~ WM	ST. CHARLES HOMES ~~2211 Neville Ct.~~ ~~St. Charles, MD~~ 7/7/80	Curtis F. Peterson 336 Post Office Rd ~~Waldorf, MD 20601~~ ~~(301) 843-66~~	● ●	● ●	● ●	● ●	● ●		ANNULLED				~~HCW 1~~			~~Sunworks Liquid A&P~~	2,000 10,000 (-10,000)
H-8857 H-9257 WM	HARTMAN BRIDDELL WATKINS Lot #205, Section II Liberty Knolls Libertytown, MD	Kent Briddell 313 N. Washington St. Rockville, MD 20850 (301) 829-2237	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● S	● ●	3	H 1			Site-built Passive	2,000 10,000
H-8858 H-9258 WM	M. S. MILLINER CONSTRUCTION, INC. Lot #10, Vista Farms Myersville, MD	Michael S. Milliner Rt. 1, Box 344K Myersville, MD 21773 (301) 293-1285	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● M	● ●	3	H 1			Site-built Passive	2,000 10,000
H-8859 H-9259 WM	WARREN L. SMITH, INC. Lot #5, Section 5, Bellamy Manor Estates Kempsville Borough Virginia Beach, VA	Warren L. Smith 798 Oriole Drive Virginia Beach, VA 23451 (804) 425-0909	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● S	● ●	2	H 1			Site-built Passive	2,000 10,000
H-8860 H-9260 WM	BRADCO CONSTRUCTION CO., INC. Scenic View Heights Wytheville, VA	Bob Aker 685 South First St. Wytheville, VA 24382 (703) 228-2694	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● S	● ●	4	HW 1			Sunstar Liquid A&P	2,000 10,000

Figure 3-5. Sample of a Grant Management Control Sheet

and written communication with the GTR and the Boeing's grant management personnel, periodic program reviews were held, generally on a monthly basis, for project reviews and problem discussions.

Field personnel targeted four visits to each grant site during the course of construction. However, for a variety of reasons, such as schedule slippage, technical problems, and grantee requests for assistance, there was an average of six visits per site over the full program. Some sites also received more than four visits because of the coordination, installation, and checkout of site instrumentation. No formal record was kept of the number of telephone and letter contacts with the grantees, but a typical grant log shows in excess of a dozen such contacts per grant.

Thereafter, each award package contained an invitation to a HUD-sponsored kick-off meeting at an appropriate regional location. The technique, long used in major construction projects to ensure a coordinated approach, seemed appropriate here. At these meetings, the HUD Government Technical Representative (GTR) and any other HUD personnel in attendance were introduced and the relationship of the GTR and other HUD personnel to the grant process was explained. The GTR then conducted a general discussion of the overall Federal solar program and the HUD residential demonstration in particular. The procedures for completing a grant project were discussed in detail.

- The grantee was awarded a project of a particular type, size, and location, and was expected to complete the project as awarded. Changes in the basic scope of the project such as system types or type and location of the buildings were discouraged and could not be accepted without review and approval by a HUD change board.

- Grantees were reminded that HUD intended a "hands-off" role. While HUD had expressed technical concerns, where appropriate, grantees were assured that HUD would not involve itself in making project design or construction decisions. HUD's comments or suggestion were for the grantees' consideration and sole determination.

- HUD expected grantees to produce a project schedule and perform accordingly. It expected the grantees to file the reports required by the grant work statement along with incremental-payment invoices in accordance with the approved project schedule.

- HUD expected reasonable access to the projects for purposes of maintaining progress visibility and verification of compliance with the grant terms. HUD would not supervise or inspect the construction of the project.

- HUD was prepared to offer reasonable assistance with technical questions, code and regulatory problems, and financing issues, if asked.

- Grantees were advised that HUD's responsibilities and interests in the field would be looked after by representatives of the management support contractor. If the grantees required assistance, they could advise the appropriate field representative or communicate directly with the GTR.

Project visibility was maintained by the preparation and upkeep of corresponding sets of Grant Management Control Sheets at the headquarters offices of HUD and Boeing in Washington, D.C., and Kent, Washington (near Seattle), respectively. Similar sets for the regions were maintained at the support contractor's field offices in Huntsville, Alabama, and Denver, Colorado. Sub-regional offices were maintained at Simsbury, Connecticut; Indianapolis; Minneapolis; and Foster City, California. Figure 3-5 is a sample control sheet for IP Cycle 5 and is identical to those used for all cycles.

Site visit reports, telephone contacts by field personnel, grantee reports, and grantee contacts with the control centers or the regional and sub-regional offices provided status inputs. Grant files were maintained at all offices, each containing a contact log and all pertinent correspondence. In addition to day-to-day telephone

Grantees were required to furnish the GTR with four reports of their progress on the project. HUD made payments upon approval of the reports in accordance with the following schedule:

Report	Payment
#1 - Project Schedule	None
#2 - Final Design & Calculations	20% of Grant Amount (Installment #1)
#3 - Construction Report	70% of Grant Amount (Installment #2)
#4 - Final Report	10% of Grant Amount (Installment #3)

When HUD received reports, a copy was forwarded to the responsible field representative for review and concurrence before the GTR gave his approval and released the incremental payment. Initially, payments were slow in reaching the grantees when due, by reason of delays in the HUD finance system. However, expedited processing was arranged and invoices were hand-delivered to the finance office for prompt payment. By the end of Cycle 2, most delays were the result of insufficencies in the grantee's submittal and not in the HUD processing system.

Generally, the grantees seemed to appreciate the entire administrative procedure. Their participation in the kick-off meetings seemed to set the tone for a cooperative process during the course of the grant activities.

While numerous change requests were submitted for various purposes, fewer than 24 resulted in approval to change the location or nature of a project. Grantees generally accepted the suggestions made to them as technical concerns. The "hands-off" role worked reasonably well; most grantees were happy not to have us involved in their day-to-day operations. The biggest short-fall was that grantees failed to maintain schedules and did not volunteer slippage information to the field representative until a field follow-up was made.

We had no trouble gaining reasonable access to the projects, but relatively few grantees sought assistance during the construction phase. Most grantee requests were for technical assistance at about the time of system check-out or early in the system operation period, when unforeseen problems were encountered.

Most of the grantees made a good-faith effort to comply with their grant requirements. They came to view the field representative as their advocate within the program structure. Generally, they maintained a constant, open line of communication with the appropriate field representative on matters related to the solar portion of their projects. Where the relationship did not flourish as described, it can be attributed for the most part to deteriorating conditions in the housing market, a perceived reluctance of purchasers toward solar homes resulting in grantee disenchantment with the program, difficulties between the grantee and solar supplier/installer, or other circumstances which put the grantee in financial trouble and diverted attention from the project.

On balance, the grantees were cooperative and receptive to the help accorded them. The grant management procedures worked reasonably well and a respectable percentage of the projects was completed. In a stronger housing market and with less reluctance on the part of consumers toward solar projects, this aspect of the program could have exceeded original expectations.

CHAPTER 4. DATA COLLECTION AND ANALYSIS

One of HUD's main tasks in the residential demonstration program was to collect and publish information on the performance of solar heating and cooling systems and on their acceptance by the various parties that influence the housing market. This information was used to develop definitive performance criteria, improve solar equipment, estimate the economics of solar systems compared with alternative investments, and for market development and other purposes. Accordingly, HUD included in the management support contract with Boeing the requirement to collect technical and non-technical data and to coordinate the installation of instrumentation in selected projects. The contract further specified that Boeing coordinate with other government agencies and contractors as appropriate for the data collection activity.

PLANS AND PREPARATIONS

Planning started in February 1976 to define the data to be collected and establish responsibilities for accomplishing the collection. Boeing identified which data elements would be collected on all projects and which would be collected on selected projects, and established the basic approach to be taken in storing and recalling the collected data. Three types of data were to be collected: 1) non-technical, 2) technical, and 3) instrumented. The plan differentiated between the data collecting tasks and responsibilities for site-systems grants versus those for integrated projects grants. Initial planning was completed in May 1976.

During the first year, an extensive coordination effort established a cohesive data program that met the needs of the various contractors, agencies, and data users. Non-technical data needs were established primarily by Boeing and RERC with HUD guidance and assistance. Similar close coordination defined the detailed technical data elements that were to be collected. Working with NASA, IBM, NBS, ERDA, and HUD, we established instrumentation requirements, such as hardware selection, hardware availability, and interface responsibilities. In June, HUD selected Franklin Institute Research Laboratories (FIRL) as its information dissemination contractor; FIRL was then included in the coordination efforts.

By July, it was apparent that better communications were required between the various agencies and contractors. Accordingly, a Data Users Coordinating Committee (DUCC) was established. The DUCC had its first meeting in August, and met thereafter every month or two for approximately two years until the data program was well established.

DATA COLLECTION APPROACH

The data collection plan called for a limited amount of data to be collected on all projects, with increasingly more detailed data to be collected on smaller groups of projects. (See Table 4-1 for exact sample sizes.) Data collected on all projects were limited to summary descriptive information about the grant itself (project location, number of units, grant value, etc.), very limited technical descriptive data (collector manufacturer, collector area, liquid or air system, etc.), and limited

TABLE 4-1
DATA COLLECTION SUMMARY

	NO. OF GRANTS	NO. OF SYSTEMS	NO. OF ELEMENTS	TOTAL DATA ITEMS
NON-TECHNICAL DATA				
GRANT	668	1,255	51	34,068
GRANTEE	497	10,098[1]	93	71,411
UTILITY CONSUMPTION	214	316	15	174,305[2]
MARKET AND CONSUMER ACCEPTANCE	220	381[1]	N/A	320,000
TECHNICAL DATA				
F-CHART	140	428	118	50,504
SLR	79	79	35	2,765
TECHNICAL CONCERNS	N/A	556	15	8,340
DESIGN INTEGRATION	57	70	N/A	N/A
INSTRUMENTED DATA	68	83	35	150,000,000[3]

1 DWELLING UNITS
2 11,687 UTILITY BILLS TRANSCRIBED IN TOTAL
3 ASSUMES EACH SENSOR CHECKED EVERY 5 MINUTES, 24/HOURS/DAY/180 DAYS

construction and marketing information (construction start and completion dates, selling price, etc.). This information was obtained from the grant application, design drawings, and reports submitted by the grantees. Most of these data would have been collected even if there had not been a data collection program, as they were needed for the management and administration of the grants themselves.

More detailed data were collected from groups of projects, or samples. The largest sample was those projects chosen as sources of non-technical data about marketing and consumer acceptance. Over one-third of the grants in the program were selected for what was called special data collection. RERC and Boeing gathered non-technical data, both objective and subjective, from virtually all the parties involved in the residential construction industry--builders, lenders, local officials, utility companies, grantees, designers, purchasers, and renters. In addition, Boeing collected utility consumption data (copies of utility bills) with the concurrence of the residents and cooperation of the utility companies involved. To round out the data on these selected projects, DBA and Boeing collected technical descriptive data needed to perform F-Chart and Solar Load Ratio (SLR) calculations.

Projects chosen for non-technical data collection (i.e. utility consumption and market and consumer acceptance) were those best meeting the following criteria:

- o most units to be sold on the open market, with a limited number of rental projects (residences with "captive" occupants--such as student dormitories--were specifically excluded)
- o units with high visibility
- o projects geographically distributed around the country
- o projects in locations identified in the A.D. Little matrix (Reference 1), where possible
- o all instrumented projects unless the occupants were "captive" or if the installation was on a large multi-family building with a central heating system

Planning also covered repair and maintenance data on those projects selected for special data collection. Initially, this was to have been accomplished by means of maintenance contractors, under Boeing contracts, which would report all maintenance or repair occurrences. However, after considering the liability exposure of both Boeing and HUD, the plan was abandoned, to be replaced with voluntary reporting to Boeing by the occupants. This method proved to be marginally successful, at best.

Subsequent to the initial planning, it was decided to document and maintain a history of problems encountered during the installation and checkout of any of the systems in the program, and of problems occurring after completion of the checkout (during the operational phase). During construction and installation, this information was obtained by means of grantee reports and contacts by Boeing field representatives with the grantees. During the operational phase, this information was obtained by RERC contact with occupants and from data received from instrumented sites, occupant reports, and complaints made to Boeing, HUD, or members of Congress. The growing record of operational problems, particularly those being encountered on instrumented systems, was largely responsible for the decision to implement the repair program in 1979 (Reference 3).

The smallest sample size of projects chosen for special data collection involved those that were instrumented to obtain solar-system performance information. Approximately 5% of the solar systems installed in the program were so chosen and instrumented. The actual procurement and installation of the instruments (described in more detail in the following section) was a joint undertaking of the grantees, Boeing, and IBM (later superseded by Vitro). To round out the data base on these projects, extensive detailed technical descriptive data were obtained. Initially, it was planned to have Design Integration Monitors (DIM), under subcontract to AIARC, obtain the technical data on instrumented site-systems and have DBA obtain such data on any instrumented integrated project. With the demise of the site-systems approach, the integrated projects grants were left as the only choice for instrumented installations. Thus, the DIMs were assigned the responsibility of collecting the technical data (also described later) on any instrumented installation.

The number of instrumented projects was limited by the number and availability of site data acquisition subsystems to be furnished by DOE. The criteria used for selecting projects for instrumentation were:

- o both air and liquid systems
- o as many of the solar-collector manufacturers in the program as possible
- o both active and passive systems
- o geographically distributed around the country
- o of various configurations
- o large multi-family, hot water-only projects
- o where possible, projects having grantees and contractors sufficiently sophisticated to be able to handle the increased complexity of the instrumentation installation task

The data to be collected, as described by the management support contractor's plan (Reference 4), involved various kinds of information, from various sources, on varying numbers of grants. After collection, the data were accumulated and stored in specific data files.

Grant File--This file contains basic project and system information for each application funded by HUD.

Grantee Report File--Based on periodic reports submitted by grantees, this file contains the schedule, construction, marketing and occupancy experiences of each project.

Market and Consumer Acceptance File--Based upon responses to surveys, this file describes the actions and perceptions of the participants involved in the solar and conventional home building industry, including builders, purchasers, lending institutions, and others.

Utility Consumption File--This file contains over 11,000 utility bills from both conventional and solar-heated dwellings.

F-Chart Data File--This file describes the technical details of a sample of the active solar systems and the results of a calculation that predicted the performance of these solar systems.

SLR Data--These data list the results of a Solar Load Ratio calculation that predicted the performance of passive systems, which were part of the Passive Design Competition.

Technical Concerns File--Based on many sources, this file is a compilation of problems and maintenance needs of numerous solar systems.

Design Integration Data--These data document the precise details of a small sample of the solar systems constructed.

DATA COLLECTION

Table 4-1 showed the various data files established, and the relative number of grants on which the data were collected. A more detailed discussion of each of the data files appears in the following sections.

Grant Data

The grant data describe those projects awarded grants and the people or firms who agreed to install solar equipment in residential dwellings according to the terms and conditions required. The grant data file itself grew incrementally, starting in the grant application review and award process. During most of the grant award cycles, HUD received several hundred applications. Boeing transcribed and NBS produced computer-generated reports used to organize and evaluate these applications. Data on the successful applicants were then transferred from the application file to the grant file. This process of building the grant file was repeated for the eight award cycles beginning in 1975 and continuing into early 1980. Boeing transcribed a total of 3,837 applications and established a grant data file for 943 grants, which contained over 48,000 data items.

The grant file (Reference 5) itself was created to be a working record of the quantity, types, and kinds of solar systems funded by HUD. As such it corresponds to HUD's grant contract instruments. The file (Fig. 4-1 is a sample page) describes each residence's size and location and gives some information about the solar-heating system including the kind of solar heating (active or passive), its purpose (space heating, cooling, domestic-water heating), the type of collector and storage, and the calculated system performance. Volume V of this report, Summary of Data Findings, includes these kinds of information (in summary form) and all data elements in the file.

As the grant file matured, Boeing updated it to reflect changes to the system, dwelling, or the grant itself since the grant award. Changes were mostly due to housing market conditions that caused the grantee to decline the grant, decide not to construct, or construct fewer units. Occasionally, with HUD approval, minor technical changes were made in the solar system constructed compared to the system proposed. The technical portion of the grant file data reflected these changes.

It is important to understand that different quantities of grants, solar systems, or units apply depending on the use of these numbers. As explained in Chapter 2, 943 separate grants were awarded. By April 1, 1981, 154 grants had been cancelled, so in fact 791 grants were in the program. HUD, through the management support contractor, expended funds and effort to support grantees that eventually dropped out of the program. The number 943 is correct for awards, or for HUD and management support contractor activities, while 791 would be used when counting the number of grants actually funded and completed. Numbers of solar systems, units, and other grant file data follow the same rationale.

There are other conditions where still different numbers are appropriate. Some projects received two grants, one for design and one for construction, both supporting the same solar system. To avoid double-counting the same project, the data program uses 668 grants, instead of 791, as a standard to describe each of the different grants in the program. This was the number of data sets or records counted when inspecting the final grant-file listing. The count included design-only grants which did not result in actual, constructed, solar systems as part of the demonstration. Deleting the design-only grants leaves 497 funded and construction completed grants. In a similar way, the 1,255 solar systems and 10,098 units freqently referenced in this document were actually constructed. Figure 4-2 shows graphically the quantity of grants described.

```
81 JUL 22 PRINTED     DUMP OF ALL SOLAR GRANTS                                          CYCLES 1,2,3,4,4A,5 AND P1        PAGE NO.  30
81 JUL 20 LOADED                                                                                                          SG-C1
********************************************************************************************************************************

GRANT/  APPLCT        BUILDER/APPLICANT ORGANIZATION   BUILDER/APPLICANT ORGANIZATION  ORGN        TOT COST   APPL       GRANT
ID NUM  NUMBER  CYC   AND ADDRESS                      CONTACT PERSON                  TYPE        OF SOLAR   REQUEST    AWARD
******  ******  ***   ******************************** ******************************  **********  ********   ********   ********
 H2474   D177    1    PUERTO RICO URBAN RENEWAL CORP   DAVID C. BLUM                   LHA         $ 48000    $ 48000    $ 21000
                      606 BARBOSA AVE PO BOX W         TEL: 202 293-2139 EXT:
                      RIO PEDRAS            PR 00928
                      TEL: 202 293-2139                                 TYPE OF FINANCING: HUD PUBLIC HOUSING

                      BUILDING NUMBER 1: 1, 2, 3

       PROJ LOC  01   ADR:                                 CSZ: RIO PEDRAS        PR 00928   COUNTY:
                      HUD/GSA REGION: 02    SEA:           DEGREE DAYS:                 1

         MOD SEQ 1    HOUSING TYPE: MFM      NUMBER DWELLING UNITS:    4      NUMBER SOLAR SYSTEMS:     4
                      CONSTRN TYPE: NEW           NUMBER BUILDINGS:    1       COND AREA/SYSTEM(S):   26520 SQ FT

                      DESIGNATORS: 1

                                TRANSFR  COL  COL  TOT COST  COST TO   LOAD    USED  BTU/DD/ AUXILIARY                      STR AUX
            SYSTEM:   TYPE KIND MEDIUM  TYPE SQ-FT OF SOLAR    GVT   MBTU/YR MBTU/YR  SQ-FT   MBTU/YR  SOLAR MANUFACTURER   MED FUEL
            *******   **** **** ******* **** ***** ********  ******** ******* ******* ******* ******** ******************   *** ****
               1        W   PAS  LIQUID  FLP    28 $   4000 $   1750      18       8            10.00  STATE INDUSTRIES     LQ    E

         MOD SEQ 2    HOUSING TYPE: MFM      NUMBER DWELLING UNITS:    4      NUMBER SOLAR SYSTEMS:     4
                      CONSTRN TYPE: NEW           NUMBER BUILDINGS:    1       COND AREA/SYSTEM(S):         SQ FT

                      DESIGNATORS: 2

                                TRANSFR  COL  COL  TOT COST  COST TO   LOAD    USED  BTU/DD/ AUXILIARY                      STR AUX
            SYSTEM:   TYPE KIND MEDIUM  TYPE SQ-FT OF SOLAR    GVT   MBTU/YR MBTU/YR  SQ-FT   MBTU/YR  SOLAR MANUFACTURER   MED FUEL
            *******   **** **** ******* **** ***** ********  ******** ******* ******* ******* ******** ******************   *** ****
               1        W   PAS  LIQUID  FLP    38 $   4000 $   1750      18       8             8.00  HELIOTHERM INC       LQ    E

         MOD SEQ 3    HOUSING TYPE: MFM      NUMBER DWELLING UNITS:    4      NUMBER SOLAR SYSTEMS:     4
                      CONSTRN TYPE: NEW           NUMBER BUILDINGS:    1       COND AREA/SYSTEM(S):         SQ FT

                      DESIGNATORS: 3

                                TRANSFR  COL  COL  TOT COST  COST TO   LOAD    USED  BTU/DD/ AUXILIARY                      STR AUX
            SYSTEM:   TYPE KIND MEDIUM  TYPE SQ-FT OF SOLAR    GVT   MBTU/YR MBTU/YR  SQ-FT   MBTU/YR  SOLAR MANUFACTURER   MED FUEL
            *******   **** **** ******* **** ***** ********  ******** ******* ******* ******* ******** ******************   *** ****
               1        W   PAS  LIQUID  FLP    38 $   4000 $   1750      18       8             8.00  SOLAR ENERGY PROD    LQ    E


GRANT/  APPLCT        BUILDER/APPLICANT ORGANIZATION   BUILDER/APPLICANT ORGANIZATION  ORGN        TOT COST   APPL       GRANT
ID NUM  NUMBER  CYC   AND ADDRESS                      CONTACT PERSON                  TYPE        OF SOLAR   REQUEST    AWARD
******  ******  ***   ******************************** ******************************  **********  ********   ********   ********
 H2478   0082    1    NEWARK HOUSING AUTHORITY         MELVIN GLICKMAN                 LHA         $ 30182    $ 30182    $ 30182
                      57 SUSSEX AVE                    TEL: 201 622-1030 EXT:
                      NEWARK                NJ 07103
                      TEL: 201 622-1030                                 TYPE OF FINANCING: HUD PUBLIC HOUSING
```

