# Quality Improvement of Photovoltaic Testing Laboratories in Developing Countries

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# Preface



This training manual is one of four manuals prepared for the World Bank project, Mitigating Global Climate Change through the Development of a Quality Process Infrastructure for Renewable Energy (referred to as the Quality Program for Photovoltaics, or QuaP-PV, for short). This training manual is specific to quality improvement of photovoltaic (PV) testing laboratories. It addresses testing of PV components and small systems.

The manual is organized in three parts. The main text contains seven chapters dealing with laboratory accreditation, and PV product testing and certification. Each of four appendixes is an important reference document for quality improvement of PV testing laboratories. The viewgraphs correspond to the material in the main text.

This manual is recommended as a text for training workshops on the quality improvement of PV testing laboratories. A pilot workshop based on the manual was presented in Jaipur, India, October 4–8, 1999. The pilot workshop indicated that the content of this manual can be covered in sufficient detail in a three-day training workshop.

# Acknowledgments



The authors wish to acknowledge other Florida Solar Energy Center (FSEC) technical staff who contributed to the manual. They included Dr. Gerard G. Ventre, and Messrs. Steven Durand, Jim Dunlop, and Brian Farhi. Chapter 2 of the text was based on Laboratory Accreditation in the United States, a U.S. government document by M. A. Breltenberg (NISTIR publication 4576, May 1991). Most of the material in chapters 4 and 5 came from work undertaken during preparation of the proposed World Bank-assisted China Renewable Energy Project. We consulted the Photovoltaic Test Laboratory Quality Manual, developed by PV GAP, with the support of the Energy and Atmosphere Programme of the United Nations Development Programme. Appendix 2 materials were drawn from the Web site of the American Association for Laboratory Accreditation. Appendix 3 materials were drawn from PV GAP Recommended Standards for PV Stand-Alone Systems, as well as for Terrestrial Module Blank Detailed Specifications for Crystalline Silicon PV and for Thin-Film PV Modules. We appreciate the assistance of the above-mentioned organizations.

We would also like to thank FSEC staff, including Mesdames Nancy Grossman and Dianne Wood for typing the entire manuscript, and Mary Freen for technical editing. Ms. Rebecca Kary of Alpha-Omega Services, Inc., did thorough editing, formatting, and styling of the entire text material.

A number of technical specialists provided the review of the training manual, including Mr. Enno Heijndermans of the World Bank, Mr. Anil Relia of the National Accreditation Board for Laboratories (New Delhi, India), Mr. Girdhar Gyani of the Indian Institute of Quality Management (Jaipur, India), Dr. V. P. Mathur of the Rajasthan Electronics and Instruments Limited (Jaipur, India), and Dr. Harold Post and Dr. Michael Thomas of Sandia National Laboratories, Albuquerque, New Mexico. The assistance of these individuals in revising the manual is very much appreciated.





# 1.1 Objective of the Project

he main goal of the overall Quality Program for Photovoltaics (QuaP-PV) project is to provide training to manufacturers of PV components and systems, testing organizations, and installation and maintenance service organizations on the importance of quality control and on ways to implement quality control systems. The objective of the task activities covered in this manual is to improve the capabilities of laboratories in developing countries to test and certify PV modules, balance of system (BOS) components, and loads. The specific objective is to improve the quality of testing services provided by these laboratories to their clients to meet international standards, including International Standardization Organization (ISO) standards and International Electrotechnical Commission (IEC) PV standards. This objective was accomplished by developing a training manual specifically for laboratories in developing countries and providing pilot training based on the manual.

# 1.2 Objectives of the Manual

The content of the training manual is directed to the technical, management, and administrative staff of the laboratories of developing countries, who are currently testing PV modules or BOS components, or who expect to do so in the near future.

The objectives of the training manual are as follows:

- To improve the quality of PV testing services offered by third-party independent laboratories to PV manufacturers, users, system owners, system financiers, and other stakeholders and interested parties.
- To provide a guide or reference book for higher-level staff of testing laboratories to help them implement high-quality PV testing in their laboratories, consistent with technically sound and, preferably, internationally recognized test procedures, which conform to a well-established and documented quality system based on ISO 17025 requirements.
- To provide training material, including audiovisual aids, for the senior staff to train the junior staff and technicians in PV test procedures and quality system requirements.

The effectiveness of the training material and the reference book was verified by conducting a pilot training workshop for the upper-level staff in India based on the training manual. The manual was modified based on the feedback.

# 1.3 Scope of the Manual



Improvement of the quality of services offered by PV testing laboratories to the product manufacturers, users, and other stakeholders requires four main elements:

- Developing and implementing internationally accepted quality control and quality assurance systems for testing laboratories, in accordance with ISO 17025 and Guides 16, 23, 28, 38, 40, and 56, and other international standards.
- Obtaining accreditation as a certification laboratory for PV modules and BOS components from a suitable accreditation agency.
- Adapting or modifying, and then successfully implementing, internationally recognized test procedures, standards, and recommended practices for testing and certification of PV modules and BOS components.
- Identifying and procuring the necessary equipment and instrumentation to carry out complete test procedures.

