404
10/7/80
I.S.

SERI/TP-641-773
UC CATEGORY: UC-58d

Dr. 1822

CONF-800927--2

QUALITY-ASSURANCE NEEDS AND GOALS IN SOLAR ENERGY CONVERSION

GORDON E. GROSS

MASTER

JULY 1980

SEVENTH ANNUAL NATIONAL
ENERGY DIVISION CONFERENCE
AMERICAN SOCIETY FOR QUALITY CONTROL

PREPARED UNDER TASK NO. 3141.00

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Prepared for the
U.S. Department of Energy
Contract No. EG-77-C-01-4042

DISCLAIMER

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price:
Microfiche $3.00
Printed Copy $4.00

SEVENTH ANNUAL NATIONAL ENERGY DIVISION CONFERENCE

QUALITY-ASSURANCE NEEDS AND GOALS IN SOLAR ENERGY CONVERSION

Gordon E. Gross
Principal Scientist
Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

ABSTRACT

A discussion of the status of quality assurance activities in solar energy conversion technologies and of the needs for further efforts in this area is presented. The importance of reliability and quality assurance activities to various end users is briefly discussed. Some details of such activities in wind, active heating and cooling, and photovoltaic technologies are given. Suggestions for an integrated reliability, quality assurance program are presented and their importance to the growth of solar energy application is discussed.

I. Introduction

This presentation must be taken as a qualitative overview of the situation regarding reliability and quality assurance in solar energy technologies and of the needs for more effort in these areas. It is not a technical paper but rather a general discussion of certain needs which must be met if solar energy is to become a major contributor to industrial and private activities.

Key issues in decisions to utilize any technology are the life cycle cost of applying the technology and the dependability of the estimates on which that cost is based. Life cycle cost is a function of many variables including initial capital cost, operating, maintenance, and replacement costs, and other factors such as taxes, insurance, and contingency costs. Quality assurance efforts can lead to improving several of these variables in ways that make solar application more attractive.

The value of reliability in a solar energy application depends on the nature of the user. To the homeowner reliability means freedom from service calls and dependability of service. In the case of solar heating with the usual public utility backup system, the homeowner often does not know if the solar unit works or not. An excellent example of such a situation was found in a study of solar homes under a SERI subcontract. Here a hydronic solar heating system was declared completely satisfactory and trouble-free by its owner. An engineering examination of the system showed no water flow in the collector loop—the fault traced to a pump which, due to faulty assembly, had never worked.

As one progresses up the scale of energy users or sellers to the public utility company one finds a more profound interest in reliability. Here the very viability of a system depends on it being available on demand. The availability plays a key roll in the credit the public service commissions allow to a utility company for investment in capital items. Furthermore, the modest rates of return on investment and the large capital cost of utility systems lead to long lifetime requirements in such cases--usually some 40 years. Clearly a situation demanding high quality standards and thorough quality control programs.

In this presentation an attempt will be made to portray the current status of quality assurance plans and activities in the solar arena, some anecdotal discussions of reliability problems calling for quality assurance activity, and some suggestions for further action in solar QA.

II. The Current Status of Quality Assurance in Solar Energy Conversion

Quality assurance usually does not become a significant activity in a technology field until demanded by widespread use, frequent complaints or attention getting incidents. Many industries today have very sophisticated quality assurance programs which have yielded extremely dependable telephone service, automobiles, aircraft, utility service, etc. These industries were well developed before they established their fine quality control departments.

The solar industry is hardly more than an embryo but its unique position of public visibility and interest do not allow the luxury of "mature first, QA later." Every failure in this field receives widespread attention from the news media to the cocktail crowd. A similar situation prevailed with early aircraft but the average citizen felt no identity with those early day aviators and no public agencies were pressing those citizens to become users of the "flying machines." Picture what a "passenter flying machine demonstration act of 1915", might have produced.

The early demonstrations of solar heating called into service many very novel concepts many of which represented excellent engineering design. The components and materials which were used, however, were too often not suitable to the conditions to which they were exposed. The daily cycling of temperature loosened hose fittings, the ultraviolet radiation destroyed polymers, the high temperatures degraded antifreeze mixtures, and components satisfactory in other service soon failed in solar use.