Figure 4-1. Sample Page from Grant File

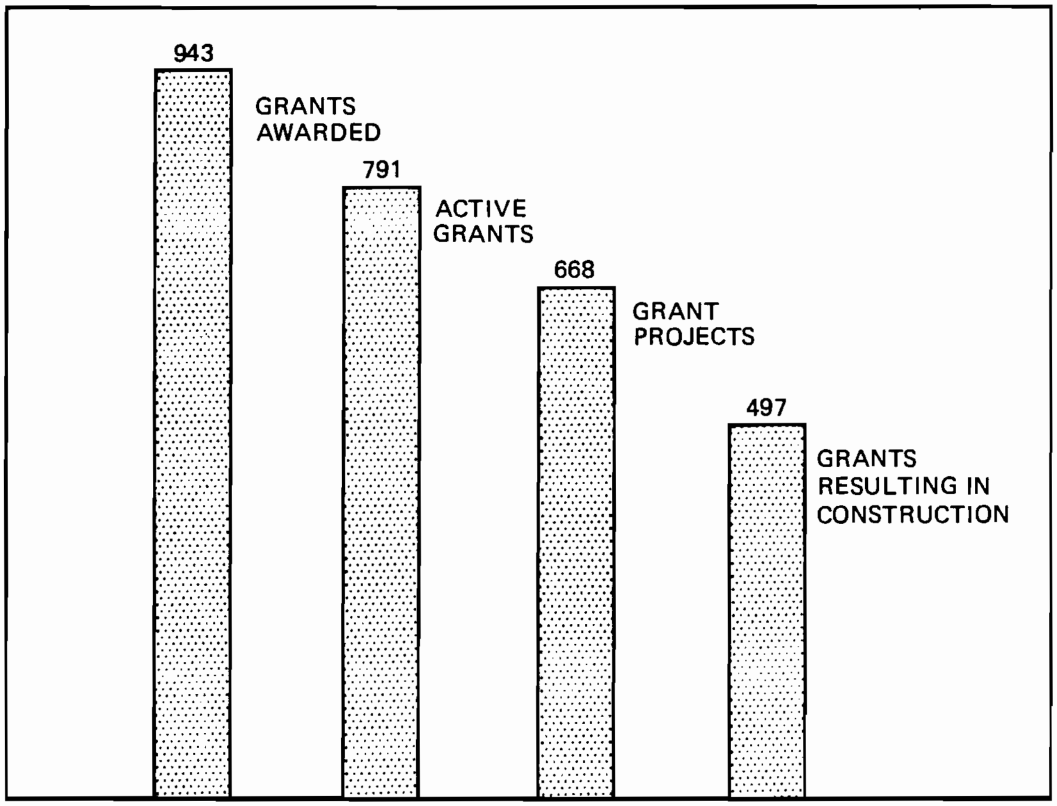


Figure 4-2. Quantity of Grants at Various Stages

Grantee Report

The grantee reports were a means of collecting, organizing, and assessing the experiences and knowledge gained by the grantees during construction of their solar systems. Boeing transcribed selected entries from the four reports required of each grantee as part of the grant contract agreement. Report 1 was a record of the expected construction schedule and true project address. Report 2, although not transcribed as grantee-report data, was a complete design of the solar system. Report 3 was a record of the construction, with dates of work completion and experiences gained in areas such as codes, zoning, labor, materials, equipment, and system start-up. Report 4 was a record of the occupancy of the project and includes information such as marketing success and acceptance, selling price, and mortgage information. Volume V of this report lists all of the data elements in the grantee report file (Reference 6). The file itself (Fig. 4-3 is a sample) has randomly selected identification numbers instead of the grant contract numbers so that the privacy of the grantees and owners can be protected. In this way sensitive data were collected without violating the Privacy Act.

Figures 4-4 and 4-5 are samples of the kinds of data summaries produced from grantee report data. Figure 4-4 shows the distribution of sales prices for new, single-family, solar-heated homes. Figure 4-5 shows that most solar projects were constructed quickly though some systems required many months to complete.

```
        ********************************
        * GRANTEE REPORT 1 DATA SUMMARY *
        ********************************
PROJECT ID = E3090GA010000
  GRANT AWARD DATE = 06/07/77      REPORT DATE  = 06/08/77
 INSTRUMENTATION (GRANT) = NO      CONSTRUCTION = NE
  ADDRESS = ALBUQUERQUE
            BERNALILLO
            NM     87122
CONSTRUCTION FINANCIAL STATUS = YES
CONSTRUCTION FINANCE PROBLEMS:
    - NO PROBLEM
```

```
        ********************************
        * GRANTEE REPORT 6 DATA SUMMARY *
        ********************************
PROJECT ID = E3090DC010060
 REPORT DATE = 06/08/78     INSTRUMENTATION (UNIT) = NO
 INITIAL SALES PRICE = 0110000          UNIT STATUS =   SOLD
   FINAL SALES PRICE =  0110000
 INITIAL RENTAL RATES:  1 BR =          OTHER  =
                        2 BR =          STUDIO =
                        3 BR =
   FINAL RENTAL RATES:  1 BR =          OTHER  =
                        2 BR =          STUDIO =
                        3 BR =
MORTGAGE DATA:   APPROVAL DATE = 06/20/78     TYPE = CONV
  AMOUNT = 0088000       INT RATE =  9.75%  PERIOD (MOS) = 360
 POINTS/FEES =          MTG ARRANGED BY = PURCHASER
 MORTGAGOR = ALBUQUERQUE FEDERAL SAVINGS & LOAN
  ADDRESS =  6400 UPTOWN BLVD. N.E.
             ALBUQUERQUE        NM  87110 PHONE:(505) 883-3100
MORTGAGE PROBLEMS:
    - NONE
    - NONE
    - FAVORABLE, ENTHUSIASTIC
MARKETING DATA: HOUSE 1ST OFFERED XD         MKT PER (WKS) XA
 SALES CONTRACT = 06/20/78   OCCUP DATE = 07/15/78
 NO. OF VISITORS = XA       NO OF PURCHASERS =  XA
MARKETING PROBLEMS:
MARKETING PUBLIC REACTION:
```

```
        ********************************        REPORT D-R2
        * GRANTEE REPORT 3 DATA SUMMARY *        DATE   05 JAN 79
        ********************************        PAGE  360
PROJECT ID = E3090000010000  REPORT 2 DATE = 06/07/77
  REPORT 3 DATE = 08/21/78  FINAL DESIGN COMPLETE DATE = 08/01/77
CONSTRUCTION: BEGIN = 08/24/77   BEGIN SOLAR INSTAL     = 10/25/77
          COMPLETE = 06/19/78   SOLAR TEST COMPLETE    = 06/10/78
BUILDING PERMIT DATA:           PERMIT APPROVAL DATE  = 08/17/77
    APPROVING AUTHORITY = BERNALILLO COUNTY ZONING
  BUILDING PERMIT PROBLEMS: - NONE
  ADDRESS = 812 6TH N.W.
            ALBUQUERQUE        NM   87102
OCCUPANCY PERMIT DATA:          PERMIT APPROVAL DATE  = 07/07/78
    APPROVING AUTHORITY = BERNALILLO COUNTY ZONING
 OCCUPANCY PERMIT PROBLEMS: - NO PROBLEM
  ADDRESS = 812 6TH N.W.
            ALBUQUERQUE        NM   87102
ZONING/LAND USE DATA:           ZONING APPROVAL DATE  = 08/31/73
    APPROVING AUTHORITY = BERNALILLO COUNTY ZONING
  ZONING/LAND USE PROBLEMS: - NO PROBLEM
  ADDRESS = 812 6TH N.W.
            ALBUQUERQUE        NM   87103
BUILDING CODES:   LOCAL CODE BASED/NOT BASED ON NAT'L CODE = NO
 NATIONAL =                LOCAL =BERNALILLO COUNTY UNIFORM BLDG CD
CONSTRUCTION FINANCING:  APPROVAL DATE = 08/17/77
  TYPE = NORMAL  AMT = 070,000     RATE =  9.00% PERIOD (MOS): 000
FINANCING ORGANIZATION =   UTAH MORTGAGE CO.
  ADDRESS = 8810 MOUNTAIN RD. PL. N.E.
            ALBUQUERQUE        NM  87122  PHONE: (505) 865-8686
SOLAR WARRANTY = YES OWNERS MANUAL = YES  SALES/RENTAL TERMS = YES
   HUD TERMS = YES AUX TYPE = ELECTRIC   AUX OTHER =
CONSTRUCTION PROBLEMS: ETC:
         DELIVERY PROBLEMS: - NONE
        BREAKDOWN PROBLEMS: - NONE
            LABOR PROBLEMS: - NONE
    BLDG INTERFACE PROBLEMS: - NONE
                             - MORE INFO. IN FILES
      OTHER CONSTR PROBLEMS: - NONE
ADDITIONAL COMMENTS:
            SOLD DURING CONSTRUCTION - NO MARKETING
```

Figure 4-3. Samples of Grantee Report Data

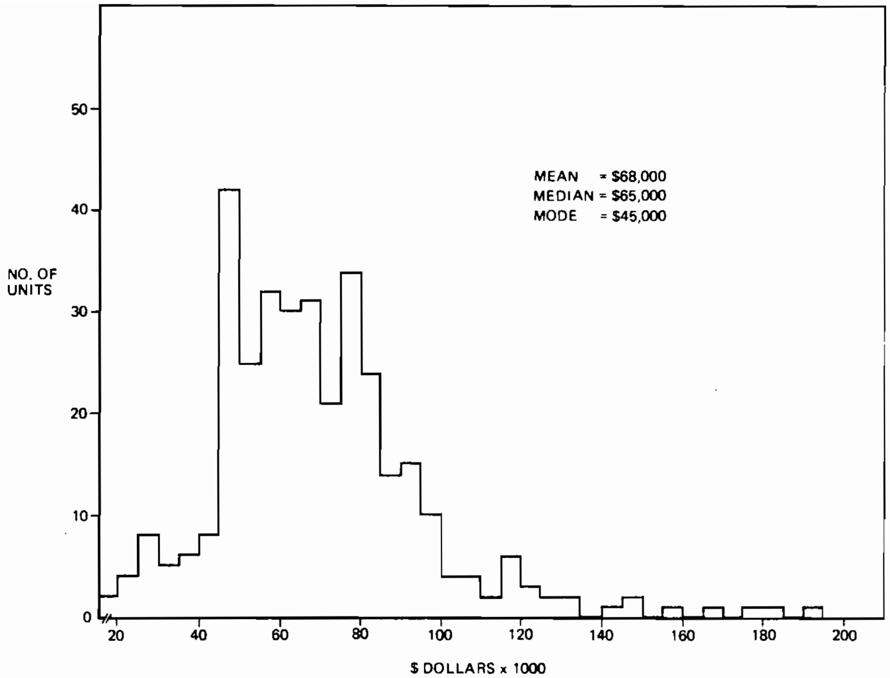


Figure 4-4. Sales Price for Single Family Detached Units

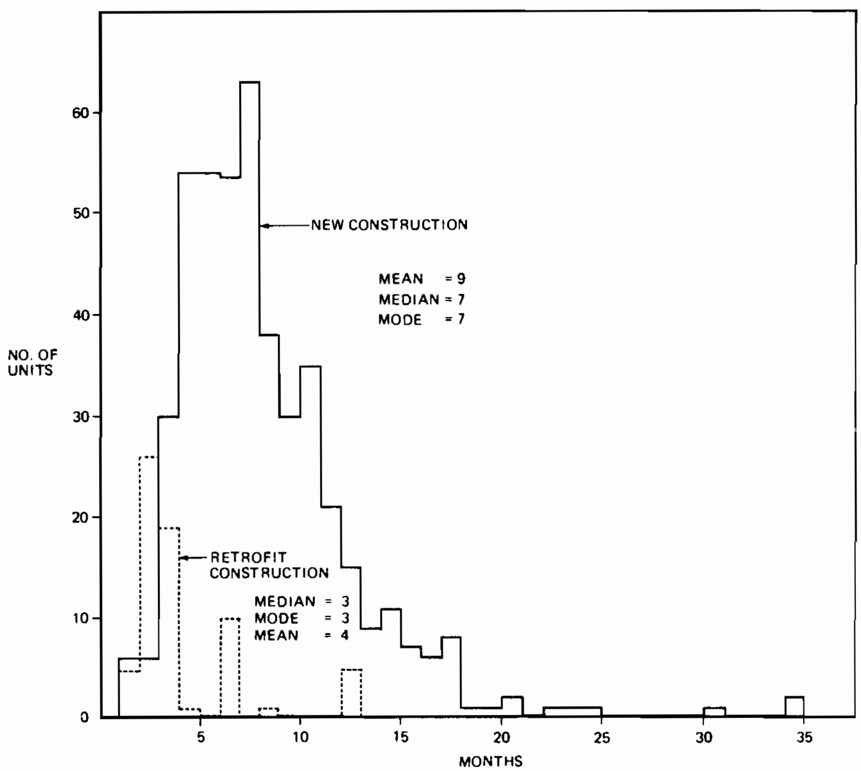


Figure 4-5. Construction Period for Single Family Detached Units

Utility Consumption

As the solar energy systems became operational, data were compiled on the economic aspects of actual system operation through the collection of utility bills and associated information from a sample of the solar systems funded by HUD (Reference 7). The sample corresponded to other data-collection efforts in the technical and non-technical areas as described in this section.

Boeing and its subcontractors collected the utility consumption information. Initial contacts were made with homeowners during consumer-acceptance surveys (described later) conducted by RERC. During the survey, homeowner permission was obtained for HUD to receive a duplicate copy of the utility bill. For those residences not surveyed, Boeing field representatives obtained homeowner permission. In most cases duplicate bills were sent by utility companies directly to a post office box maintained by Boeing. In all, about one-third of the grants were included. Ultimately, data from over 11,000 bills (over 170,800 data items) were transcribed and put into the data bank. Figure 4-6 is a sample of the utility file (Reference 8). Table 4-2 is a summary comparison of energy consumed by single-family solar or non-solar homes. The various sections of the table show the apparent solar savings when controlled for home size and the effects of climate.

Marketing and Consumer Acceptance

Concurrent with the collection of other non-technical data, information was gathered on marketplace dynamics that affect system marketability and consumer acceptance. A Boeing subcontractor, RERC, surveyed participants in the residential-housing market place who could have had a major effect on the construction, sale, or acceptance of these solar homes. Questionnaires were tailored for specific market participants; e.g. code officials, mortgage lenders, builders. Table 4-3 is a complete list of the survey instruments (each containing about 100 separate questions). One-fourth of the grants were covered.

Collection of data by the Federal government is subject to Privacy Act limitations. Therefore the survey instruments were submitted for approval through HUD to the Office of Management and Budget (OMB) in July 1976. OMB approved the questionnaires, and data collection began in September 1976. The questions asked during the surveys, and answers received, are contained in Volumes I and II of Marketing and Consumer Acceptance Data (Reference 9). This data file primarily contains active-solar system data. Corresponding passive data were not computerized but were compiled in the final report of findings on the 1978-79 passive awards, Volume 2 (Reference 10).

The initial survey at the grant site was scheduled immediately after completion of the solar unit. This survey evaluated the housing market by means of interviews with the grantee and comparative non-solar builders. It included field-survey inspections of not only the solar home and subdivision but also competitively priced conventional homes (comparative homes) and subdivisions in the same area.

Institutional surveys were scheduled according to the timing of their involvement--in the initial construction and marketing phase or later, following home sale and owner occupancy. Therefore, as part of the initial marketing survey, those interviewed included construction lenders, building-code and planning and zoning officials, and representatives of the utility companies—both the firm supplying auxiliary service to the solar unit and the non-participant, alternative utility. The

UTILITY CONSUMPTION REPORT

PROJECT ID: 2180480020000

REPORT: BF-R1
DATE: 08 JUL 81
PAGE: 3

ENERGY TYPE: ELECTRIC

SUPPLIER: EAST CENTRAL ELECTRIC
ADDRESS: DRAWER 1178
OKMULGEE OK 74447

CODE: OK 03

START DATE OF BILLING PERIOD	END DATE OF BILLING PERIOD	PRESENT METER READING	PREVIOUS METER READING	ENERGY CONSUMED	UNITS	RATE CODE	ENERGY COST	SURCHARGE	TAX	TOTAL COST THIS PERIOD	FLGS 1234
060577	070577	8562	8146	416	K		20.32	3.00		23.32	
070577	080577	9112	8562	550	K		23.80	3.00		26.80	
080577	090577	9510	9112	398	K		18.50	3.00		21.50	
090577	100577	10053	9510	543	K		24.29	3.00		27.29	
100577	110577	11027	10053	974	K		40.68	3.00		43.68	
110577	120577	11327	11027	300	K		16.30	3.00		19.30	
120577	010578	11557	11327	230	K		13.13	3.00		16.13	
010578	020578	11762	11557	205	K		11.78	3.00		14.78	
020578	030578	12359	11762	597	K		24.91	3.00		27.91	
030578	040578	12609	12359	250	K		13.67	4.05		17.72	
040578	050578	12997	12609	388	K		20.52	4.05		24.57	
050578	060578	13382	12997	385	K		19.81	4.05		23.86	
AVERAGE ENERGY CONSUMED FOR 1 YR:				436 ***		AVERAGE ENERGY COST FOR 1 YR:				23.90 ***	
060578	070578	13724	13382	342	K		17.31	4.05		21.36	
070578	080578	14274	13724	550	K		24.10	4.05		28.15	
080578	090578	14274	14274		K		4.03	4.05		8.08	
090578	100578	14656	14274	382	K		19.99	4.05		24.04	
100578	110578	15630	14656	974	K		42.31	4.05		46.36	
110578	120578	15630	15630		K		4.03	4.05		8.08	
120578	010579	16263	15630	633	K		28.42	4.05		32.47	
010579	020579	16468	16263	205	K		11.29	4.05		15.34	
020579	030579	17213	16468	745	K		31.24	4.05		35.29	
030579	040579	18086	17213	873	K		37.65	4.05		41.70	
040579	050579	18474	18086	388	K		21.92	4.05		25.97	
050579	060579	18533	18474	59	K		5.78	4.05		9.83	
AVERAGE ENERGY CONSUMED FOR 1 YR:				429 ***		AVERAGE ENERGY COST FOR 1 YR:				24.72 ***	
060579	070579	18885	18533	352	K		19.59	4.05		23.64	
070579	080579	19924	18885	1039	K		40.46	4.05		44.51	
080579	090579	20543	19924	619	K		27.06	4.05		31.11	
090579	100579	20925	20543	382	K		20.60	4.05	.47	25.12	
100579	110579	21064	20925	139	K		10.87	4.05		14.92	
110579	120579	21064	21064		K		4.03	4.05		8.08	
120579	010580	21697	21064	633	K		30.03	4.05		34.08	

UTILITY PROVIDES A MONTHLY BILL

Figure 4-6. Sample Utility Consumption Report

TABLE 4-2
MEAN UTILITY ENERGY CONSUMPTION

	GAS			ELECTRIC			TOTAL		
	MEAN	##	STDEV	MEAN	##	STDEV	MEAN	##	STDEV
HEATED LIVING AREA (SQ. FT.)									
COMPARATIVES	1897	45	525	1914	24	42	1913	69	505
ALL SOLAR	1989	60	594	1763	70	414	1867	130	515
ACTIVE	1985	56	584	1789	57	382	1886	113	500
PASSIVE	2044	4	822	1646	13	535	1740	17	610
HEAT ONLY	1799	16	640	NO CASES			1799	16	640
MILLION BTU/YEAR									
COMPARATIVES	148.75	45	67.50	78.53	24	31.54	124.33	69	66.48
ALL SOLAR	72.58	60	41.36	64.07	70	25.74	67.99	130	33.98
ACTIVE	73.55	56	41.97	66.62	57	26.41	70.06	113	35.01
PASSIVE	58.88	4	32.77	52.87	13	19.69	54.28	17	22.34
HEAT ONLY	66.81	16	65.08	NO CASES			66.81	16	65.08
DEGREE DAYS/YEAR									
COMPARATIVES	5607	45	1798	5096	24	2103	5429	69	1910
ALL SOLAR	4879	60	1845	5394	70	1750	5157	130	1806
ACTIVE	4824	56	1843	5288	57	1810	5058	113	1833
PASSIVE	5658	4	1946	5861	13	1423	5813	17	1496
HEAT ONLY	4453	16	1900	NO CASES			4453	16	1900
BTU/SQ. FT./YEAR									
COMPARATIVES	75746	45	29953	45284	24	24386	65151	69	31548
ALL SOLAR	37230	60	20564	38480	70	19235	37903	130	19792
ACTIVE	37855	56	21040	39438	57	20362	38654	113	20623
PASSIVE	28470	4	9580	34281	13	13008	32913	17	12270
HEAT ONLY	35321	16	31197	NO CASES			35321	16	31197
BTU/SQ. FT./DEGREE DAY									
COMPARATIVES	14.78	45	6.07	10.27	24	7.02	13.21	69	6.72
ALL SOLAR	9.33	60	8.32	7.58	70	3.77	8.38	130	6.33
ACTIVE	9.61	56	8.53	7.84	57	3.76	8.72	113	6.60
PASSIVE	5.37	4	3.51	6.40	13	3.72	6.16	17	3.35
HEAT ONLY	8.87	16	9.33	NO CASES			8.87	16	9.33

- NUMBER OF CASES
STDEV - STANDARD DEVIATION
HEAT ONLY - BACK-UP FUEL NOT USED FOR WATER HEATING

TABLE 4-3
SURVEY INSTRUMENTS

QUESTIONNAIRE ADMINISTERED TO:	SAMPLE SIZE
ACTIVE SOLAR SYSTEMS	
SINGLE-FAMILY (SF) BUILDER OR DEVELOPER	138
COMPARATIVE SF BUILDER OR DEVELOPER	260
MULTI-FAMILY (MF) BUILDER OR DEVELOPER	
PURCHASER	276
COMPARATIVE PURCHASER	252
PROSPECTIVE PURCHASER	52
RENTER	
COMPARATIVE RENTER	
PARTICIPATING CONSTRUCTION LENDER	105
PARTICIPATING PERMANENT LENDER	129
NON-PARTICIPATING LENDER	92
INSURANCE COMPANY/AGENCY	112
AUXILIARY UTILITY COMPANY	92
ALTERNATIVE UTILITY COMPANY	43
LOCAL PLANNING/ZONING OFFICIAL	105
LOCAL BUILDING CODE OFFICIAL	104
LOCAL TAX ASSESSOR	68
FOLLOW-UP BUILDER	121
FOLLOW-UP COMPARATIVE BUILDER	137
FOLLOW-UP COMPARATIVE PURCHASER	28
FOLLOW-UP PURCHASER	173
SECOND FOLLOW-UP PURCHASER	117
THIRD FOLLOW-UP PURCHASER	51
HOUSE/SITE DESCRIPTION	530
269 SOLAR GRANT HOUSES	
261 COMPARATIVE HOUSES	
PASSIVE SOLAR SYSTEMS	
BUILDER/DESIGNER/PURCHASER	10
BUILDER/DESIGNER	26
DESIGNER	38
BUILDER/CONTRACTOR	37
PURCHASER--CUSTOM HOMES	9
PURCHASER--SPECULATIVE HOMES	33
PERMANENT LENDER	32
CONSTRUCTION LENDER	32
FOLLOW-UP BUILDER/DESIGNER	34
FOLLOW-UP DESIGNER	34
FOLLOW-UP BUILDER/CONTRACTOR	32
FOLLOW-UP PURCHASER--CUSTOM HOMES	16
FOLLOW-UP PURCHASER--SPECULATIVE HOMES	21
HOUSE/SITE DESCRIPTION	73

remaining interviews of the permanent lenders, insurance agents, and tax assessor were conducted concurrently with the later consumer surveys. We ceased interviewing some of the institutions early in the program because responses were so consistent that there was little more to be gained. This was particularly true with the local tax assessors.