This manual addresses all four elements, and includes plans for implementing the laboratory accreditation requirements, and for setting up a quality control and quality assurance system for PV testing laboratories in developing countries. These plans are primarily based on ISO Guides, some of which are listed here:

- ISO Guide 2: General Terms and Their Definitions Concerning Standardization and Related Activities.
- ISO Guide 7: Requirements for Standards Suitable for Product Certification.
- ISO Guide 16: Code of Principles on Third Party Certification System and Related Standards.
- ISO Guide 23: Methods of Indicating Conformity with Standards for Third Party Certification Systems.
- ISO 17025: General Requirements for the Technical Competence of Calibration and Testing Laboratories.
- ISO Guide 27: Guidelines for Corrective Action to Be Taken by a Certification Body in the Event of Misuse of Its Mark of Conformity.
- ISO Guide 28: General Rules for a Model Third Party Certification System for Products.
- ISO Guide 38: General Requirements for Acceptance of Testing Laboratories.
- ISO Guide 40: General Requirements for Acceptance of Certification Bodies.
- ISO Guide 42: Guidelines for a Step-by-Step Approach to International Certification System.
- ISO Guide 44: General Rules for ISO or IEC International Third Party Certification Schemes for Products.
- ISO Guide 56: An Approach to the Review by a Certification Body of Its Own Internal Quality System.

The manual also covers the existing and evolving standards and recommended practices for testing, qualification, and certification of small PV systems, PV modules, batteries, charge controllers, inverters, and low-voltage DC lights. These standards have been developed by the IEC, PV GAP, Institute of Electrical and Electronics Engineers (IEEE), American Society for Testing and Materials (ASTM), and Underwriters Laboratories (UL) of the United States.

The QuaP-PV project comprises 18 activities and a management task. The manual focuses on meeting the needs of Activity 4 and Activity 8.

Activity 4: Preparing the Training Manual for Quality Control of Testing Laboratories

Activity 8: Conducting Pilot Training in India

A pilot training course based on the manual was conducted in Jaipur, India, October 4–8, 1999. The instructors were working engineers in the field of photovoltaics and included Florida Solar Energy Center technical staff and Electronic Test and Development Centre (ETDC; Bangalore, India) personnel. The pilot training workshop indicated that the content of this manual can be covered in sufficient detail over three days.

Based on the feedback received from the workshop audience and review of the final draft of the manual by professionals in the PV community, the final draft was revised, and this final training manual has been produced.

# 1.4 Organization of the Manual

The training manual is organized in three parts. The main text contains seven chapters dealing with laboratory accreditation, and PV product testing and certification. Each of four appendixes is an important reference document for quality improvement of PV testing laboratories. The viewgraphs correspond to the material in the main text.



# Chapter 2 Laboratory Accreditation



laboratory that certifies that products meet certain standards needs to be accredited. This chapter describes the general requirements for laboratory accreditation.

# 2.1 General Laboratory Accreditation

Testing laboratories can be accredited in a number of ways. One way is to accredit a laboratory to test in an entire field of testing, or a "broad sphere of science, engineering, or technology used to describe a general area of testing for classification purposes." A laboratory can also be accredited in a scientific discipline, such as electronics, or for a specific technology (such as photovoltaics), or in relation to specific products, such as PV module testing. Accreditation can also be limited to the conduct of specified test methods. In general, the broader the scope of approval, the more difficult and time-consuming it is for the accrediting body to thoroughly assess the laboratory's ability to perform all test methods within that scope. The narrower the scope of accreditation, however, the more likely it is that a laboratory that performs a broad range of testing will have to obtain multiple accreditations.

# 2.2 Criteria for Evaluating and Accrediting Laboratories

Any or all of the following criteria may be used when assessing a laboratory for accreditation. In addition, criteria specific to the type of laboratory, the nature of the work being performed, and the purpose for which the accreditation program was established may also be imposed.

- Laboratory organization and independence (no conflict of interest). The laboratory should be a legal entity organized in a manner that permits it to perform all required functions in a satisfactory fashion. It should also be impartial or independent, and free from outside influence that might bias the integrity of the work performed.
- Financial stability. The laboratory may be required to have sufficient resources to properly maintain and use the test equipment and facility, to satisfactorily perform all required functions, and to adequately indemnify itself against financial liabilities and penalties resulting from its operations.
- *On-site inspection.* The laboratory may be required to pass an on-site evaluation by assessors appointed by the accrediting body. The evaluation should include a review of all relevant information concerning the ability of the applicant to comply with the accreditation criteria.