None of these disturbing events should be surprising in a new technology. They could, however, be minimized by testing programs such as used in industries like refrigeration, automotive, and others. The events could also have served very useful purposes had they been made part of a QA and reliability study. If each demonstration activity were to have incorporated in it a task to collect, analyze and report failure data, that data could have lead to increased reliability of subsequent systems through improved standards and QA methods.

Several areas of solar technology have grown to a point where industries such as aircraft and electronics have begun to play major roles. In these cases the high QA traditions of those industries are evident in their solar activities.

One example of such an advanced QA activity is in the Boeing Company's plans for the Mod 2 Wind Machine. This machine, planned for a minimum rotor diameter of 300 ft. would be tested as a potential electric utility component. It would be designed for 30 year life. The Boeing Company has developed a reliability plan for their design and have based it on data from industrial and military sources including:

Edison Electric Institute: Equipment Availability Component Cause Code Summary Report

Rome Air Development Center: Nonelectric Reliability Notebook AD/A005 657

Boeing Company: Component Removal Data 727, 737, 747 Commercial Aircraft

They have computed probable system and component failures per year, mean times to repair, and maintenance schedules for the Mod 2 design on the basis of data from such sources as those above.

Fault trees have been developed and possible failure modes have been predicted. From these fault trees and failure modes, a complete set of quality and design requirements have been conceived. While recognizing the uncertainty introduced into the final Mod 2 operation by conditions different from those on which the underlying data are based, the reliability plan does minimize the chances for a totally unexpected failure.

III Solar Heating and Cooling

The solar heating and cooling area is divided into residential and commercial sectors for most demonstration activity. The residential part of the federal programs was not originally planned with a strong QA or reliability activity. The commercial part of the program has included more attention to such matters. A solar reliability and materials program at the Argonne National Laboratory (ANL) is using data obtained from various U. S. Department of Energy sponsored heating and cooling programs to generate a reliability data base and to develop a general reliability and materials program plan for future solar projects.

The ANL uses the following data to evaluate reliability and maintainability of existing solar installations:

- Descriptions of as-built systems
- Equipment specifications
- Operating mode description

- Flow schematics
- Sensor type and location
- Installation problems
- System checkout problems
- Operational performance
- Maintenance experience.

This data is gathered through such communication channels as the National Solar Data Network and through direct contact with field personnel at the various test sites. An ANL field engineer is assigned to several demonstration sites to coordinate and report on data activities.

If a system is down for an extended period, if a component fails, or if monitored data show system degradation, an ANL field engineer visits the site. If found advisable by the engineer, the faulty components may be sent to ANL for detailed study. This thorough following of performance and analysis of failures is a key element in a reliability program. It is one of few ways that quality standards can be correlated with field performance.

A system of daily log keeping provides records of minor problems which may not require the immediate attention of the field engineer.

Further reading on the ANL program is provided in references sited at the end of this paper.

IV Photovoltaic Solar Energy Conversion

As might be expected withthe advanced state of the solid state art, the photovoltaic field has a quite well designed QA and reliability program. The U. S. Department of Energy has set a goal of a 20 year lifetime for photovoltaic arrays. The National Photovoltaic Program focuses reliability activities according to the type of application or nature of the project as shown in the partial list below.

- Concentrator Arrays
  Reliability activities under
  cognizance of Sandia Laboratories
  Albuquerque, NM

- Flat-Plate Arrays
  Reliability activities under
  cognizance of Jet Propulsion Laboratory (JPL)
  Pasadena, CA

- Field Application/Demonstration Site Monitoring
  Reliability activities under cognizance of
  Massachusetts Institute of Technology/Lincoln
  Laboratories (MIT/LL)

In the case of concentrator arrays, attention is focused on optics, tracking systems, and reliability/durability of materials in cells and interconnections. Tests include aging at constant temperature, effects of temperature humidity cycling, and aging by illumination-temperature cycling. Durability tests also include measurement of ultraviolet degradation of glazings, sealants, and encapsulant and evaluation of effects of wind and hail. In the hail area there is a serious lack of standards to be used in selecting suitable materials.