The solar-home buyer and comparative purchaser were interviewed after the solar unit had been occupied for at least a month. The comparative, non-solar purchasers were chosen from among people who bought a residence in the same subdivision or neighborhood as the solar house. An attempt was made to match the comparative purchaser's residence as closely as possible to the solar unit in price and time of sale. Follow-up telephone surveys of purchasers were conducted every six months to determine trends in utility rates and attitudes toward solar energy systems, and to identify problems in maintenance and operation. A few comparative purchasers were also interviewed six months after their initial contact as a control measure. In addition, follow-up interviews with participating and non-participating builders were conducted approximately six months after the original grant unit had been sold. Volume V of this report contains a summary of the findings from these surveys. Figures 4-7 through 4-10 are samples of the kinds of analyses conducted. They show the housing costs and the occupants' feelings about energy savings, for active (Reference 11) and passive solar homes.

HOMEOWNERS' PERCEPTIONS OF WHETHER USE OF SOLAR SYSTEM HAS RESULTED IN UTILITY COST SAVINGS
(Percent of Respondents)

	1st Round	2nd Round	3rd Round
Perceive savings	62%	65%	67%
Do not perceive savings	27	21	21
Not sure/don't know	11	14	12
Total	100%	100%	100%
	(N = 167)	(N = 116)	(N = 50)

Source: Real Estate Research Corporation

Figure 4-7. Homeowners' Perceptions of Utility Cost Savings from Active Solar Systems (Facsimile)

ASKING AND SELLING PRICE OF
SOLAR AND COMPARATIVE HOUSES*
(Percent of Units)

	Asking Price	
	Solar Houses	Comparative Houses
Less than $40,000	3%	7%
$40,000 - $60,000	39	33
$60,000 - $80,000	36	35
$80,000 or more	22	25
	100%	100%
Median	$65,600	$65,400
	(N = 265)	(N = 251)

	Selling Price	
	Solar Houses	Comparative Houses
Less than $40,000	3%	9%
$40,000 - $60,000	44	30
$60,000 - $80,000	35	25
$80,000 or more	18	36
	100%	100%
Median	$65,550	$70,000
	(N = 226)	(N = 103)

	Asking Price per Square Foot	
	Solar Houses	Comparative Houses
Less than $30	6%	21%
$30 - $40	49	49
$40 - $50	29	22
$50 or more	16	8
	100%	100%
Median	$38.50	$35.45
	(N = 263)	(N = 248)

	Selling Price per Square Foot	
	Solar Houses	Comparative Houses
Less than $30	13%	19%
$30 - $40	41	46
$40 - $50	28	24
$50 or more	18	11
	100%	100%
Median	$39.10	$35.35
	(N = 224)	(N = 103)

*As of September 1980

Source: Real Estate Research Corporation

Figure 4-8. Prices for Comparable Active Solar and Non-Solar Houses (Facsimile)

	MEDIAN TOTAL SALES PRICE	MEDIAN SALES PRICE PER SQ. FT.
PASSIVE INITIATIVE [a]	$ 83,000	$50.43
CYCLE 5 [b]	105,825	52.45
BOTH (P1 AND C5)	92,000	50.72
ACTIVE [c]	62,550	39.10
CONVENTIONAL [c]	64,500	41.08

a. MEDIAN PRICE BASED ON 23 HOUSES SURVEYED AND SOLD BETWEEN 1980 AND 1981.

b. MEDIAN PRICE BASED ON 24 HOUSES SURVEYED AND SOLD BETWEEN 1979 AND 1980. UPDATED DURING 1981 WHERE NECESSARY.

c. MEDIAN PRICE BASED ON 226 HOUSES SURVEYED AND SOLD BETWEEN 1976 AND 1979. PRICE PER SQUARE FOOT BASED ON N-224.

d. MEDIAN PRICE BASED ON A SAMPLE OF 11,000 HOUSES SOLD IN 1980. INCLUDES TOWNHOUSES. PER-SQUARE-FOOT FIGURE DERIVED BY DIVIDING MEDIAN TOTAL SALES PRICE BY MEDIAN SIZE.

NOTE: ALL PRICES INCLUDE LAND. HOWEVER, BECAUSE OF VARIATION IN THE INTERPRETATION OF "LIVING AREA" FOR PASSIVE HOMES—ESPECIALLY WITH REGARD TO "FINISHED" BASEMENTS AND PASSIVE FEATURES (E.G., GREENHOUSES) —AND DISCREPANCIES IN SALES PRICES REPORTED BY BUILDERS AND PURCHASERS, ALL PRICE FIGURES MUST BE CONSIDERED APPROXIMATE. FOR PASSIVE AND ACTIVE HOMES, MEDIAN SALES PRICE AND PRICE PER SQUARE FOOT WERE DETERMINED INDEPENDENTLY, BASED ON THE RESPECTIVE FREQUENCY DISTRIBUTIONS FOR EACH CATEGORY.

SOURCES: U.S. BUREAU OF THE CENSUS, CONSTRUCTION REPORTS, SERIES C25, CHARACTERISTICS OF NEW HOUSING: 1980 (U.S. DEPARTMENT OF COMMERCE, WASHINGTON, D.C. 1981), P.42, 45. U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, MARKETING AND MARKET ACCEPTANCE DATA FROM THE RESIDENTIAL SOLAR DEMONSTRATION PROGRAM: 1980, VOL. I: DETAILED ANALYSIS PREPARED BY REAL ESTATE RESEARCH CORPORATION (SPRINGFIELD, VIRGINIA: NATIONAL TECHNICAL INFORMATION SERVICE, 1980), P. 45. REAL ESTATE RESEARCH CORPORATION.

Figure 4-9. Comparison of Median Sales Prices (Facsimile)

PF45C SAVINGS AS EXPECTED? TOTAL

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
YES	1.	12	32.4	70.6	70.6
NO - A LOT LESS	2.	1	2.7	5.9	76.5
NO, SOMEWHAT LESS	3.	1	2.7	5.9	82.4
NO, MORE	5.	3	8.1	17.6	100.0
NOT ASKED	-1.	16	43.2	MISSING	100.0
NO ANSWER	0.	4	10.8	MISSING	100.0
	TOTAL	37	100.0	100.0	

Figure 4-10. Sample of Data: Passive Savings Expected

F-Chart Data

Thermal performance of solar systems was a key to the expected viability of solar heating and cooling. Grantees submitted technical details of their final designs as one of their contractual requirements. From the design information, data were extracted to produce technical data files. The data corresponded to the inputs needed for mathematical calculation of solar system performance. For active systems, data were organized to make computer or hand calculation of performance possible by use of the F-Chart method, developed by the University of Wisconsin. The data file therefore takes that name.

The F-Chart data elements were collected by the Boeing subcontractor, DBA, then transcribed and loaded into the Solar Data Center Database operated by NBS. The file (Reference 12) has information from about one-fourth of all the grants, and contains over 50,000 data elements. The grants covered were the same as those included in other data files so that a complete picture or profile of the dwelling, the solar system, and occupant life style was produced. The F-Chart data (Fig. 4-11 is a sample) describe the solar systems and include information like: collector tilt and azimuth, absorber material and coating, storage size and type, kind of freeze protection, and calculated system performance.

Figures 4-12 and 4-13 are typical summaries of the data. They show solar fractions predicted for active systems that provide domestic hot water and space heating.

SLR Data

Passive systems also have a technical file that takes the name of the calculation method, Solar Load Ratio. The SLR method of calculating solar-system performance was developed by the Los Alamos Scientific Laboratory. The file itself (Reference 13) is in a different format than the F-Chart data file described

CARD NUMBER: 1

• TECHNICAL DESCRIPTION (FCHART) DATA REPORT •

REPORT : DA-81
DATE : 05 JUN 81
PAGE : 8

				••••••••••••COVER PLATES••••••••••••					••••••••••••COVER PLATES••••••••••••					••ABSORBER••	
PROJECT I.D.	AZIMUTH ANGLE	TILT ANGLE	NET AREA (SQ.FT.)	MATL. KIND	ADDITIONAL MATERIAL INFO	MATL. DESC.	THICK (IN.)	NO. CP	MATL. KIND	ADDITIONAL MATERIAL INFO	MATL. DESC.	THICK (IN.)	NO. CP	COAT-ING	SUBST MATL.
23148FC0001	0010	50	0350	GL		TE	.125	02						FL	ST
22151FC0001	0010	34	0790	FR		SH	.040	01						FL	AL
23152FC0001	0000	30	0504	GL		TE	.125	01						FL	AL
23152FC0002	0000	37	0357	GL		TE	.125	01						FL	AL
23152FC0003	0C02	27	0357	GL		TE	.125	01						FL	AL
23152FC0004	0002	34	0357	GL		TE	.125	01						FL	AL
23155FC0001	0000	50	0249	GL		TE	.188	01	PS		SH	.008	01	FL	CO
23156FC0001	0000	50	0500	FR		PO	.037	02						FL	OT
23157FC0001	0000	37	0225	GL		TE	.187	02						FL	CO
23162FC0001	0000	57	0333	GL		TE	.188	01	PS		SH	.005	01	FL	CO
23164FC0001	D000	29	0249	GL		SS	.125	02						FL	CO
24002FC0001	0000	30	0149	GL		TE	.188	01						SE	CO
24004FC0001	0000	43	0640	PS		SH	.040	02						FL	OT
24005FC0001	0000	57	0534	GN		TE	.125	01	MY		SH	.187	01	FL	OT
24010FC0001	0000	60	0210	GN		TE	.188	01						FL	CO
24014FC0001	0000	45	0244	GW		TE	.187	01						FL	AL
24014FC0002	0000	45	03C3	GW		TE	.187	01						FL	AL
24014FC0003	0C00	45	0244	GW		TE	.187	01						FL	AL
24014FC0004	0000	45	0305	GW		TE	.187	01						FL	AL
24014FC0005	0000	45	0244	GW		TE	.187	01						FL	AL
24014FC0006	0000	45	0244	GW		TE	.187	01						FL	AL
24014FC0007	0000	45	0244	GW		TE	.187	D1						FL	AL
24014FC0008	0000	45	0183	GW		TE	.187	01						FL	AL
24014FC0009	0000	45	0244	GW		TE	.187	01						FL	AL
24014FC0010	0000	45	0305	GW		TE	.187	01						FL	AL
24014FC0011	0000	45	0244	GW		TE	.187	01						FL	AL
24014FC0012	0000	45	0244	GW		TE	.187	01						FL	AL
24014FC0013	0000	45	0244	GW		TE	.187	01						FL	AL
24014FC0015	0000	45	0183	GW		TE	.187	01						FL	AL
24020FC0001	0005	58	0273	GL		TE	.125	01						SE	CO
24020FC0002	0015	58	0273	GL		TE	.125	01						SE	CO
24032FC0001	0006	45	0299	GL		TE	.188	01						SE	CO
24032FC0002	0008	34	0552	PS		SH	.250	01						FL	CO
24033FC0001	0000	30	0259	FR		SH	.040	01						FL	AL
24036FC0001	0020	80	0352	FR		SH	.040	01						FL	CO
24036FC0002	0023	34	0198	FR		SH	.040	01						FL	CO
24036FC0003	0023	34	0198	FR		SH	.040	01						FL	CO
24036FC0004	0020	34	0305	FR		SH	.040	01						FL	CO
24036FC0005	0+23	50	0340	GW		TE	.125	01						SE	CO
24036FC0006	0+23	50	0340	GW		TE	.125	01						SE	CO
24036FC0007	0C20	80	0352	FR		SH	.040	01						FL	CO
24101FC0001	0003	40	0252	OT	GLASS TUBE		.125	02						SE	OT
24101FC0002	0000	40	0252	OT	GLASS TUBE		.125	02						SE	OT
24106FC0001	0000	28	2669	FR		RE	.040	01						FL	CO
24116FC0001	0014	40	3150	GL		TE	.188	01	PS	FOLDED	SH	.010	01	FL	CO
24116FC0002	0014	40	2704	GL		TE	.188	01						SE	CO
24122FC0001	0000	45	0270	GN		TE	.188	01						FL	AL
24122FC0002	0000	45	0270	GN		TE	.188	01						FL	AL
24122FC0003	0000	45	0270	GN		TE	.188	01						FL	AL

Figure 4-11. Sample of Data: F-Chart

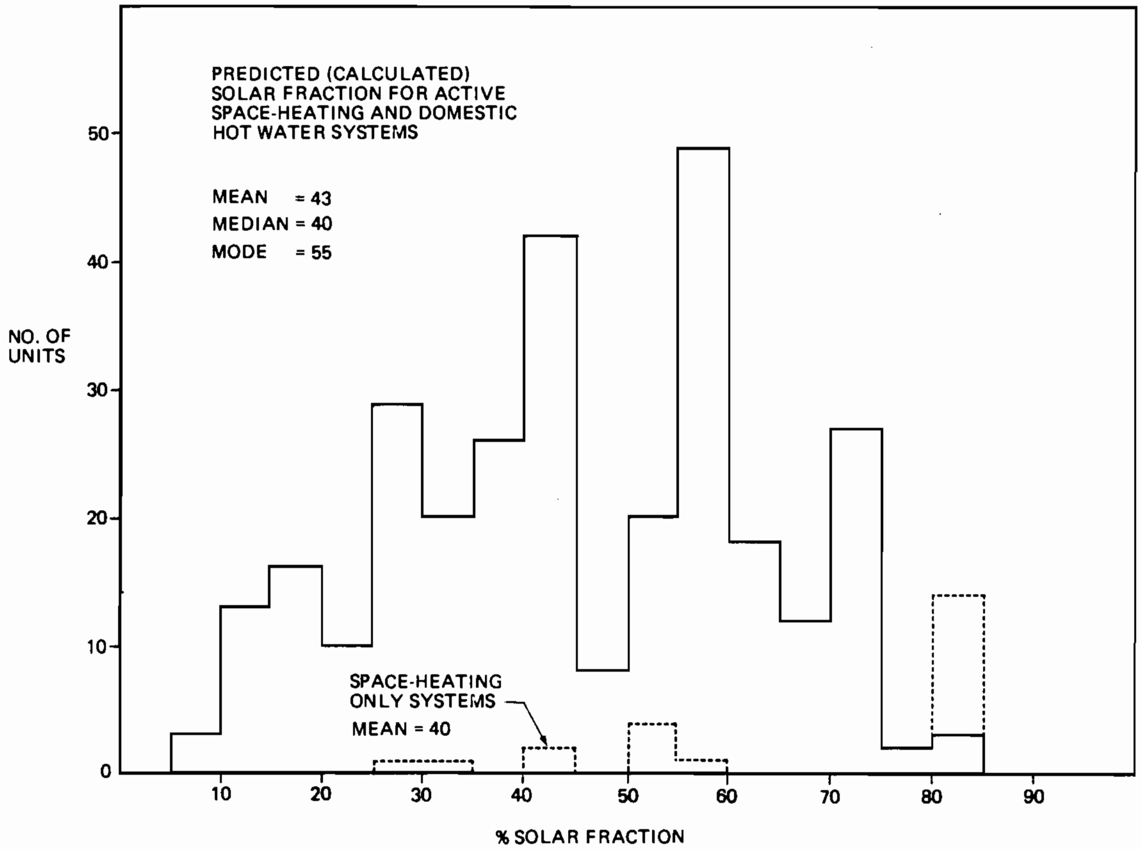


Figure 4-12. Predicted Solar Fraction, Combined Space-Heating and Domestic Hot Water--Active Systems

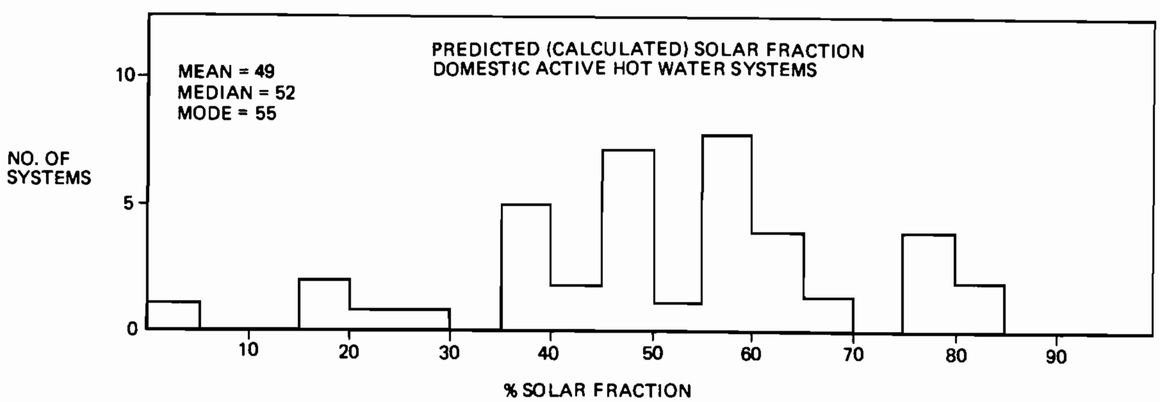


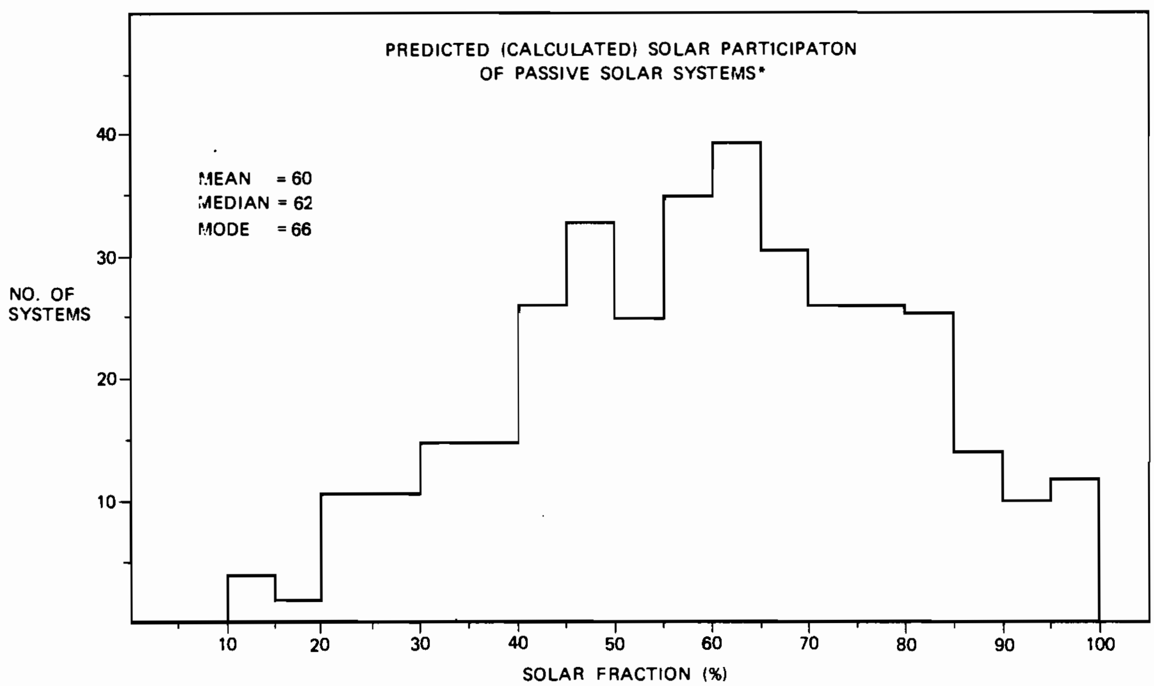
Figure 4-13. Predicted Solar Fraction, Domestic Hot Water--Active Systems

previously. It is a computer run of the input data and results of an SLR calculation for all of the systems that HUD funded in the passive initiative awards. This amounts to about one-half of all passive systems funded by HUD throughout the demonstration.

Figure 4-14 shows the predicted solar fractions of passive systems in the program. Volume V of this report contains summaries and lists of data elements collected for both this and the F-Chart file.

Technical Concerns Data

Descriptions of the problems encountered and repairs required were grouped into the technical concerns file (Reference 3). It records solar-system operating experiences in the areas of repair and maintenance. All problems and maintenance needs were not reported, however. This file is a record of only those problems reported to HUD before data collection was suspended. It cannot support conclusions that any given number of solar systems were problem-free.



*INCLUDING CONSTRUCTED AND DESIGN-ONLY PASSIVE SYSTEMS

NOTE: THREE TYPES OF PASSIVE SYSTEMS WERE IN THE DEMONSTRATION; DIRECT, INDIRECT, AND ISOLATED. MANY WERE COMBINATIONS. DIRECT-GAIN SYSTEMS TEND TO HAVE THE HIGHEST SOLAR FRACTION, FOLLOWED BY INDIRECT, THEN ISOLATED PASSIVE TYPES.

Figure 4-14. Predicted Solar Participation—Passive Systems

The purpose of the file is to organize, for easy reference and analysis, data collected from many and varied sources. Data were coded using a system developed by NBS to produce a consistent and reliable data base. The system involves the identification of 1) the hardware element (the component that malfunctioned), 2) the action taken (the procedure taken to eliminate the problem), 3) the event itself (all events associated with the particular problem), 4) the general performance area affected (thermal, mechanical, etc.), and 5) the system status (the condition of the system at the time of the problem).

Volume V of this report has summaries of the data and a list of those data elements collected. A summary of the technical concerns file is shown in Table 4-4. Figure 4-15 is a sample of the data.

Detailed Technical Descriptive Data

One goal of the demonstration program was to identify, by monitoring the actual participants, the design integration process that brought together, into one design, the residential dwelling and the solar system. HUD assigned this activity for the residential demonstration to Boeing. Boeing and its subcontractor, AIARC, selected 26 architect and engineering firms, expert in design and solar applications and distributed throughout the country, to provide the on-site monitoring and data collection required. The primary duties of the design integration monitors were to 1) gather extensive, detailed, technical, building and solar-system data on demonstration projects chosen to be instrumented, and 2) document the design process. AIARC developed a Design Integration Monitor's Handbook, which was used as a guide and organizational tool so that data and information collected was comparable and, to the degree possible, standardized.

The solar systems chosen for monitoring were the same systems selected for instrumented performance-data collection. The purpose of the instrumentation was to provide technical performance information. The purpose of the DIMs' building and solar-system documentation was to provide the information base for the analysis of technical performance. The purpose of the design-process documentation was to provide some of the information necessary to develop manuals of practice for the design of buildings using solar energy. All DIM packages included, for example, solar-system schematics and descriptions of operation*. Extensive technical detail, such as make and model of a circulation pump, power use, and GPM flow data, was also collected. Highly detailed data, such as gasket material, thickness of cover plate, and percent water to antifreeze, were collected to provide information about materials use and performance.

Original plans (Reference 14) called for the data to be collected by monitoring the process of integrating the solar system with the house design. This was to be accompished through the site-systems approach of combining a generic solar system and a site-specific residence. With the termination of the site-systems approach, control of the design integration process was lost. In the integrated projects, the design integration was largely accomplished before grant award. Therefore, a combination approach was used, collecting the DIM data from detailed final designs and from on-site inspection after construction.

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*Each instrumented project resulting in performance reports has a "Solar Project Descriptive Document" available from the National Technical Information Service on microfilm or paper.

TABLE 4-4

TECHNICAL CONCERNS SUMMARY REPORT—HARDWARE ELEMENT

• TECHNICAL CONCERNS SUMMARY REPORT - HARDWARE ELEMENT •

DATE: 08 JUL 81
PAGE: 22
REPORT: CB-HAS

SORTING KEYS ARE: ID #, SYS #

ID # / # OF SYS / SYS #	COLL	TRAN/DIST	STOR	CONT	AUX	OTHER	TOTAL	CYCLE / # OF UNITS / NEW/RET / HSGTYPE	SYSTYPE	SYSKIND	TRMED
SINGLE FAMILY, AIR TRANSFER MEDIUM											
CYCLE 1 TOTALS:	11	13	3	6	2	7	42	NO. OF SYSTEMS WITH PROBLEMS:	12		
CYCLE 2 TOTALS:	34	37	12	14	38	5	140	NO. OF SYSTEMS WITH PROBLEMS:	53		
CYCLE 3 TOTALS:	49	115	45	62	27	9	307	NO. OF SYSTEMS WITH PROBLEMS:	90		
CYCLE 4 TOTALS:	2			1			3	NO. OF SYSTEMS WITH PROBLEMS:	2		
CYCLE 4A TOTALS:	2	13		3			18	NO. OF SYSTEMS WITH PROBLEMS:	13		
CYCLE P1 TOTALS:	1						1	NO. OF SYSTEMS WITH PROBLEMS:	1		
CYCLE 5 TOTALS:	1							NO. OF SYSTEMS WITH PROBLEMS:	0		
TOTALS:	99	178	60	86	67	21	511	NO. OF SYSTEMS WITH PROBLEMS:	171		
SINGLE FAMILY, LIQUID TRANSFER MEDIUM											
CYCLE 1 TOTALS:	80	40	19	20	15	27	201	NO. OF SYSTEMS WITH PROBLEMS:	52		
CYCLE 2 TOTALS:	93	103	52	116	4	63	433	NO. OF SYSTEMS WITH PROBLEMS:	105		
CYCLE 3 TOTALS:	47	67	71	44	11	18	258	NO. OF SYSTEMS WITH PROBLEMS:	93		
CYCLE 4 TOTALS:	3	2		4	2		11	NO. OF SYSTEMS WITH PROBLEMS:	6		
CYCLE 4A TOTALS:	19	15	17	1	1	1	54	NO. OF SYSTEMS WITH PROBLEMS:	24		
CYCLE P1 TOTALS:								NO. OF SYSTEMS WITH PROBLEMS:	0		
CYCLE 5 TOTALS:	1						1	NO. OF SYSTEMS WITH PROBLEMS:	1		
TOTALS:	243	227	159	187	33	109	958	NO. OF SYSTEMS WITH PROBLEMS:	281		

HUD SOLAR DEMONSTRATION RESIDENTIAL PROJECTS

* TECHNICAL CONCERNS SUMMARY REPORT *

DATE :05 JUL 81

PAGE : 1
REPORT : CB-D3

SORTING KEYS ARE : ID #, SYS #, DATE

ID #	SYS #	DATE	STAT	PERF AREA	HARDWARE ELEMENT	ACTIONS	EVENTS	FREQ	DIRECT COST	ACT TAKEN BY	SOPR
2423	01	03/05/77	4	THER	TRAN/HEAT EXCHANGER	REPLACE	FREEZE-UP	1	$	G	N
		05/19/80	4	MECH	AUX/HEAT PUMP	REPAIR	MECHANICAL OPERATING, BUT IMPROPERLY INCORRECT MANUFACTURING	1	$*	H	C
		05/19/80	4	DURA	COLL/LIQUID PIPE ASSEMBLY	REPAIR	LEAKAGE DAMAGED LEAKAGE OF SYSTEM FLUIDS ACCESS FOR REPAIRS INADEQUATE	1	$ 11342	H	R
		05/18/80	4	THER	CONTROLS	REPLACE	ELECTRICAL	1	$*	H	R
		06/09/80	4	GENE	TRAN/INSULATION	REPAIR	THERMAL	1	$	G	N
		12/12/80	4	DURA	COLLECTOR UNITS	REPAIR	LEAKAGE DAMAGED LEAKAGE OF SYSTEM FLUIDS FROM COMPONENTS	3	$	G	N

CYCLE: 1 NO.SYS: 001 NO.UNITS: 1 N/R: N HSGTYPE: SFD SYSTYPE: H W SYSKIND: A TRMED: L FCHART: *

ID #	SYS #	DATE	STAT	PERF AREA	HARDWARE ELEMENT	ACTIONS	EVENTS	FREQ	DIRECT COST	ACT TAKEN BY	SOPR
2426	01	07/16/76	4	THER	COLL/LIQUID PIPE ASSEMBLY	REPLACE	STRUCTURAL FAILED TO OPERATE BURST	8	$	G	N
		09/23/76	2	DURA	COLL/HEADERS-CONNECTORS	REPAIR	LEAKAGE DAMAGED LEAKAGE OF SYSTEM FLUIDS BETWEEN COMPONENTS	1	$	G	N

Figure 4-15. Sample of Data: Technical Concerns

Instrumented Data

As mentioned previously, Boeing had the responsibility for coordinating the installation of instruments in selected projects. The instrumented data effort involved the following tasks, some of which were accomplished by Boeing and some by others:

- o determining the information that was to be acquired and how that information would be used (basically a system design)
- o selecting the specific instruments (sensors) that would be needed for each installation and determining where they were to be placed (site-specific design)
- o acquiring the sensors, calibrating them, and shipping them to each job site
- o designing, fabricating, and shipping to each job site the data acquisition subsystems that would receive the signals from the sensors
- o installing and checking out the sensors
- o installing and checking out the data-acquisition subsystems and connecting them to telephone lines that would transmit the information to the data-processing computer
- o maintaining the solar subsystems and instrumentation after installation
- o processing and analyzing the data and publishing the results

In the above sequence of tasks, the basic instrumentation systems design was accomplished as a team effort by NASA, NBS, IBM, and ERDA, with assistance from Boeing, HUD, and others. One of the results of this effort was a master list of acceptable sensors for use on the program.

Upon receipt of a grantee's final solar design (Grantee Report #2), Boeing prepared a schematic instrumentation design and returned this to the grantee along with a sensor identification list and a detailed sensor-installation handbook (Reference 15). From this the grantee was expected to prepare a dimensioned solar-installation drawing that could be used by a contractor. Boeing assisted HUD in negotiating a grant modification to fund this additional design activity. After design completion, a further grant modification was negotiated to cover the additional cost of installing the sensors and connecting the wiring.

Boeing acquired and calibrated the sensors and sent them to the job site. IBM designed, fabricated, and sent to the job site its proprietary site data acquisition subsystem (SDAS) and a junction box (J-box), and arranged for the connection of the SDAS to the telephone line. The grantee's contractor connected the sensor wiring to the J-box. A custom-wired cable, prepared by IBM, connected the J-box to the SDAS.

Boeing checked the sensor operation and installation, while IBM checked the operation and installation of the SDAS installation. Maintenance of the instrumentation was accomplished by Boeing (sensors and wiring) and by IBM (SDAS). The instrumented data were processed and analyzed by IBM (later Vitro) and published by the National Technical Information Service (NTIS). (A list of reports available from NTIS is included in <u>Availability of Solar Energy Reports from the National Solar Data Program</u>--Reference 16.)

It was originally planned that close to 100 solar systems would be instrumented under the program. Due in part to availability limitations of SDASs, 83 solar systems (68 grants) were actually instrumented in the residential program. Virtually all of the generic-system types in the program were represented in the instrumentation program—air systems, liquid systems, active systems, and passive systems, as well as all climatic areas in the continental United States and Hawaii.

One of the most difficult tasks in the instrumentation program was to select a) instrumented projects that met the technical and geographical criteria and b) grantees with sufficient technical sophistication and motivation to design and install the instruments in a proper and timely manner. This was not always possible. It was not unusual to have a grantee express initial interest in instrumentation, only to lose interest abruptly when the effort required became clear. When that happened, work would halt, and it would then be difficult to have the job resumed and kept up until instrumentation was completed.

The instrumentation program was very challenging. During one four-month period in 1977, it took the equivalent of about 20 people--instrumentation engineers, support from DBA, at least one person in Boeing's home office, and, nearly full time, the nine field representatives. Thereafter, the effort needed to install instrumentation on additional sites and to repair and maintain previously instrumented sites with reported problems was substantial.

One of the prime benefits of the instrumentation program was the evidence received (by means of read-outs) that something was wrong at the solar site. When IBM (later Vitro) became aware that something was amiss, it would notify Boeing, which would visit the site to determine what the problem was. In some cases, the instrumentation was found to be malfunctioning, and Boeing would make the necessary repairs. Often, however, the solar system itself was the problem. This was most dramatically indicated in the case of air systems. Those systems universally had such extensive leaks in the ductwork and storage as to make the instrumented data nearly impossible to interpret. Thus, the unplanned result of the instrumentation program was to provide the first indication of apparent widespread solar-system problems. This ultimately led to the significant repair activity discussed in Chapter 5.

Volume V of this final report contains summary findings of the performance of the instrumented sites. Figures 4-16 through 4-18 are samples of the analysis of the instrumented data. Figure 4-16 shows the measured performance of domestic hot water systems, 4-17 describes passive-system performance, and 4-18 is a similar graph for active space-heating systems. Specific performance reports for 66 of the 83 instrumented sites can be obtained through the NTIS.

DATA STORAGE AND RETRIEVAL

During planning, it became apparent that the volume of data to be collected dictated automated data storage, retrieval, and analysis. HUD and NBS established the Residential Solar Data Center (SDC) to provide these services. Using the NBS Univac 1108 computer and supported by NBS staff, this data center was the repository for most of the non-technical and technical non-instrumented data collected. Substantial coordination between Boeing and NBS, FIRL, DBA, RERC, and HUD was needed to establish interface responsibilities, develop transcription and report formats, maintain accuracy of the data, and determine the validity of using certain data in specific applications.

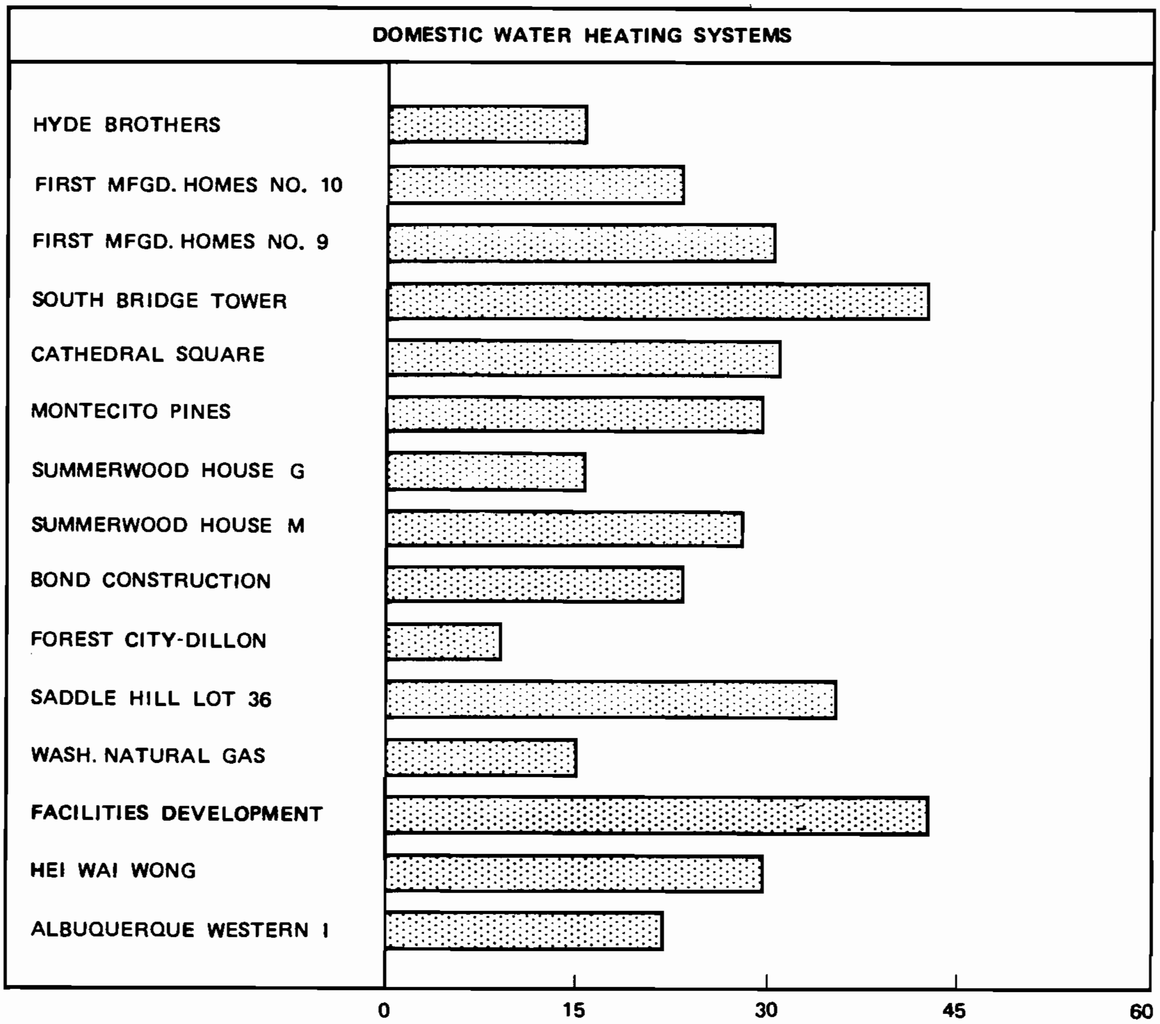

Figure 4-16. Incident Solar Energy Delivered to Load--
Domestic Hot Water

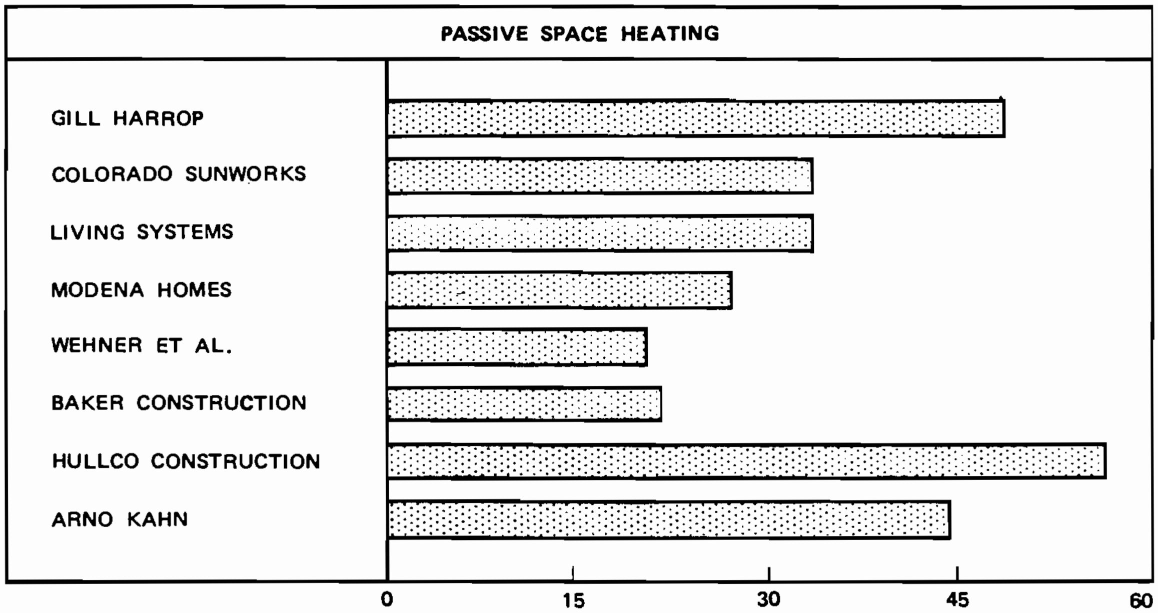

Figure 4-17. Incident Solar Energy Delivered to Load--Passive Space Heating

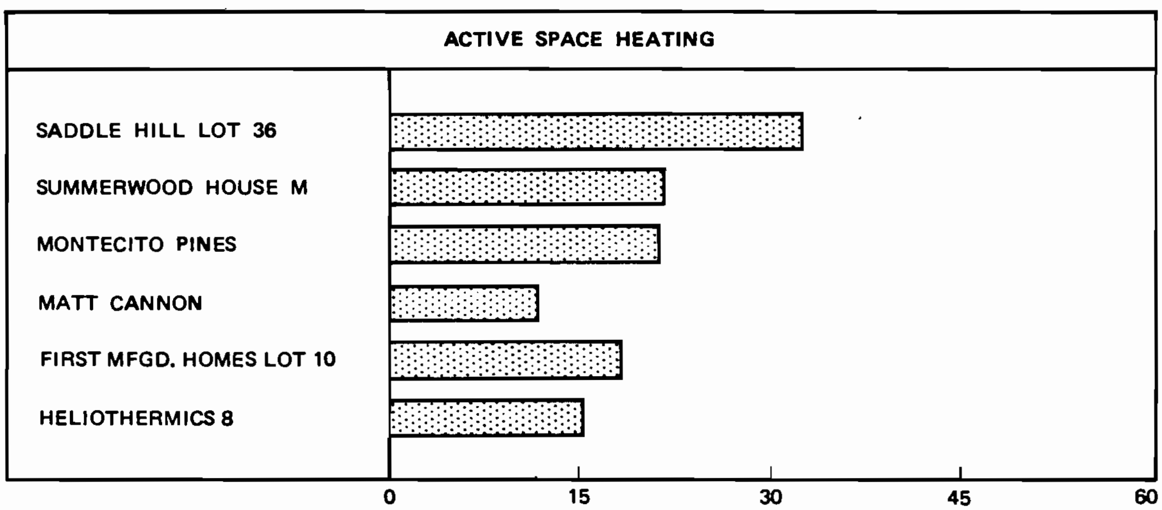

Figure 4-18. Incident Solar Energy Delivered to Load--Active Space Heating

SDC converted data collected and transcribed by Boeing and its subcontractors into reports and computer printouts, which substantially aided both the organization of the data-collection process and the subsequent data analysis and evaluation. Figure 4-19 shows how the data base itself was organized and how computer programs and interactive data-file access were used.

Instrumented data were handled in an entirely different way. Sensor-derived data were transmitted by telephone lines from the homes to a computer, then processed and stored by a DOE contractor. Boeing's role was limited to design and installation of sensors and maintenance of those sensors, once installed.

DATA ANALYSIS AND REPORTS

There was a variety of uses for the data collected: information, analysis, basis for reports and publications, and program management tools. Volume V of this report, Summary of Data Findings, is a synopsis of data analysis.