Flat plate arrays are more fully developed than concentrating PV systems and, as would be expected, the program for their further evaluation contains a wider range of QA and reliability activities. The Low-Cost Solar Array (LSA) reliability program includes:

- Specification Generation
- Module Qualification Testing
- Field Testing
- Reliability Analysis and Prediction Studies
- Life Prediction Studies
- Problem/Failure Reporting System
- Failure Analysis
- Quality Assurance
- Component Testing.

Again notice the specific attention to problem and failure reporting and failure analysis. The Jet Propulsion Laboratory which leads the LSA project, uses their own facilities and those of other National Laboratories to perform studies which can diagnose failures and lead to both reduction of failure probability and prediction of lifetime of future components and materials.

Further reading on the JPL/LSA program is contained in references cited at the end of the paper.

Suggestions for QA - Reliability Activities

The need to eliminate the deterring effects of failures in solar energy systems and to provide dependable estimates of their reliability to potential users mandates that we establish an element of QA and reliability in all solar projects. At this point it must be recognized that such actions are occurring but they must be moved to a more significant place in the list of project priorities.

The design of the needed QA and reliability programs must be guided by:

- the need for a closed loop of feedback between field experience and product design and

- the need to economize the programs' efforts by transfer of data and methods between the solar technologies so far as applicable to avoid duplication of efforts.

The programs must make use of thorough record keeping, such as daily logs and failure reports in addition to automatically recorded data. Many instances can be cited where a component which has proven faulty in one solar test shows up in another test to continue its contribution to failure. Thorough maintenance records will prevent such repetitions and will provide bases for estimating this component of operating and maintenance expenses.

In order to build an effective QA and reliability element into solar projects, it will be necessary to start early in the funding cycle to include such an element into contract requirements. The penalty of failure to make that effort will be continued negative public image of solar equipment and serious delays in public acceptance of such equipment.

References:

Methodology for Designing accelerated Aging Tests for Predicting Life of Photovoltaic Arrays. ERDA/JPL-954328-77/1. Pasadena, CA, February 1977.

"Project Quarterly Report for the Period July 1967 - September 1976", Low-Cost Silicon Solar Array Project. ERDA/JPL-1012-77/1. Pasadena, CA.

"Review of World Experience and Properties of Materials for Encapsulation of Photovoltaic Arrays." ERDA/JPL-954328-76/4. Pasadena, CA, 31 July 1976.

"Terrestial Service Environments for Selected Geographic Locations", ERDA/JPL-95432-76/5. Pasadena, CA, 24 June 1976.

U.S. DOE. Evaluation of Available Encapsulants for Low Cost, Long Life Silicon Arrays. JPL-9543282. Pasadena, CA, June 1978.

Proceedings of the 13th LSA Project Integration Meeting. DOE/JPL 1012-29. Pasadena, CA, April-August 1979.

Preliminary Evaluation of Selected Reliability, Maintainability, and Materials Problems in Solar Heating and Cooling Systems. ANL/SDP-TM-78-2; SOLAR/0900-78/70. Argonne, IL, September 1978.

Reliability and Maintainability Evaluation of Freezing in Solar Systems. ANL/SDP-TM-78-3; SOLAR/0901-78/70. Argonne, IL, September 1978.

Reliability and Maintainability Evaluation of Solar Collector and Maniford Interconnections. ANL/SDP-TM-79-4; SOLAR/0902-79/70. Argonne, IL, March 1979.

Reliability and Maintainability Evaluation of Solar Control Systems. ANL/SDP-TM-79-5; SOLAR/0903-79-70. Argonne, IL, March 1979.

Influence of Solar-Fluid Properties on Thermal Performance Based on National and Measured Values. ANL/SDP-TM-79-6; SOLAR/0904-79/70. Argonne, IL, May 1979.