The program bibliography contains references to all major reports and pubications written or developed by the residential solar program. Boeing was responsible for a number of publications. Among these were the following major efforts:

- Marketing and Market Acceptance Data from the Residential Solar Demonstration Program: 1980
- Passive Solar Homes in the Marketplace
- Installation Guidelines for Solar DHW Systems
- Solar Domestic Hot Water—A Reference Manual
- Final Report of the Management Support Contractor (five volumes)

In addition to these publications and others described in the bibliography, Boeing assisted in analyses and studies published by other data users. Assistance included supporting Franklin Research Center's public information services and publications with specialized data and supporting NBS in its publication efforts. Special studies and program-evaluation data were also supplied to HUD.

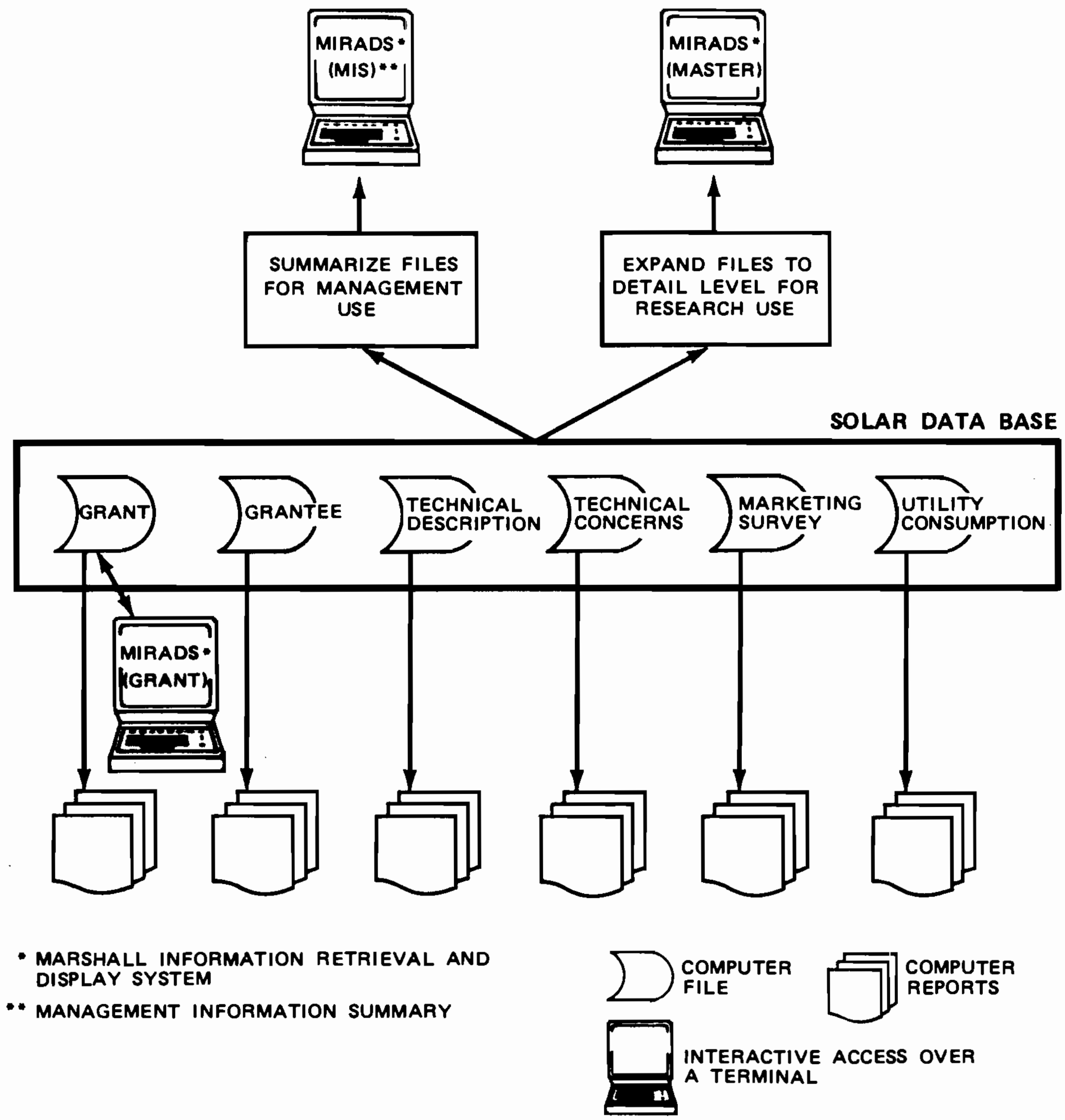

Figure 4-19. Solar Data Structure

CHAPTER 5. REPAIR PROGRAM

HUD awarded 943 grants during the residential demonstration. However, when adjustment is made for those grants that were for design only and grants that were annulled or terminated, 497 actually resulted in construction. The 497 grants involved 10,098 living units and 1,255 solar systems. Any statistical references or percentages given here are related to the foregoing numbers of grants and units. See Figures 5-1, 5-2, and 5-3.

The wide variation in the numbers can be explained by giving some examples. An award for a multi-family apartment building of 200 units is one grant and one system. On the other hand, an award for single-family detached housing is one grant and as many systems as there are units in the grant, i.e. a five-unit grant involves five systems.

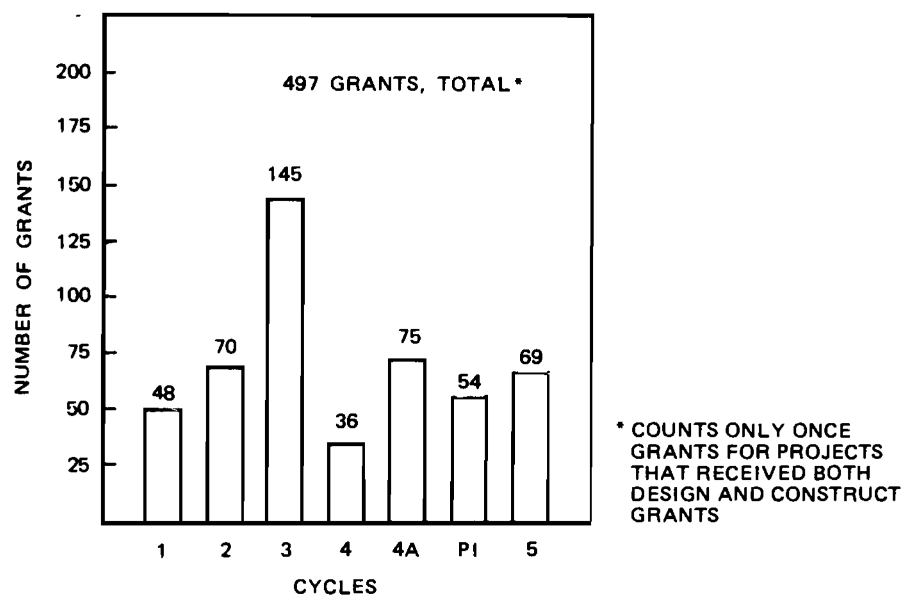

Figure 5-1. Number of Grants Constructed per Cycle

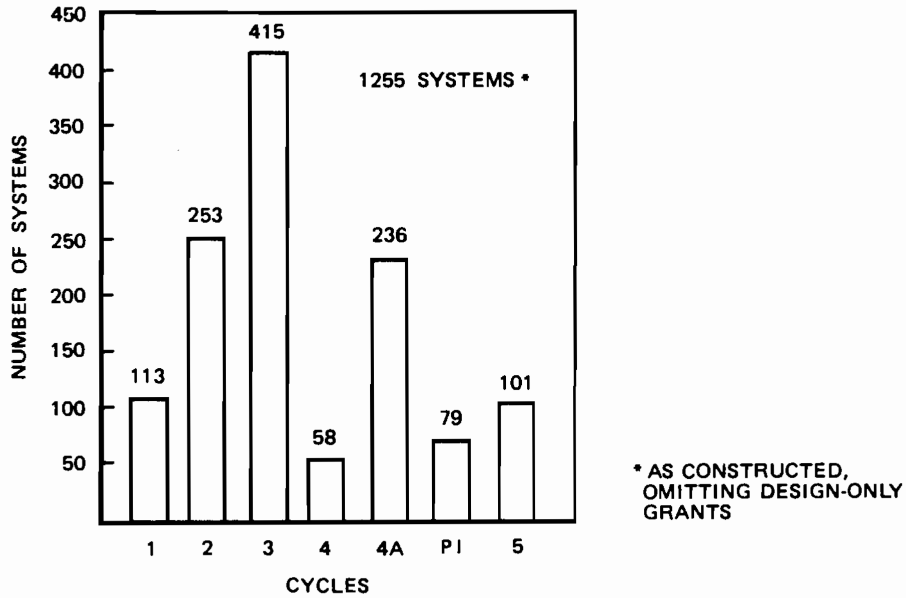

Figure 5-2. Number of Systems Constructed per Cycle

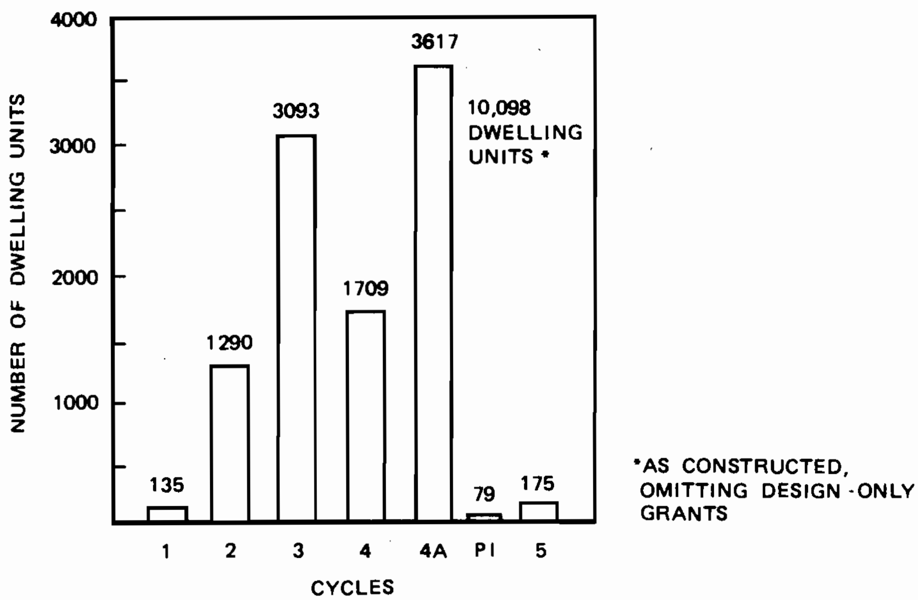

Figure 5-3. Number of Units Constructed per Cycle

ORIGINS OF THE REPAIR PROGRAM

Shortly after units produced in the various award cycles became operational, reports of problems began to surface during routine site visits, planned purchaser surveys, or investigation of instrument anomalies. In many cases, the home purchaser or the grantee made calls directly to HUD or to the appropriate Boeing field office to register their solar system complaints. Most of these direct complaints came after the owners or grantees involved had been unable to get satisfaction from their respective contractors.

Initially, these complaints were handled by referral through the Boeing field representatives to the grantees for corrective action. Typically, the problem would become dormant only to recur, in more serious fashion, at a later time, with more purchaser irritation. During this period, HUD was striving to maintain a "hands-off" posture toward the builder-purchaser relationship. Boeing field representatives did, however, encourage manufacturers and builders to respond to reported problems. Boeing entered into direct contract activity only where there were problems with instrumented systems--either in the instrumentation per se, or in the system in a manner that prevented proper functioning of the instruments. For the most part, the earliest problems involved air systems, which leaked so badly that the instrumentation would not work properly.

During 1978 the incidence of trouble reports began to increase rapidly. Boeing's experience and findings on instrumented systems gave indication that there were serious problems with almost all types of active systems. Starting in January 1979, HUD began to respond to limited numbers of complaints over and above the repair activities being conducted for instrumented systems. Problems then were examined on a case-by-case basis. By this time, the range of problems had grown to leaking liquid systems, repeated pump failures, and malfunctioning controls. HUD made specific authorization as to the level of corrective action. By summer, the volume of complaints reaching HUD from various sources involved many recurrent circumstances. The need for a formalized review, tracking, investigation, and correction procedure became obvious lest the purchasers of troubled systems sustain significant financial losses. HUD therefore directed Boeing to develop a plan for a formal review process.

While the plan was in development, the Government Accounting Office (GAO) issued a report (dated October 9, 1979) critical of the program for not taking more effective and comprehensive action to ensure that all systems were operating properly. The basis of the findings was an independent, random investigation by GAO of 20 operational grants involving 91 dwelling units. GAO's investigation revealed a serious, short-term failure rate roughly equivalent to what HUD had found up to that point. As with HUD's investigations, there were signs that the rate was time-related and could be expected to worsen considerably.

At about the same time that the GAO report was published, HUD, having considered various recommendations, coordinated with DOE and adopted a plan for formal action. A review board was established to conduct a methodical assessment of reported problems and prescribe the corrective action to be taken. It consisted of the HUD division director, the solar program manager, and key members of the solar technical staff. Key solar staff members from DOE and NBS were invited to participate as consultant/advisors to the board.

PROCESS DESCRIPTION

With the establishment of the HUD System Operating Problem Review Board, a procedure was developed for problem identification, investigation, board review, and resolution. Initially, because of the backlog of complaints on hand and the rate at which new problem reports were reaching HUD, it was decided that no full-scale survey of all projects would be undertaken. The backlog and its current rate of growth were as much as the available, experienced manpower could effectively assimilate.

At that time, problem reports were reaching HUD either directly from grantees or purchasers or through complaints by such parties to field representatives. Other reports originated with the field personnel, as the result of direct observation while on routine site visits, and from the read-out of data at the instrumented sites. A System Operating Problem Report (SOPR) was prepared for each of the problems on hand and for all new problems as they were reported. The SOPR provided a summary statement and an action report through to the ultimate resolution of each problem. Figure 5-4 is a sample.

Each SOPR was entered on a control board, which was displayed in the solar work room and served as the basic review tool for meetings of HUD's review board. A sample of the control board format appears as Figure 5-5.

In October 1979, the HUD problem review board held its first monthly meeting. Each grant that had been identified as a current problem was discussed. The board then prescribed actions to be taken by the management support contractor and its solar-engineering subcontractor (DBA). Milestones were established for the completion of action items and further review and disposition by the review board. In addressing the problems, the board considered the nature and probable source of the trouble and in most cases ordered a technical review of the site by DBA. DBA, in company with the appropriate Boeing field representative, visited the site. The review team made a technical assessment of the problem and provided a visit report to Boeing, along with recommendations for problem resolution, which the review board considered at its next meeting.

Basically, in considering the results and recommendations of the site technical analysis and circumstances of that particular grant, the board could determine one or more of several actions to be appropriate.

- If the grantee, the owner, or DBA had resolved the problem during the site visit, the matter was deleted from further board consideration.

- If the problem continued after the site visit, a determination was made as to whether the system was repairable and whether the grantee (including the manufacturer/installer) was responsible for the problem and was capable and willing to perform the repair. If so, HUD technical assistance was authorized.

- If the problem was beyond the scope and responsibility of the grantee team or it could no longer perform, a HUD repair of the system was authorized.

- If the system, on the basis of condition and poor performance, would be of

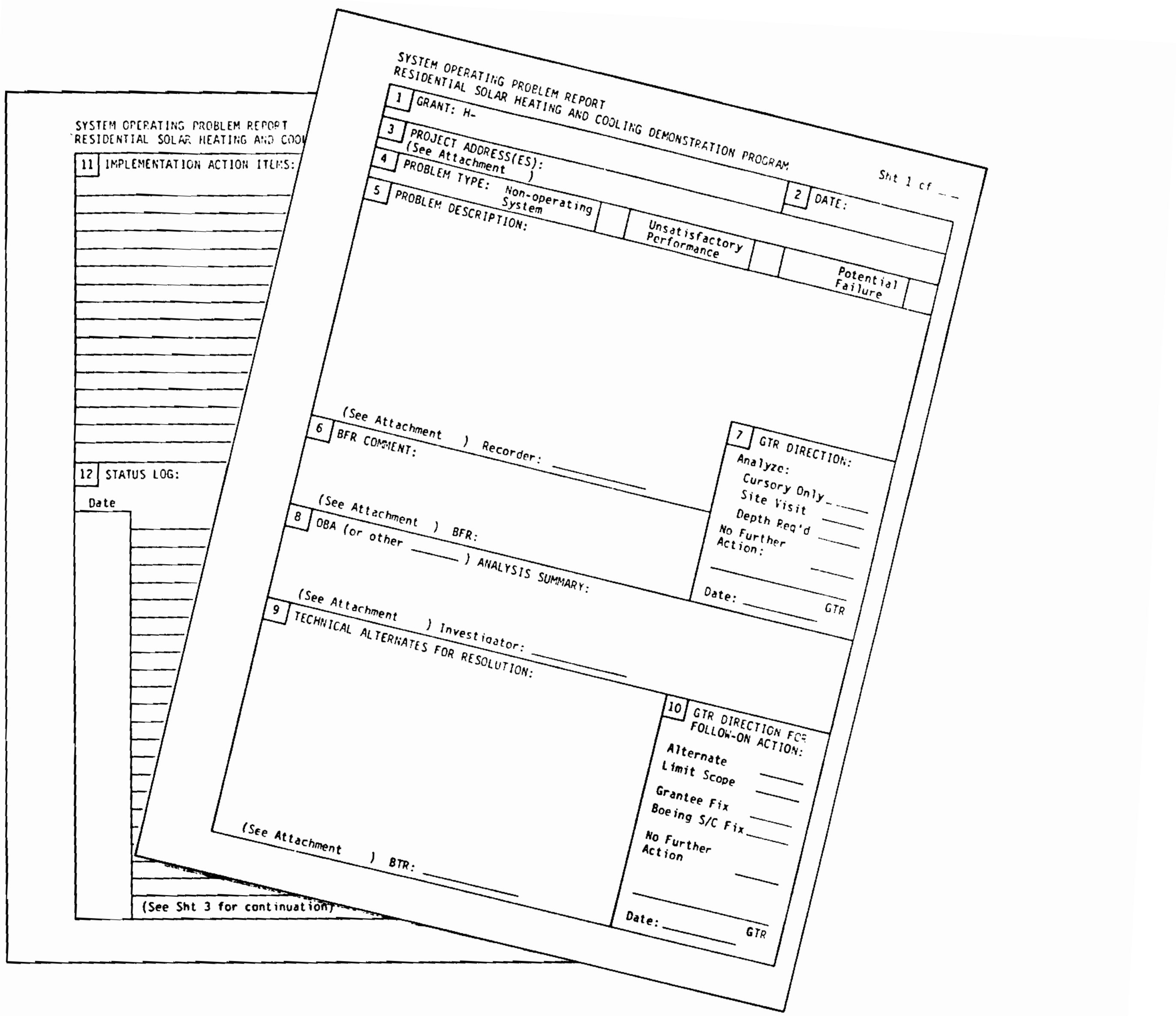

Figure 5-4. Format for System Operating Problem Report

SOLAR SYSTEM OPERATING PROBLEM CONTROL SHEET

STATUS AS OF 12/14/82

WESTERN | WESTERN

				IDENTIFICATION & REVIEW				RECOMMENDATIONS & DISPOSITION		PROBLEM RESOLUTION BY HUD				FOLLOW UP	
GRANT NO H- BFR (I)	GRANTEE NAME & PROJECT ADDRESS	UNITS/TYPE SYSTEM TYPE GRANT AMT	SYSTEM PROBLEM DESCRIPTION — ESTIMATED REPAIR COST	REPORTED BY	SOPR PREP (BLKS) (1-6)	HUD-PRE GTR DISPO (BLOCK) (7)	DBA TECH ANALYSIS (BLOCK) (8)	TECH ALTER & RESOL (BLOCK) (9)	HUD-PRE GTR DISPO (BLOCK) (10)	WORK SCOPE & SPECS	CONTR PROPL / GOV EST	HUD/GTR APPROV / WORK IN PROGRESS	CHECK OUT	GRANTEE OR HUD FIX	REMARKS
H-8187 BB	WITKIN HOMES 10482 W. IDA PL DENVER, CO	1 SFD HW LIQ (A) $8,650	POTENTIAL CORROSION PROBLEMS DUE TO OPEN SERVICE LOOP, FERROUS COLLAR & COVER ON STORAGE TANK & STEEL HEADS ON H/E FOAMED (BALLOON) CONSTRUCTED STORAGE TANK HAS BLISTERS & SEPARATED LINER. $600	SURVEY	●	TECH REVIEW SITE	●	●	HUD REPAIR	●	● / ●	● / ●	○ 1/15/83		WORK DELAYED BECAUSE OF SALE OF HOME.
H-8183 BB	GUTRICH DEVEL. CO. 489 S. KINGSTON CIRCLE AURORA, CO	1 SFD HW LIQ (A) $8,700	POTENTIAL CORROSION PROBLEMS DUE TO OPEN SERVICE LOOP, FERROUS COLLAR & COVER ON STORAGE TANK & STEEL HEADS ON H/E FOAMED (BALLOON) CONSTRUCTED STORAGE TANK HAS BLISTERS & SEPARATED LINER. $3,506	SURVEY	●	TECH REVIEW SITE	●	●	HUD REPAIR	●	● / ●	● / ●	● 9/30/82		WORK COMPLETE
H-8156 BB	ED THOMAS & ASSOC PAOLA, KS	2 SFD HW AIR (A) $21,192	HUD REQUESTED BOEING TO CHECK FOR PROBLEMS SIMILAR TO H-8157 SINCE SOLAR SYSTEM WAS INSTALLED BY SAME GRANTEE AND SOLAR INSTALLER. APPROX. $21,168	HUD	●	TECH REVIEW SITE	●	●	HUD REPAIR (1 Unit) REMOVE (1 Unit)	●	● / ●	● / ●	○ 1/15/83		WORK UNDERWAY. NO PROBLEMS
H-8407 JH	HOUSING AUTHORITY OF JOLIET, JOLIET, IL	139 MF W LIQ (A) $115,000	SYSTEM DOWN DUE TO NUMEROUS LEAKS IN COLLECTOR HEADER JOINTS $19,312	GRANTEE	●	TECH REVIEW SITE	●	●	HUD REPAIR	●	● / ●	● / ●	● 11/15/82		WORK COMPLETE
H-2778 BB	UNIV. OF COLORADO 1940 WALNUT ST. BOULDER, CO	95 MF HW LIQ (A) $245,000	SYSTEM IS FUNCTIONALLY OPERATIONAL BUT HAS NUMEROUS PROBLEMS THAT WILL SHORTEN ITS LIFE AND INHIBIT PERFORMANCE. LENNOX COLLECTORS HAVE USUAL PROBLEMS ASSOCIATED WITH THIS MFR. $39,307	SURVEY	●	TECH REVIEW SITE	●	●	HUD REPAIR	●	● / ●	● / ●	○ 12/15/82		EIGHT WEEK LEAD TIME FOR DELIVERY OF TUBE BUNDLE IS CAUSING DELAY.
H-2465 BB	SOLAR ENG. CONSTR. 1525 E. COUNTY RD. 58 FT. COLLINS, CO	1 SFD HW LIQ (A) $9,450	HUD DIRECTED BOEING TO INVESTIGATE CONDITION OF SOLAR SYS. COLLECTORS ARE ALUM. & PAST REPAIR EXPERIENCE INDICATES POTENTIAL CORROSION PROBLEMS. $8,070	SURVEY	●	TECH REVIEW SITE	●	●	HUD REPAIR /REMOVE	●	● / ●	● / ●	○ 12/20/82		SYSTEM OPERATIONAL ON MANUAL CONTROL. CONTROL SYSTEM PROBLEM.
H-8436 BB	CITY OF BOULDER 7TH & WALNUT BOULDER, CO	81 MF HW LIQ (A) $195,000	G.E. EVACUATED TUBULAR SYSTEM APPROX. 10% OF COLLECTORS HAVE BROKEN TUBES, STEEL TANK COATING NOT RATED FOR HIGH OPERATING TEMP. CONTROL AND CORROSION PROBLEMS. $7,966	SURVEY	●	TECH REVIEW SITE	●	●	HUD/GE REMOVE	●	● / ●	● / ●	○ 12/20/82		MINOR WORK REMAINING TO BE COMPLETED.
H-2466 CC	VINCENT L. OREDSON 1155 GREENMEADOWS WAY ASHLAND, OR	1 SFD HW LIQ (A) $7,100	OPEN SYSTEM STEEL TANK. COLLECTOR VENT CONTINUOUSLY OVERFLOWS AND REDUCES SOLAR CONTRIBUTION. NOISY PIPING AND FLIMSY REFLECTOR PANELS $17,175	SURVEY	●	TECH REVIEW SITE	●	●	HUD REPAIR	●	● / ●	● / ●	○ 12/20/82		SHADING DEVICE AND COLLECTOR VENT UNDERWAY.

Figure 5-5. Sample of a Problem Control Sheet

questionable performance value when repaired, Boeing was directed to suggest to the owner that the solar system be removed and replaced with an equivalent conventional energy system. If the system could be repaired, but the owner no longer wanted the risk of future problems, HUD authorized the removal of the system.

Following the board's choice of action, DBA was directed to develop a work scope and specifications. HUD, if it was to be involved in funding the effort, also required preparation of a government cost estimate of the work. HUD and Boeing reviewed the work scope and specifications for any corrective action proposed by DBA. Following such coordination, if the repair was to be funded by the grantee team, the work scope and specifications were turned over to them for use in accomplishing the work. If the work was to be funded by HUD, the cognizant Boeing field representative gave the work scope and specifications to a repair contractor for a proposal to accomplish the work. Having obtained a satisfactory cost proposal, Boeing forwarded the package to the GTR for authorization of contract award. Once work was commenced at the grant site, whether by the grantee or under a Boeing repair contract, the field representative maintained periodic follow-up on the work in progress. He relayed monthly status information to the HUD control function. Each active project was individually reviewed at HUD's monthly meeting until the board found that the required action was complete.

In choosing contractors for repair or removal of systems, a deliberate decision was made to deal with the original grantee/installer wherever possible. The logic for this decision centers on the fact that most of the system problems resulted from a lack of understanding rather than deliberate oversight. If these grantees/installers were going to remain in the solar field, it was important from the standpoint of future consumers that they share in the learning experience, which the repair or removal of the systems would provide. Boeing followed this course of contractor selection in every case except where the parties were no longer in business, did not want any further involvement, or were unacceptable to the homeowners.

The repair program continued in the above-described mode with no formal surveys being conducted. A significant number of problems came to HUD's attention and were taken into the program. However in May 1980 a roof fire, caused by an overheated collector on a grant project in Boulder, Colorado, triggered an investigation into collector materials and configurations that could represent a potential hazard. This investigation eventually led to a survey at 33 grant locations, involving 54 systems, where the reported configurations posed theoretically hazardous conditions. While the investigation and survey did not discover any actual additional hazards, most of these grants were taken into the repair program for other deficiencies noted in the surveys. The investigation led to a survey of all solar-attic houses, involving another 16 grants and 23 systems; all were incorporated into the repair program.

Apart from these limited surveys, HUD continued its repair program on the basis of letting the problem reports find their way to HUD as opposed to searching them out in the field. This approach to provided sufficient activity for the available manpower resource and the projected available funds.

In early 1981, problem reports from the field began to dwindle to a level of two or three per month. If allowed to continue at that rate, the repair program would take years; only a stronger effort could produce an effective, timely conclusion. From HUD experiences to date, it was appropriate to assume that there were still a significant number of problems in the field, of varying degrees of severity. With the passage of time, it was reasonable to assume that many of the owners had, by then, lost track of where to go with a complaint. Because of a serious recession in the home construction market, many of the grantees/installers had gone out of the business or sought greener pastures, and were no longer accessible to the owners. Funding cutbacks at DOE also had substantially reduced the monitoring of instrumented systems. Such monitoring had been a major source of problem identification in the past.

HUD assessed the situation and drew three important conclusions.

- o There were additional repair funds available, which could be used effectively if a significant project activity were maintained. This would produce a reasonable balance of repair and administrative costs and optimize the number of repairs accomplished by the end of the management support contract.

- o There were not sufficient funds, in any case, to correct <u>every</u> problem that a random survey might uncover. Given a wide variance in the range of problem severity, the most equitable approach would be to provide for all possible life, safety, or health hazards first and then assess the remaining potential problems by category of severity, match the unvisited grants to their appropriate categories, and begin a prioritized survey of the remaining grants. The priority would be based on the rank-order of severity. The worst of the problems would be identified and repaired to the maximum extent of the funds available.

- o Any problem reports reaching HUD from other sources would still be investigated and incorporated in the repair program as before.

In keeping with these conclusions, DBA reviewed potential hazard conditions. The review led to a collector condition survey and, ultimately, to the removal of all copper-clad plywood absorbers. (Volume II of the final report covers this subject in depth; see Case Study #3, Lucke & Strassel Builders.) Further, an assessment was made that identified corrosion in liquid systems as the most serious problem to be encountered after all life, safety, and health hazards were considered. Within the grouping of grants with potential corrosion problems, there were system configurations that were potentially more troublesome than others. Survey priorities were arranged accordingly.

Table 5-1 is a synopsis of the corrosion survey, which was accomplished in the order set forth. Boeing/DBA began the surveys in July 1981 and continued them through May 1982. All the projects surveyed were incorporated into the repair program for action.

In summary, 229 grants were involved in the repair program. This number compares with the total of 497 grants in the demonstration overall (excluding design-only and annulled grants).

TABLE 5-1
PRIORITIES FOR CORROSION SURVEY

Category of Precedence	Number of Grants	Number of Units	Number of Systems
1. HUD-funded projects	10	412	18
2. Oldest projects with corrosion potential	10	22	12
3. Aluminum collectors	4	5	5
4. Open systems (both sides), steel tank, dissimilar materials	8	20	20
5. Open systems (both sides), any tank, dissimilar materials	19	50	50
6. Open systems (service loop only), any tank, dissimilar materials	10	19	19
7. Additional ZRC tank coatings (not found in categories 1-6 above)	4	348	4
Totals	65	876	128

In considering these statistics it should be noted that the most serious system problems were addressed, but there is reason to believe that many remain unreported and unresolved. The uninvestigated problems could have substantially increased the scope of the repair program if funds had been available.

PROBLEM TYPES

Problems encountered during the repair program usually involved active space-heating systems. HUD awarded few grants for domestic hot water (DHW)-only systems in single-family residences; most such systems were installed in large, multi-family projects with care for engineering and maintenance.

Our data base for passive systems is, so far, too limited to allow formal conclusions. Most of these projects were in the later grant cycles. On a percentage basis, complaints about passive systems have been negligible.

The various solar-system problems can be put in two classes. While a "significant" problem, obviously, is prime cause for concern, any system with a number of "general deficiencies" is likely to fail, as well. The following sections outline, in layman's terms, the major problem categories. Volume II of the final report is a more detailed technical description, written around typical case studies.

SIGNIFICANT PROBLEMS

Significant problems fell into five categories: hazardous installations, corrosion, collector degradation, thermal transfer and storage losses, and control deficiencies.

Hazardous Installations

The hazard potential of some solar systems was not generally recognized until a fire occurred in the roof-mounted collector array of a solar project in Boulder, Colorado. After prolonged periods of stagnation, the foam insulation behind the absorber plate had degraded and exposed the plywood collector box to extremely high absorber-plate temperatures. The plywood ignited and burned through to the adjoining roof. The collector was destroyed and the roof was moderately damaged (Fig. 5-6).

HUD directed that an investigation be made to identify all solar systems that presented a life-safety hazard. Approximately 1,100 system designs were reviewed. When necessary, field investigations were made to check and verify actual conditions. Most solar installations were found to pose no identifiable danger to life or safety or other long-term effects of degradation. Those that did were divided into two categories.

Potential threat to life--Collectors in this grouping, because of their configurations or materials of construction, were capable of igniting and catching the adjoining structure on fire. They had two significant characteristics.

- o Flush-mounted on roof with collector constructed of either wood or metal and containing foam insulation in direct contact with or in close proximity to the absorber plate--When subjected to prolonged periods at collector

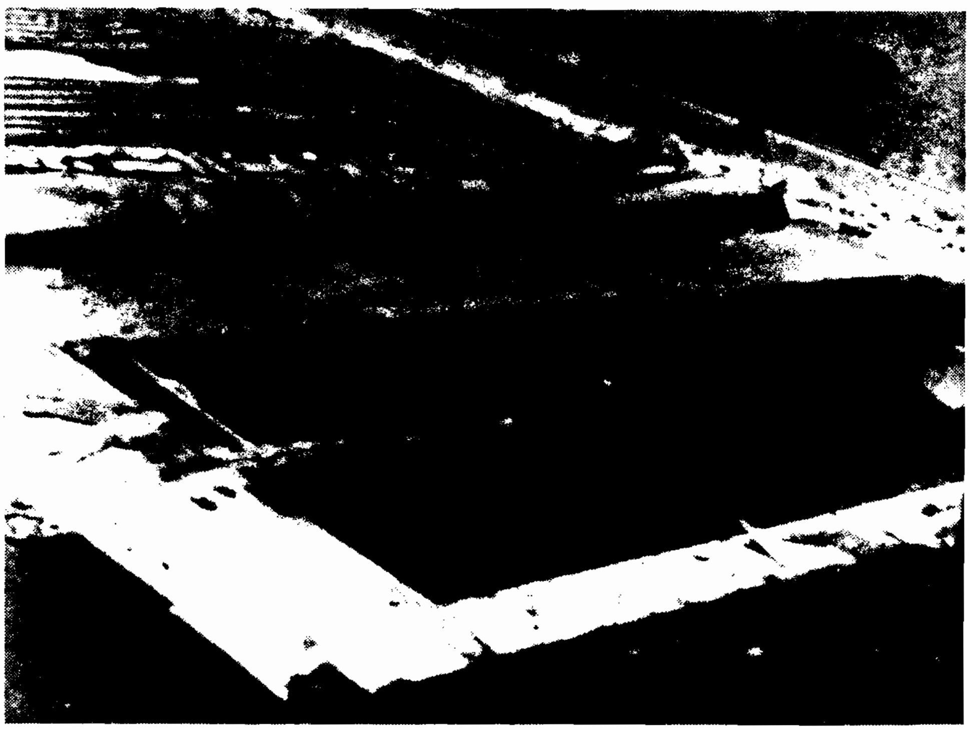

Figure 5-6. Roof Damage Caused by Overheated Collector

stagnation temperatures, foam insulation was found to degrade and lose its insulating values. Absorber-plate temperatures over 400°F in double-glazed collectors and up to 350°F in single-glazed collectors can occur under conditions of stagnation. Urethane and isocyanurate foams will outgas and degrade at temperatures in these ranges. All other foam insulation encountered in the demonstration program degraded at even lesser temperatures. Once the protection afforded by the insulation was lost, wood in the collector box or on the roof in direct contact with a metal collector was exposed to temperatures in the range that could cause ignition. A total of 58 collector systems in this grouping was investigated. Of them, four systems were found to be hazardous (one actually caught fire) and were replaced, by the manufacturers, with suitable collectors.

- Wood or other combustible material in direct contact with the absorber plate--One type of site-assembled collector was made with a plywood core encapsulated in a metal skin. The copper surface on top acted as the absorber. The back surface was aluminum. The absorber panels were designed so they could be fastened directly to the roof substructure. Fluid passageways and glazing were added to make up a site-built collector system that served also as a roof. High stagnation temperatures caused the plywood to degrade, in many cases turning to charcoal. No fires were known to occur with this collector system, but there was great concern that it would happen. In all cases, however, the structural contributions of these panels were lost and the residences involved were exposed to the potential for serious damage from wind or snow loads. All of the 30 collector systems in this category were removed or replaced with more suitable collector systems.

Long-term structural degradation--Collectors or solar systems in this grouping contained wood members subjected to prolonged exposure to high temperatures that would cause permanent structural degradation of these members. They had wood structural members and sheathing exposed to temperatures generated by the solar system in excess of 150°F. Studies conducted by the Forest Products Laboratory of the U.S. Department of Agriculture have shown that wood begins to undergo an irreversible loss in strength when subjected to long-term exposure to temperatures above 150°F. Nineteen solar attic air systems were the only solar demonstration systems that had this problem. They were all repaired by covering the exposed wood with insulation or with a reflective white paint. Attic ventilation systems were also upgraded, if required, so that summertime stagnation temperatures would not exceed 150°F.

The subject of hazardous collector systems and high temperature degradation of wood is completely explained and documented in Volume III, High Temperature Exposure of Wood Structures in Solar Systems.

Corrosion

The problems of corrosion in solar systems have various causes. The results, however, are the same: devastating, on an extremely short-term basis. Basically, all of the problems appear to relate to a near-universal manufacturer/designer/installer oversight or misconception of the chemistry of the systems they are marketing and installing. All liquid systems apparently were conceived, produced, and installed with the technology of residential hydronic-heating systems in mind.

The industry failed to recognize that solar systems reach much higher temperatures than ordinary hydronic systems. They contain, for the most part, both open and closed loops, with reactions to temperatures, fluids, and materials that are virtually unknown in standard systems. The result, as shown by Table 5-2, is that most liquid systems we investigated as part of our repair program had the potential for major, disastrous corrosion failure.

The problems can be more particularly explained and demonstrated by considering the places where corrosion occurs.

1. Collector loop—The collector loop, if closed, contains fluids for freeze protection not normally found in standard, residential, hydronic systems. Usually these fluids are glycol solutions containing inhibitors to prevent or retard corrosion. However, the solutions generally were developed for other uses (i.e. automotive cooling systems) where the life cycle, ease of maintenance, and penalty of failure are of significantly less consequence.

Of the solutions available, ethylene glycol offers the best performance under higher temperatures. It is not frequently used, however, because its toxicity requires a double-wall heat exchanger--an additional cost factor--if the loop in which it runs is in contact with the potable-water supply.

Many installations employ propylene glycol. It is essentially non-toxic and does not require a double-wall heat exchanger. Therefore it is considerably less costly. Such a solution, however, is not compatible with metals containing or coated with zinc (e.g. galvanized pipe or collector water passageways) and produces sludge deposits which can clog the systems.

TABLE 5-2
SUMMARY OF SYSTEM OPERATING PROBLEMS

ON PROBLEM LIST TO DATE (599 TOTAL):
422 liquid systems
153 air systems
24 passive systems

OF THE 599 SYSTEMS:
326 (54%) had collector-manufacturing problems
276 (46%) had collector-installation problems
247 (41%) had storage-installation problems
440 (73%) had transport/distribution problems
212 (35%) had control problems
58 (10%) had potential fire-hazard problems

OF THE 422 LIQUID SYSTEMS:
268 (64%) had severe corrosion problems

OF THE 153 AIR SYSTEMS:
129 (84%) had storage and transport leakage problems

The use of either solution introduces a maintenance element. Frequent testing of the fluid is required to maintain a proper pH balance. If the pH level is not maintained, "glycolic acids" can develop under high-temperature situations and will attack all system components; in the case of propylene solutions it also can allow the generation of hydrogen gases. As the pH balance worsens, the inhibitors are consumed and the degadation process is substantially enhanced. Solar-system purchasers have not received adequate information about this aspect of maintenance. Often, no convenient means for maintenance were provided either. Even with detailed information, inspection procedures, and access, the problem remains. This is not a process that the puchaser can visually observe or have called to his or her attention. Therefore, until the results of corrosion (e.g. leaks into the living space) become apparent, the problem can be as conveniently ignored as a clogged return air filter, but with more serious consequences.

Other significant problems found in the closed collector loops were storage tanks with coatings that could not withstand the high temperatures being generated and dissimilar metals with a potential for galvanic corrosion. These, however, usually occurred in tandem with the more serious problems mentioned above, and merely complemented the destruction process.

If the collector loop is open (i.e. drain-down or trickle system) antifreeze fluids normally are not present so temperature degradation of antifreeze solutions is not a significant problem. However, in the drain-down process, the system ingests oxygen; in such systems, all of the distribution-loop problems discussed next can occur and can also destroy system performance.

2. Open distribution loop--In the open distribution loop portion of these systems, high temperature and oxygen ingestion from the air in the vented storage tanks (neither of which is a normal condition of a typical residential hydronic system) combine to support a highly destructive corrosive process. The action is generally enhanced by a high incidence of dissimilar metals and specifically enhanced by the degree of metals dissimilarity, lack (or impropriety) of tank coatings, and a number of lesser factors. With the presence of continuous oxygen ingestion, the diversity in metals, and the temperatures to be attained--all of which exist in varying degrees in all of the liquid systems in our sample--the attack of corrosion is rapid and grossly destructive.

Figure 5-7 is a photograph of a typical multi-metal piping system with severe corrosion potential. Figure 5-8 shows a corroded pump housing and impeller from an open system that mixed metals.

The situation with respect to homeowner awareness of the impending problems is even worse than in the case of the collector loop. With only one known exception, there is no evidence in our sample of any form of treatment having been added to any system. Nor is the purchaser usually cautioned to maintain a certain balanced condition. Rather, the purchaser is generally not aware that there is a potential problem and will only learn of the situation with the onset of leaks or a system malfunction due to corrosion clogging.

The probability of the purchaser carrying out periodic maintenance and inspection is as doubtful as it is in the case of the collector loop. Firms, utility

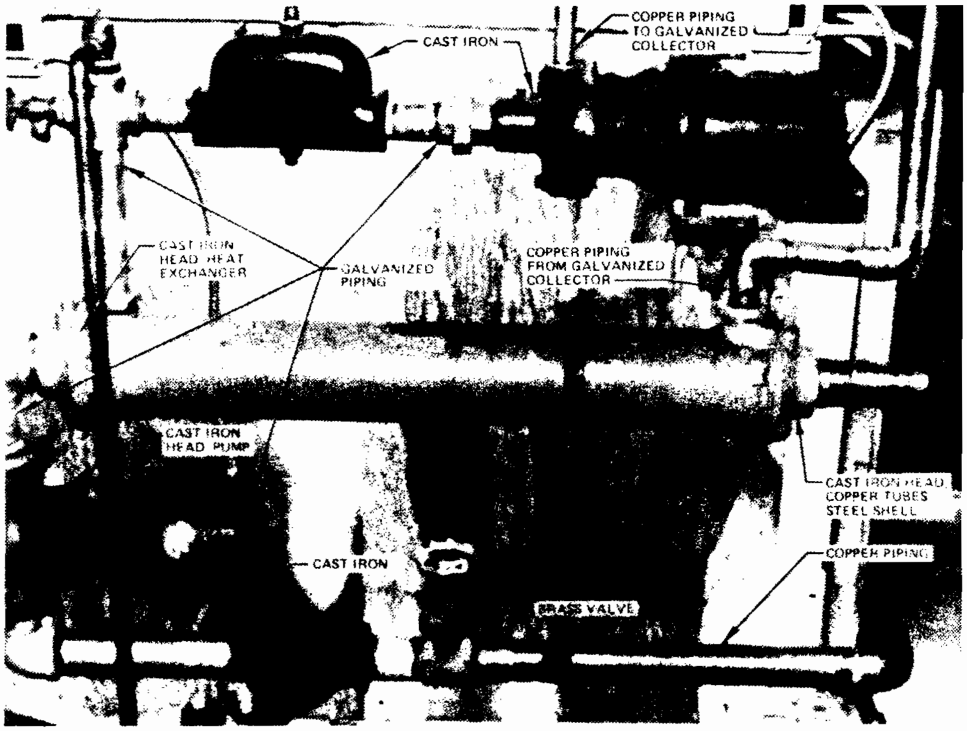

Figure 5-7. Multi-Metal Piping System with Potential for Corrosion

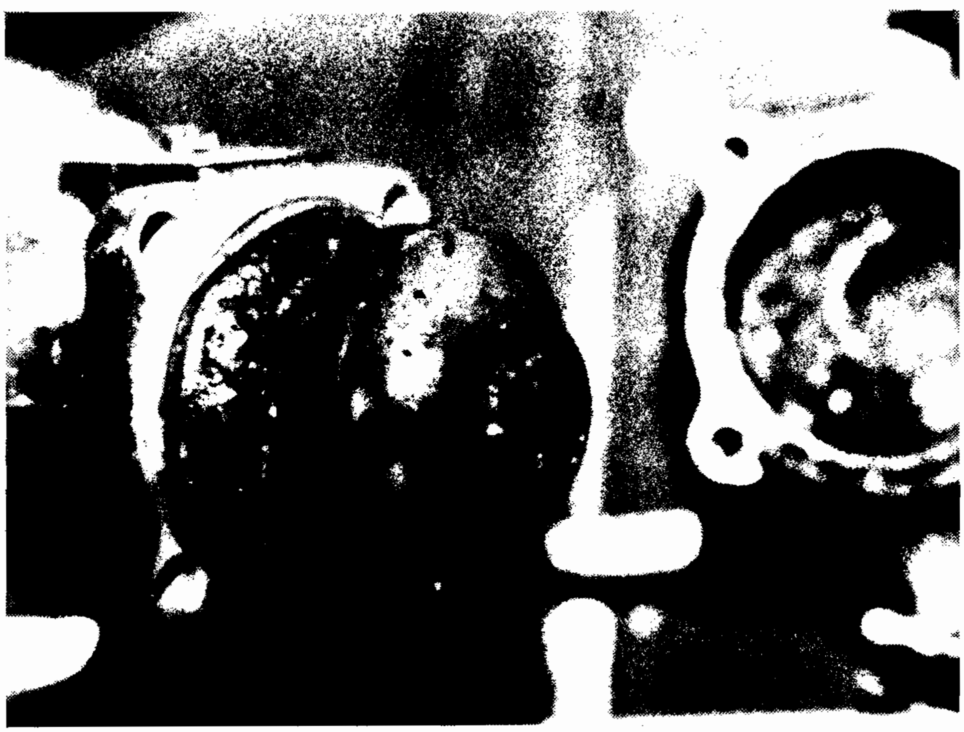

Figure 5-8. Corrosion of Impeller and Pump Housing

companies, and others involved in the residential HVAC market are aware of the general disdain with which homeowners treat such systems. In the case of normal HVAC systems, the homeowner can escape this neglect with losses in efficiency and resultant increases in utility costs and occasional replacement of a motor, pump, or heat exchanger. However in the case of a solar heating system the penalties can be of catastrophic proportion, because of secondary damage from leaks and the loss of major system components. (Volume IV of the final report covers the subject of corrosion in depth.)

Collector Deficiencies

Compared to the problems of corrosion in the delivery systems and the potential fire hazards caused by improper use of insulation and wood materials, collector systems held up reasonably well in the demonstration program. This does not mean that collectors were without fault. In fact, almost every possible fault that could occur was found on one project or another.

There were various causes for the problems. Some design or manufacturing decisions proved wrong in actual field use. Some well-designed and well-made collectors were improperly installed. Some were put into poor system arrangements. Many problems that came to light during the demonstration have resulted in product changes and improvements made by the industry. Unfortunately, in a significant number of these cases, the cure proved worse than the disease. The following discussion covers eight specific problems found with liquid and air collectors and collector systems. It does not address orientation, tilt, and shading, because these issues have become obvious to all in the solar field by now. (For reference, a cutaway view of a typical liquid collector is shown in Fig. 5-9.)

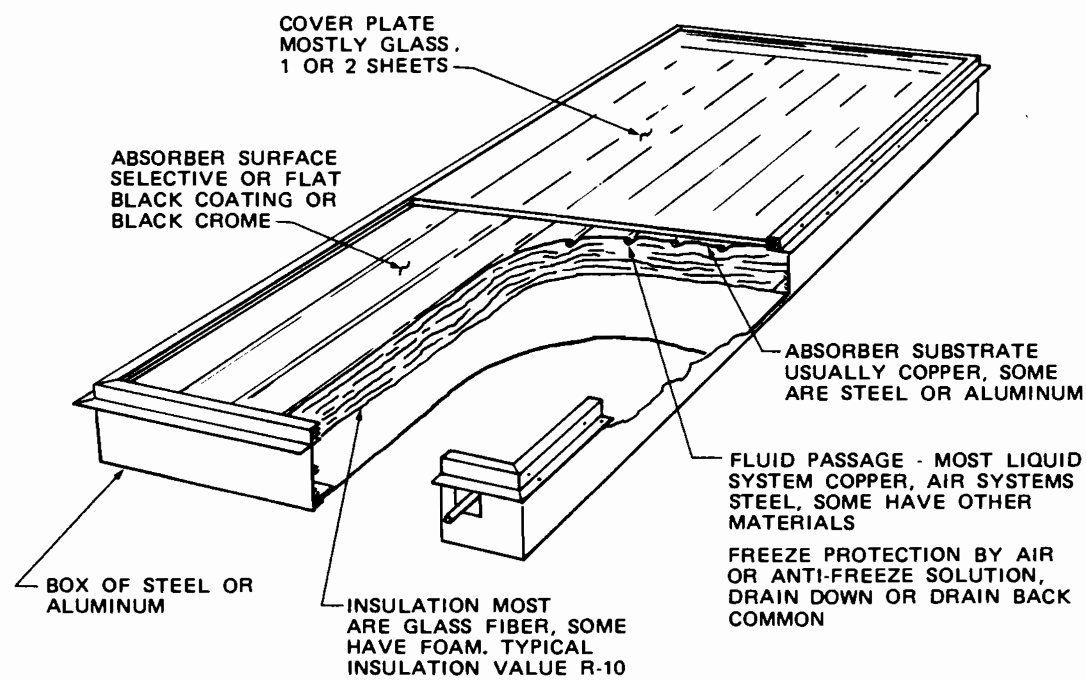

Figure 5-9. Characteristics of Typical Liquid Collector

1. Materials used for sealing double glazings and for gasketing the glazings to the collector frames frequently failed. Failure resulted in serious outgassing, which degraded the collection potential and allowed numerous leaks into the collector. The leaks, in turn, contributed to degradation of the absorber plates, fogging which affected performance, and in some cases, leakage from the collector through the roof and into the living space.

2. The choice of collector inlet/outlet locations and interconnection methods often contributed to serious fluid leaks from the system as well as difficulty in maintaining optimum flow balance, venting, and necessary drain down for freeze protection. (Piping-layout problems appear in Figs. 5-10 and 5-11.)

3. In all cases where steel or aluminum was chosen for collector water-passageways, serious corrosion resulted.

4. In choosing insulating materials for collectors, too little attention was given to the temperature ratings of the materials chosen. Material was sometimes placed in contact with, or in close proximity to the absorber plate. This causes serious degradation of a variety of foam insulations. The results of such degradation can be serious loss of insulating quality, heat losses out of the collector, and--where wood or other flammable materials were present--a potential fire hazard. In other cases, manufacturers chose fiberglass insulating materials which had been saturated with a chemical binder. These binders broke down under high temperature, causing serious outgassing and the attendant reduction in performance capability.

5. Too little recognition was given to dry stagnation in liquid systems. Few collectors were able to withstand long periods of stagnation without some significant degradation. Many systems had to be operated for extended periods in a heat-dump mode, wasting operational electric energy, to protect these collectors from self-destruction. Mylar heat traps installed in some collectors could not withstand stagnation temperatures and melted down on the absorber plate, thereby reducing collector efficiency.

6. The high leakage of many air collectors was such that available solar energy could not be collected in sufficient quantities to justify system operation. The above collector deficiencies are all preventable with proper design considerations and manufacturing techniques. Their elimination would do much for solar system efficiency and reliability.

7. Program experience with tracking collectors was generally unsatisfactory. The high efficiencies theoretically achievable with these collectors was seldom realized because mechanism malfunctions seemed to be endemic to all such collectors. The less complex flat-plate collector configurations usually proved to be the most satisfactory. What they lacked in potential as compared with tracking collectors was more than offset by a much greater collector and system reliability.

8. Evacuated-tube collectors were also generally unsatisfactory. These collectors were highly susceptible to damage both from external causes and from thermal shock, originating with the system, due to lack of controlled safeguards or the failures of same.

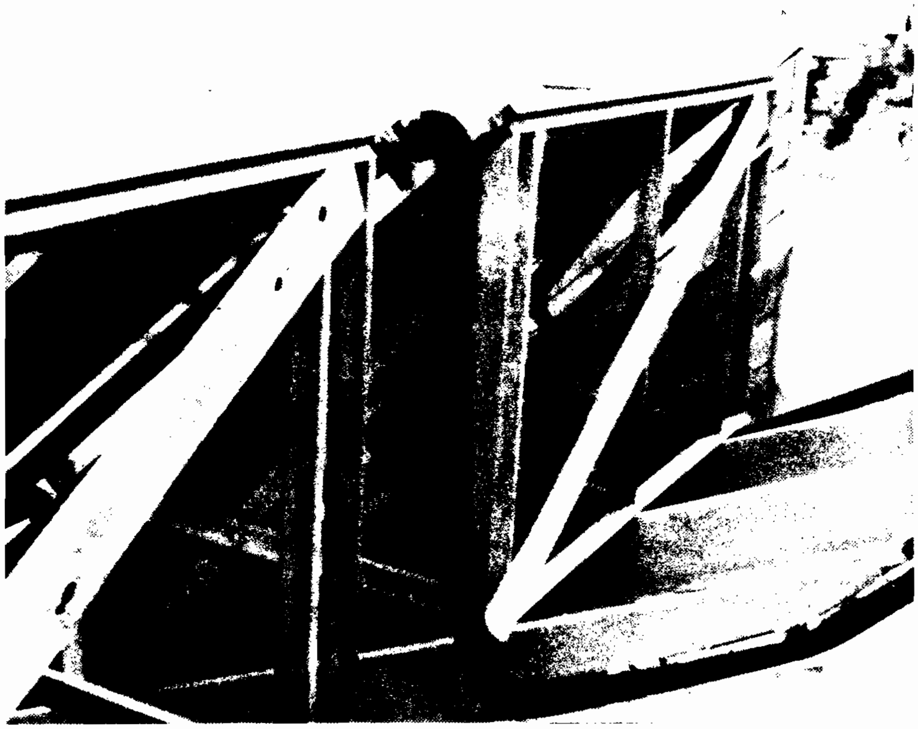

Figure 5-10. "Saw-tooth" Header Susceptible to Air Lock

Figure 5-11. Collector-to-Collector Connections with No Drain

Thermal Transfer and Storage Losses

Clearly there is no merit in a system that cannot transport, store, and deliver the collected energy when and where it is required. However, considering the numerous installations that pay slight attention to proper insulation, sealing, and dampering, one must wonder just how obvious that statement is. Basically, it appears that the solar industry did not perceive adequately the nature and function of the storage and controlled release of energy in a residential heating system.

Active space-heating systems have, for the most part, employed the same technology as standard forced-air systems. Standard air systems essentially produce and distribute heat only on demand, so the uncontrolled leakage of heat, within a structure, is of relatively minor consequence. With a reduction in efficiency and balance, the loss is to the load on demand only. In the case of solar systems, where the major enabling feature is storage for later demand use, uncontrolled losses represent a serious problem 365 days of the year, not simply when the distribution system is responding to a demand for heat. Uncontrolled losses result in insufficient response, despite the collection ability of the system, when heat is required. They also can cause overheating when the residence requires cooling. In any case, the uncontrolled release of heat to the living space when it is not needed, is always a waste of energy.

Figure 5-12 is a photograph of a system that lacks insulation on the piping; furthermore the storage tank is leaking and also losing a significant amount of heat through a poorly fitting cover.

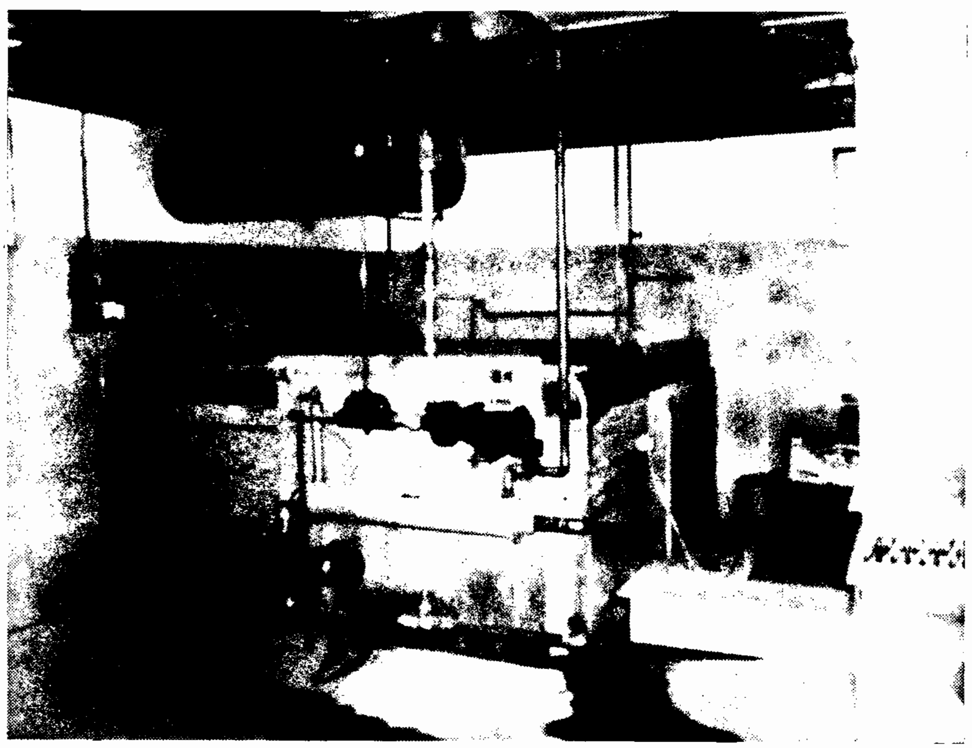

Figure 5-12. Unnecessary Heat Losses Resulting from Poor Installation

Liquid systems--In the discussion of collector piping, mention was made of numerous deficiencies found in pipe insulation. This situation also was common in the transport piping from collectors to storage. The insulation that was installed frequently was material that should not be exposed to the elements, at least not without protective covering, or should not have been used externally in any case. Many installers left so many gaps at valves, pipe bends, and brackets that the insulating value was substantially diminished. Within the structure, transport piping that called for insulation was found uninsulated in attics, walls, and ceilings where its non-conformance to specifications went unnoticed.

While the specifications for storage tank insulation were generally adequate, the application, in a number of cases, did not conform in thickness or uniformity. Some problems could be ascribed to the poor location of interior tanks, which impeded access for the insulator. Some buried tanks were uninsulated under the apparent misconception that the earth cover would provide adequate insulation.

In many cases, the installer was not required to insulate the distribution lines, was allowed to leave the job without doing so, or improperly applied the insulation that was furnished. Uninsulated distribution lines result in uncontrolled heat loss to conditioned and unconditioned space, depending on the system layout. In addition to the lost solar-derived energy, a further energy waste is imposed in the distribution pumping process by requiring more pumping energy to deliver heat from storage to the conditioned space. Where these losses occur in conditioned spaces, creating overheating and unnecessary cooling loads, the penalties are quite severe.

There were other serious potential losses besides those from the lack of insulation. For example, many storage-system designers did not properly consider the importance of stratification. Because stratification improves the heat-transfer process, losses in efficiency result when it is interrupted or destroyed.

Another serious problem involves the lack of (or improperly placed) check valves, giving systems the capacity to thermo-siphon. The reverse flow in such systems results in the loss of stored heat through the collectors, exposing the system to the possibility of serious freeze damage.

We also encountered a number of DHW systems where the issue of recirculation was not considered in terms of the probable occupants' use patterns and the length of the runs involved. For example, usage of domestic water in elderly housing projects is low and sporadic; constant recirculation wastes heat while the lack of recirculation provides poor response to demand. Generally recirculation losses were not considered in terms of the quantity and timing demands of the probable occupancy. Such systems need careful design analysis.

Air systems--Serious leakage problems were detected in virtually all of the air systems in our sample. Ducting from collector to storage usually was poorly sealed and insulated. Many applications were made with poorly supported flex-duct hose (including clothes-dryer hose), with numerous bends affecting system blower pressures. The increase in pressure creates additional leakage in poorly sealed joints, so that much energy is lost before the heat can even reach storage.

Most rock storage boxes examined in the repair program had unacceptable and virtually uncontrollable leak rates, owing to the manner and quality of fabrication.

Even when detected, many of these leaks could not be fixed because they were out of reach on the sides or bottom of the box. The size and cleanliness of the rock also varied widely. Improper sizing and cleaning has a significant effect on air flow, system pressures, and the ability to deliver heat from storage. Other problems with rock boxes included inadequate protection from high water tables and foundation leaks, resulting in water infiltration which renders the storage useless and injurious to the living environment. Rock box insulation also presented numerous problems, due primarily to poor accessibility for repairs. Many of the boxes that were otherwise adequately designed had uninsulated bottoms, permitting heat to be lost to the ground.

Distribution and transfer ductwork and system dampering generally were at or below the minimum standards for conventional, forced-air, residential systems. These systems allow uncontrolled heat loss, cause higher system static pressures, and are inadequate for air solar systems. Dampers are available that will properly protect against unwanted flow in or out of the system. There is also ductwork available that can be properly sealed and will not result in higher system pressures. These items however are not normally used in residential construction and do add to the cost of a heating system. Duct insulation techniques also were marginal, and the insulation was subject to pressure build-up (ballooning) where duct leakage occurred.

Very few air systems exhibited acceptable heat loss in transfer, storage, and distribution. At many sites chosen for instrumentation, the attempt to instrument the system had to be abandoned when leakage was found to be so widespread and inaccessible (for repair purposes) that air flows could not be accurately measured for data interpretation. It was not possible to find and repair the significant leaks in such systems.

Control Deficiencies

Control malfunction continues to be a major source of solar system problems. It has caused undue stagnation damage, over/under heating, and freeze damage--virtually all of the problems that can result from operating failures. Problems in simple control systems can be detected and revised with a minimum effort. However, most of the difficult problems occurred in over-elaborate, one-of-a-kind controls with complicated control logic. There was a fascination for complex, multi-mode controls, many of which bordered on the bizzare (Fig. 5-13).

With effective simplicity, many designers have managed not only to control the system properly but to include a simple visual device that tells the occupant certain key elements of system performance (i.e. storage and collector temperatures, pump operation, etc.). Most of the elaborate systems do not have such a device because it is difficult to adapt to an electronic marvel. This is not to suggest that there were not significant failures in simple systems, which constituted the bulk of the systems in the program. However, in the simpler systems, failure diagnosis and correction was easier to accomplish.

GENERAL DEFICIENCIES

To a certain extent, the deficiencies covered in this section are duplications or variations of those treated above. However, they are not, in and of themselves,

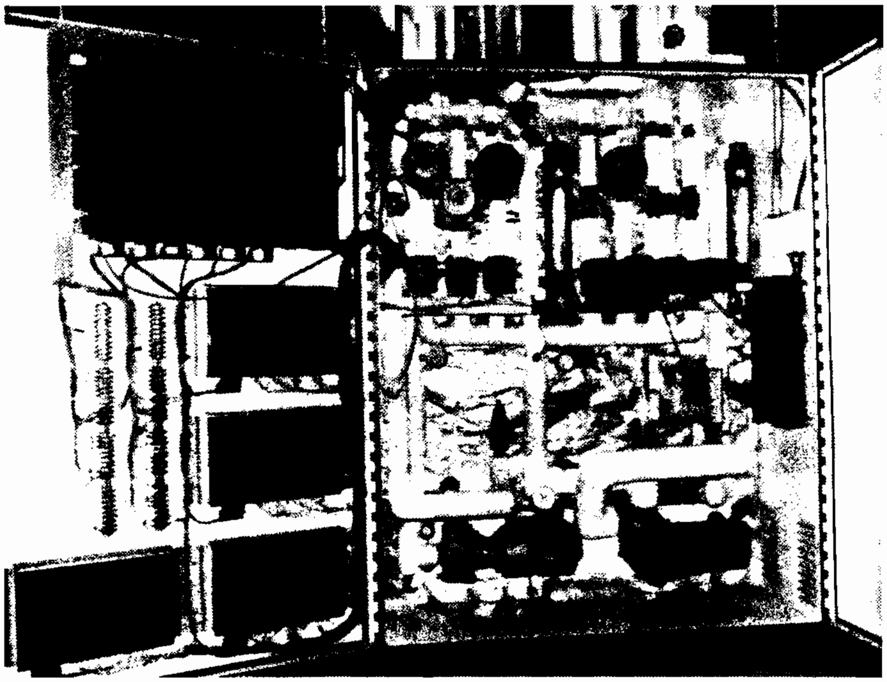

Figure 5-13. Extremely Complex Control System

devastating to the systems in which they are found. Failures on a cumulative basis could be the result if all or most of the general deficiencies were to occur in any given system.

Design Deficiencies

The design deficiencies all seem related to the misconception or lack of understanding of solar systems as they compare to conventional hydronic or forced-air residential systems. Oftentimes, the solar systems were designed by people whose basic understanding and experience in conventional systems was very limited.

Pump sizings have been a frequent problem, particularly when coupled with inadequate or faulty control systems. These deficiencies resulted in inadequate flow or excessive energy requirements.

Again and again, systems were designed with inadequate provisions for mixing warm solar-storage water in the distribution tank, thereby wastefully using back-up energy to maintain the tank temperature while adequate heated storage was available and going unused.

Many designers specified heat pumps coupled with electric resistance heaters as back-up systems. These systems were often used in areas where heat pumps are marginal for conventional use and electric heating systems are generally uneconomical. Where natural gas is the principal heating source and was available at the time of construction, the disparity in cost between gas and electrical energy was such that the annual cost to operate an optimized solar system, with electric back-up, was greater than the annual cost to operate a comparable non-solar gas heating system. The "over-the-fence" comparisons that develop from this situation were very detrimental to the growth of solar energy.

While the problems associated with dissimilar metals in liquid systems have been adequately discussed, there is an opportunity to prevent the occurrence at the design level. If the inherent problems are recognized, the designer can specify the proper materials and corrosion inhibitors and specifically require that the installer use compatible, corrosion-resistant metals and properly applied protective coatings. Designers have rarely supplied such specifications, generally providing undetailed schematics for piping systems.

A corresponding opportunity exists with respect to deficiencies in transport and storage systems in both liquid and air systems. With proper materials specification and installation details, poor insulation, ducting, and dampering could be prevented. This kind of specification or detailing was rarely found. Even when it did happen, adequate inspection for compliance during construction was seldom provided to ensure achieving the desired results.

Manufacturing Deficiencies

All of the major manufacturing deficiencies have been cited, because they contribute in virtually every case to the development of significant problems. As used in this text, "manufacturer" means "collector manufacturer." Since it is the manufacturer whose product is solely related to solar energy, it is the manufacturer who has the most at stake in the success of a solar system. While the manufacturers may not deliver packaged systems, they must maintain sufficient interest over the "system integration," by some appropriate means, to avoid design and installation deficiencies that ultimately reflect on their products. However arbitrary or inequitable this may be, it is a fact of life in the solar market place. The collector is the most highly identifiable product in a solar system. The malfunction of the system, for whatever reason, always focuses on the collector manufacturer as being responsible for the "system." Enlightened self-interest should dictate a serious effort by the manufacturer to control the circumstances and design conditions under which its product is put to use.

Installation Deficiencies

Most of the problems of installation have been addressed in the "significant" categories, because they are major contributors to system breakdown and malfunction. There is a general problem, however: the location of components in a system from the standpoint of maintenance or replacement. This and many other installation deficiencies appear to result from a general lack of understanding, at the installation-mechanic's level, of the important and different features of solar as compared to conventional systems. The lack of awareness is a training deficiency. It is often coupled with inadequate supervision by persons not equipped to provide proper installation guidance.

Maintenance and Operating Deficiencies

Information supplied to homeowners about maintenance and operation has, for the most part, been sketchy and vague. Similarly, manuals available to installation and maintenance personnel have frequently been so lacking in details and schematics as to be nearly worthless. Worse, however, is the fact that many system designs incorporated maintenance requirements, mostly critical to long-term successful operation, that were unrealistic with respect to the residential market. As an example, some manufacturers required that homeowners take fluid samples, on a quarterly basis, and submit them to a certified testing lab. The cost of such a program would exceed the savings from even the most efficient systems. The reliability of such a program depends on the laboratories' knowledge of the chemical composition of the heat-transfer fluid, and the homeowner frequently did not have this information.

There is a critical need for a "fail-safe" design for residential systems, one that minimizes homeowner maintenance. There is the related need for nominal, uncomplicated instrumentation so the homeowner or the maintenance mechanic can determine operating modes and performance levels, and detect system anomolies that call for maintenance or adjustment.

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On the following pages are listed useful publications that relate to the Residential Solar Heating Demonstration. While not a formal or comprehensive bibliography, it does identify the important works and their sources. Included are the references cited in the five volumes of this final report as well as publications produced or used by the management support contractor while performing its program responsibilities. (Asterisks mark those prepared by Boeing or its subcontractors.)

The list is in three parts: works that cover the program; those pertaining specifically to data collected; and those about technical aspects of solar heating. Certain reports, identified by their numbers, are available from HUD USER, P.O. Box 280, Germantown, Md. 20874, phone (301)251-5154, or from the National Technical Information Service, 5825 Port Royal Rd., Springfield, Va. 22161.

PART A. PROGRAM DESCRIPTION

TITLE	AUTHOR/ PUBLISHER	HUD USER #	NTIS #
Solar Heating and Cooling Demonstration Program: A Descriptive Summary of HUD Solar Residential Demonstrations, Cycle 1	AIARC HUD (PDR-162) 1976, 54 pp.		
*Solar Heating and Cooling Demonstration Program: A Descriptive Summary of HUD Solar Residential Demonstrations, Cycle 2 Solar Residential Projects, Fall 1976	AIARC HUD (PDR-230) 1977, 103 pp.		
*Solar Heating and Cooling Demonstration Program: A Descriptive Summary of HUD Solar Residential Demonstrations, Cycle 3 Solar Residential Projects, Summer 1977	AIARC HUD (PDR-230-1) 1977, 174 pp.		
*Solar Heating and Cooling Demonstration Program: A Descriptive Summary of HUD Solar Residential Demonstrations, Cycle 4 and 4A Solar Residential Projects	AIARC HUD (PDR-455) 1979, 157 pp.	0002767	
*The First Passive Solar Home Awards	FRC HUD (PDR-376) 1979, 226 pp.	(GPO Stock #023-000-00517-4)	
*Energy-Conserving Passive Solar Multi-Family Retrofit Projects, Cycle 5, Category 1, HUD Solar Heating and Cooling Demonstration Program	FRC HUD 1981, 100 pp.	005-0943	

PART A. PROGRAM DESCRIPTION
(continued)

TITLE	AUTHOR/ PUBLISHER	HUD USER #	NTIS #
*New Energy-Conserving Passive Solar Single-Family Homes, Cycle 5, Category 2, HUD Solar Heating and Cooling Demonstration Program	FRC HUD (PDR-664) 1981, 284 pp.	0002084	
A Location Matrix Plan for the Residential Solar Heating and Cooling Demonstration Program, Vol. I, Findings and Recommendations	A.D. Little A.D. Little 1976, 32 pp.		PB-253784/AS
A Location Matrix Plan for the Residential Solar Heating and Cooling Demonstration Program, Vol. II, Procedures and Appendices	A.D. Little A.D. Little 1976, 258 pp.		PB-262646/AS

PART B. DEMONSTRATION DATA

TITLE	AUTHOR/ PUBLISHER	HUD USER #	NTIS #
*Marketing and Market Acceptance Data from the Residential Solar Demonstration Program: 1980, Vol. 1, Detailed Analysis	RERC 203 pp.	0002073	PB-82-144635
*Marketing and Market Acceptance Data from the Residential Solar Demonstration Program: 1980, Vol. 2, Technical Appendix	RERC 459 pp.	0002074	PB-82-144643
*Passive Solar Homes in the Marketplace--Final Report of Findings of the 1978-79 Passive Grant Awards, Vol. 1, Discussion, 1981-82	RERC 44 pp.	0002319	
*Passive Solar Homes in the Marketplace--Final Report of Findings of the 1978-79 Passive Grant Awards, Vol. 2, Winter 1981-82	RERC 164 pp.	0002326	
*Residential Solar Demonstration Program: Findings of the Passive Solar Residential Design Competition and Demonstration, Autumn 1980	RERC 81 pp.	0050813	PB-81-170011
*Preliminary Analysis, Utility Consumption Model, Residential Solar Demonstration Program	RERC RERC 1981, 29 pp.		
*Selling the Solar Home--Some Preliminary Findings--Residential Solar Program Report #1	RERC HUD (PDR-296) 1978, 38 pp.		

PART B. DEMONSTRATION DATA
(continued)

TITLE	AUTHOR/ PUBLISHER	HUD USER #	NTIS #
*Selling the Solar Home '80	RERC HUD (PDR-514) 1980, 28 pp.	000-2077	
*Residential Solar Demonstration Program Purchaser Satisfaction with Active Solar Energy Systems, Summary Report #4	RERC RERC 1980, 69 pp.		
Grant File	NBS & Boeing NBS 1981		
Grantee Report File, Final Computer Report	NBS & Boeing NBS 1981		
Utility Consumption File, Final Computer Report	NBS & Boeing NBS 1981		
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PART B. DEMONSTRATION DATA
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PART C. SOLAR TECHNOLOGY

TITLE	AUTHOR/ PUBLISHER	HUD USER #	NTIS #
*Solar Domestic Hot Water--A Reference Manual	AIARC 1979, 117 pp.	0001230	
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SOLAR TERMINOLOGY

Absorbent--the less volatile of the two working fluids in an absorption cooling device

Absorber--the surface in a collector that absorbs solar radiation and converts it to heat energy; generally a matte black metallic surface is best

Absorption chiller--air conditioning device which uses heat at 190°F or higher to generate cooling; it may be powered by solar-heated water

Absorptivity--the ratio of the energy absorbed by a surface to the energy absorbed by a black body at the same temperature

Active solar energy systems--in contrast to passive solar energy approaches, an active solar energy system utilizes outside energy to operate the system and to transfer the collected solar energy from the collector to storage and distribute it throughout the living unit. Active systems can provide space heating and cooling and domestic hot water.

Airlock entry--a vestibule enclosed with two airtight doors; it reduces heat loss by limiting the movement of heated air

Air-type collector--a collector that uses air for heat transfer

Altitude--the angular distance from the horizon to the sun

Ambient temperature--the natural temperature surrounding an object; it usually refers to outdoor temperature

Atrium--a closed interior court to which other rooms open; it is often used for passive solar collection

Auxiliary energy--auxiliary heat plus the energy required to operate pumps, blowers, or other devices

Auxiliary heat--the heat provided by a conventional heating system for periods of cloudiness or intense cold, when a solar heating system cannot provide enough heat

Azimuth--the angular distance from true south to the point on the horizon directly below the sun

Back-up energy system--a back-up energy system using conventional fuels should be provided for heating and domestic hot water. This system should be capable of providing all of the energy demand during any period when the solar energy system is not operating. Components and subsystems may be used as parts of both systems where the component or subsystem is a recognized, acceptable product in the conventional building industry.

Berm--earth berm

British thermal unit (BTU)--a unit of heat; the quantity needed to raise the temperature of one pound of water one degree Fahrenheit

Building envelope--the elements (walls, roof, floors) of a building which enclose conditioned spaces

Clerestory--a window located high in a wall near the eaves, used for light, heat gain, and ventilation

Coefficient of heat transmission--the rate of heat transmission measured per degree of temperature difference per hour, through a square foot of wall or other building surface. It is usually called the U-value.

Collection—the process of trapping solar radiation and converting it to heat

Collector--a device which collects solar radiation and converts it to heat

Collector aperature—the glazed opening in a collector which admits solar radiation

Collector efficiency--the ratio of the heat energy extracted from a collector to the solar energy striking it

Collector tilt--the angle between the horizontal plane and the solar collector plane, designed to maximize the collector of solar radiation

Comfort zone--the range of temperature and humidity in which most people feel comfortable

Concentrating collector--a collector with a lens or a reflector that concentrates the sun's rays on a relatively small absorber surface

Conduction—the flow of heat between a hotter material and a colder material that are in direct physical contact

Conductivity--the property of a material indicating the quantity of heat that will flow through one foot of a material for each degree of temperature difference

Convection, forced--commonly, the transfer of heat by the forced flow of air or water

Convection, natural--the motion of a gas or liquid, caused by temperature or density difference, by which heat is transported

Cooling pond--a large body of water that loses heat from its surface, largely by evaportation but also by convection and radiation

Cooling tower--a device for cooling water by evaporation

Cover plate—a layer of glass or transparent plastic placed above the absorber plate in a flat-plate collector to reduce heat losses

Damper--a control which permits, prevents, or controls the passage of air through a duct

Degree-day--a unit of measurement for outside temperature; it is the difference between a fixed temperature (usually 65°F/18°C) and the average temperature for the day

Design heating load--the total heat loss from a building under the most severe winter conditions likely to occur

Design outside temperature--the lowest outdoor temperature expected during a heating season

Diffuse radiation--indirect scattered sunlight which casts no shadow

Direct radiation--sunlight which casts shadows, also called beam radiation

Direct solar gain--a type of passive solar heating system in which solar radiation passes through the south-facing living space before being stored in the thermal mass for long-term heating

Distribution--the movement of collected heat to the living areas from collectors or storage

Diurnal temperature range--the variation in outdoor temperature between day and night

Double-glazed--covered by two layers of glazing material (commonly glass or plastic)

Double-walled heat exchanger--a heat exchanger which separates the collector fluid from the potable water by two surfaces; it is required if the collector fluid is non-potable

Drain-back--a type of liquid heating system which is designed to drain into a tank when the pump is off

Drain-down--a type of liquid heating system which protects collectors from freezing by automatically draining when the pump is turned off

Earth berm--a mound of dirt that abuts a building wall to stabilize interior temperature or to deflect the wind

Emissivity--the ratio of the energy radiated by a body to the energy radiated by a black body at the same temperature

Energy audit--an accounting of the forms of energy used during a designated period, such as monthly

Eutectic salts--a mixture of two or more pure materials which melts at a constant temperature; a material which stores large amounts of latent heat

Evaporative cooling--a method of space conditioning which requires the addition of bodies of water or of moisture for cooling the living spaces

Fan coil--a unit consisting of a fan and a heat exchanger which transfers heat from liquid to air (or vice versa); usually located in a duct

Flat-plate collector--a solar collection device in which sunlight is converted to heat on a flat surface; air or liquid flows through the collector to remove the heat

Flywheel effect--the damping of interior temperature fluctuations by massive construction (see Diurnal)

Forced-air heat--a conventional heating distribution system which uses a blower to circulate heated air

Galvanic corrosion--the deterioration of tanks, pipes, or pumps, which occurs when a conducting liquid permits electrical contact between two different metals, causing the more active metal to corrode

Glauber's salts--a term for sodium sulfate decahydrate, which melts at 90°F; a component of eutectic salts

Glazing--a material which is translucent or transparent to solar radiation

Greenhouse--in passive solar design, an attached glazed area from which heat is withdrawn to the living space during the day

Heat capacity (specific heat)--the quantity of heat required to raise the temperature of a given mass of a substance one degree F

Heat exchanger--a device which transfers heat from one fluid to another

Heat gain--as applied to heating or cooling load, that amount of heat gained by a space from all sources (including people, lights, machine, sunshine, etc.)

Heat pump--an electrically operated machine for heating and cooling; when heating, it transfers heat from one medium at a lower temperature (called the heat source) to a medium at a higher temperature (called the heat sink), thereby coolig the source (outside air) and warming the sink (the house); when cooling, the heat pump functions much like an air conditioner--taking unwanted heat from the heat source (a building) and dumping it to the heat sink (the outside)

Heat sink--a medium (water, earth, or air) capable of accepting heat

Heat source--a medium (water, earth, or air) from which heat is extracted

Heat transfer--conduction, convection, or radiation, or a combination of these

Heating load--the rate of heat flow required to maintain indoor comfort; measured in BTU per hour

Heating season--the period from early fall to late spring during which heat is needed to keep a house comfortable

Heliostat--an instrument consisting of a mirror mounted on an axis moved by clockwork; the heliostat reflects sunbeams in one direction, usually to a central absorber located in a tower

Hybrid solar energy system--a hybrid system is one incorporating a major passive aspect, where at least one of the significant thermal energy flows is by natural means and at least one is by forced means

Hydronic system--a conventional heating system which circulates hot water, usually 160^{o}F to 180^{o}F, through baseboard finned pipes or radiators

Indirect gain solar--a type of passive solar heating system in which the storage is interposed between the collecting and the distributing surfaces (e.g. Trombe wall, water wall, or roof pond)

Infiltration--the uncontrolled movement of outdoor air into a building through leaks, cracks, windows, and doors

Infrared radiation--the invisible rays just beyond the red of the visible spectrum; their wavelengths are longer than those of the spectrum colors (0.7 to 400 microns), and they have a penetrating heating effect

Isolation--the amount of solar radiation (direct, diffuse, or reflected) striking a surface exposed to the sky; measured in BTU per square foot per hour (or in watts per square meter)

Insulation--a material which increases resistance to heat flow

Isolated solar gain--a type of passive solar heating system in which heat is collected in one area to be used in another (e.g. greenhouse or attic collector)

Kilowatt--a measure of power or heat flow rate; it equals 3,413 BTU per hour

Kilowatt hour (kWh)--the amount of energy equivalent to one kilowatt of power being used for one hour; 3,413 BTU

Langley--a measure of solar radiation; it equals one calorie per square centimeter, or 3.69 BTU per square foot

Latent heat--the change in heat content that occurs with a change in phase and without change in temperature; the heat stored in the material during melting or vaporization. Latent heat is recovered by freezing a liquid or by condensing a gas.

Life-cycle cost analysis--the accounting of capital, interest, and operating costs over the useful life of the solar system compared to those costs without the solar system

Liquid-type collector--a collector that uses a liquid as the heat transfer fluid

Microclimate--the variation in regional climate at a specific site; caused by topography, vegetation, soil, water conditions, and construction

Movable insulation--a device which reduces heat loss at night or during cloud periods and permits heat gain in sunny periods (e.g. insulated draperies, automatic shutters); it may also be used to reduce heat gains in summer

Nocturnal cooling—a method of cooling through radiation of heat from warm surfaces to a clear night sky

Non-potable--water that is not suitable for drinking or cooking purposes

Nonrenewable energy source—a mineral energy source which is in limited supply, such as fossil (gas, oil, and coal) and nuclear fuels.

Passive solar energy systems and concepts—passive solar heating applications generally involve energy collection through south-facing glazed areas; energy storage in the building mass or in special storage elements; energy distribution by natural means such as convection, conduction, or radiation with only minimal use of low-power fans or pumps; and a method controlling both high and low temperatures and energy flows. Passive cooling applications usually include methods of shading collector areas from exposure to the summer sun and provisions to induce ventilation to reduce internal temperatures and humidity.

Payback—the time needed to recover the investment in a solar energy system

Peak load--the maximum instantaneous demand for electrical power which determines the generating capacity required by a public utility

Percent possible sunshine--the amount of radiation available compared to the amount which would be present if there were no cloud cover; usually measured on a monthly basis

Phase-change--see Latent heat.

Photovoltaic cell--a device without any moving parts that coverts light directly into electricity by the excitement of electrons

Potable--water that is suitable for drinking or cooking purposes, meeting the requirements of appropriate health officials

Preheat--the use of solar energy to partially heat a substance, such as domestic potable water, before heating it to a higher desired temperature with auxiliary fuel.

Pyranometer--an instrument for measuring direct and diffuse solar radiation

Pyrheliometer—an instrument that measures the intensity of the direct radiation form the sun; the diffuse component is not measured

Radiation—the process by which energy flows from one body to another when the bodies are separated by a space, even when a vacuum exists between them

Refrigerant--fluid used in heating or cooling devices such as heat pumps, air conditioners, or solar collectors

Renewable energy source--solar energy and certain forms derived from it, such as wind, biomass, and hydro

Re-radiation--the emission of previously absorbed radiation

Retrofit—to modify an existing building by adding a solar heating system or insulation

Rock bin or Rock bed--a heat storage container filled with rocks or pebbles, used in air solar heating/cooling systems

R-value--see Thermal resistance

Seasonal efficiency--the ratio of the solar energy collected and used to the solar energy striking the collector; measured over an entire heating season

Selective surface--a surface that is a good absorber of sunlight but a poor emitter of thermal radiation; used as a coating for absorbers to increase collector efficiency

Sensible heat--heat which, when gained or lost, results in a change in temperature

Shading coefficient—the ratio of the amount of sunlight transmitted through a window under specific conditions to the amount of sunlight transmitted through a single layer of common window glass under the same conditions

Solar access or solar rights--the ability to receive direct sunlight which has passed over land located to the south; the protection of solar access is a legal issue

Solar cell--see Photovoltaic cell

Solar collector--a device which collects solar radiation and converts it to heat

Solar constant—the average intensity of solar radiation reaching the earth outside the atmosphere; 429.2 BTU per square foot per hour (or 1,354 watts per square meter)

Solar fraction--the percentage of a building's seasonal heating requirement provided by a solar system

Solar furnace--a solar concentrator used to produce very high temperatures; also a trade name for a modular air heating system, usually ground mounted, with rock storage

Solar gain--the part of a building's heating load, or an additional cooling load, which is provided by solar radiation striking the building or passing into the building through windows

Solar noon--the time of day when the sun is due south; halfway between sunrise and sunset

Solar radiation—energy radiated from the sun in the electromagnetic spectrum; visible light and infrared light are used by solar energy systems

Solar thermal electric power--the indirect conversion of solar energy into electricity by solar collectors, a heat engine, and electrical generators

Solarium--a living space enclosed by glazing; a greenhouse

Specific heat capacity—the quantity of heat needed to change the temperature of one pound of a material by one degree Fahrenheit (or one kilogram of a material by one degree Centigrade)

Stack effect--the rising of heated air over a dark surface by natural convection to create a draft; used to provide summer ventilation in some passive houses

Stagnation--a high temperature condition obtained in a solar collector when the sun is shining and no fluid is flowing through the collector; temperatures range from 250°F to 400°F, depending on collector design. Any condition under which a collector is losing as much heat as it gains.

Storage--the device or medium that absorbs collected solar heat and stores it for later use

Storage capacity--the quantity of heat that can be contained in a storage device

Sun-space—a living space enclosed by glazing; a solarium or greenhouse

Sun-tempering--a method that involves a significant daytime solar gain and an effective distribution system but generally lacks a storage system

Therm--a quantity of heat equal to 100,000 BTU; approximately 100 cubic feet of natural gas

Thermal lag--in an indirect gain system, the time delay for heat to move from the outer collecting surface to the inner radiating surface

Thermal mass--the heat capacity of a building material (brick, concrete, adobe, or water containers)

Thermal radiation--see Infrared radiation

Thermosiphoning--heat transfer through a fluid (such as air or liquid) by currents resulting from the natural fall of heavier, cool fluid and rise of lighter, warm fluid

Tilt angle--see Collector tilt

Tracking--for a collector, a device which causes the panel to follow the sun

Transfer medium--the substance that carries heat from the solar collector to storage or from storage to the living areas

Trickle-type collector--a collector in which the heat-transfer fluid flows in open channels on the absorber

Trombe wall--masonry, typically 8" to 16" thick, blackened and exposed to the sun behind glazing; a passive solar heating system in whch a masonry wall collects, stores, and distributes heat

U-value--see Coefficient of heat transmission.

Vapor barrier--a waterproof liner used to prevent passage of moisture through the building structure. Vapor barriers in walls and ceilings should be located on the heated side of the building.

Wet-bulb temperature--the lowest temperature attainable by evaporating water in the air; a measure of humidity

Zoned heating--the control of the temperature in a room or a group of rooms independently of other rooms

CREDITS

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