• The content of this chapter is primarily based on a U.S. government document by Breltenberg (1991), which describes the major aspects of this topic, and which is summarized in this chapter.

- Staff qualification requirements. The laboratory may be required to demonstrate that its personnel are qualified or licensed, when necessary. Each staff member should have the education, training, knowledge, and experience necessary to perform the tasks assigned, and an appropriate level of supervision should be maintained. The training of each staff member should be kept current and should be documented.
- Adequate quality system. An operational quality system appropriate to the type and amount of work performed by the laboratory may be required. The system should be reviewed by management on a periodic basis and revised, as needed, to ensure continued acceptable performance. A quality system should be suitably documented in a comprehensive, up-to-date quality manual that is readily available for consultation by staff.
- Sampling requirements. If test materials are received by the laboratory in quantities larger than the amount required for the test, the laboratory may be required to sample the material in such a manner as to ensure that the sample tested is representative of the entire quantity of material received. Where sample selection is the responsibility of the test laboratory, appropriate sampling methods and techniques should be used.
- Sample control and integrity requirements. The laboratory may be required to have an effective system to ensure both the identity and integrity of test samples. Maintaining the integrity of the sample involves preventing it from being damaged during all stages of collection, shipping, storage, or handling. Such damage can include physical damage, loss of part of the sample because of leakage, contamination by foreign materials, failure to maintain the sample within appropriate temperature or atmospheric conditions, or other deterioration, such as that which can occur if samples are held too long before testing. If the sample may be used as legal evidence, a complete record may be required of who had custody of the sample from collection through testing and, when needed, until its disposal.
- Statistical methods requirements. The statistical methods used to interpret or provide additional information about test data should be appropriate and adequate for the type and level of testing undertaken. Control charts, which help to distinguish random errors from systematic (assignable cause) errors or variations, should be employed, as needed, to alert laboratory personnel to potential problems in test procedures or equipment.
- Record-keeping requirements. A laboratory may be required to maintain all test records, observations, calculations, and derived data for all tests it performs for a given number of years. ISO/IEC Guide 38 recommends a guideline period of at least six years or as otherwise required by law or by the accrediting body.
- Test report content and format requirements. Test reports should include all information relevant to sample selection, test performance, and test results. Such information should be displayed in a format that is easy to read and understand. Data included in such reports should be routinely audited and validated, checked for questionable values, and accepted or rejected based on an established set of criteria. Audit levels—the amount of work subject to review and the extent of those reviews—should be appropriate for the type and amount of work being performed, as well as the skill of the analyst or technician conducting the tests.



- Available operational manuals and instructions. The laboratory may be required to have readily available instructions on the operation and maintenance of all materials and equipment; copies of the test methods and standards employed, along with any additional instructions needed for their application; sample selection and handling procedures; and other relevant information needed to ensure the quality of the work performed.
- Periodic reaudit of facilities. An accredited laboratory may be subjected to periodic reassessment to ensure its continued compliance with all accreditation requirements. Any significant changes in the laboratory's operations should be reported as soon as possible to the accrediting body, which should then promptly decide whether the accreditation should be continued or terminated.
- Participation in proficiency testing program. Proficiency testing evaluates the competency of a laboratory by comparing results from that laboratory with results obtained from other laboratories for tests performed on the same or similar items. Applicants may be required to satisfactorily complete a specified proficiency test, particularly in the application of test methods critical to the evaluation of the product or service.
- Adequacy of facilities and equipment. The laboratory should own or have access to all equipment required to correctly perform all test methods for which accreditation is sought. In addition, the facility should permit test methods to be conducted in a controlled environment to prevent any adverse effects on the accuracy of the test results. Specifically, the testing environment should be free from excessive temperatures, temperature fluctuations, dust, moisture, dryness, vibration, and electromagnetic or other interference. The laboratory should also have adequate lighting, heating, and ventilation. When needed, specialized facilities, such as clean rooms, should be available.
- *Equipment maintenance, repair, and calibration requirements.* Equipment calibration, preventive maintenance and repair procedures, and the choice of reference material used for calibration should be appropriate for the nature and amount of the work being performed. Equipment calibrations should be traceable to some ultimate or national reference standard.
- Adequate control over subcontractors. The laboratory may be required to have a system to ensure that testing and related work performed by another party under contract is of acceptable quality. The nature of the system should be appropriate for the type of work performed by subcontractor. The laboratory should also be able to provide to the accrediting body or other interested parties adequate evidence of the competency of all subcontractors.
- *Appeals procedure.* The laboratory may be required to have a mechanism to deal with technical questions, appeals, complaints, and challenges that originate either from the customer or from interested regulatory or accrediting bodies.



# 2.3 International and Regional Cooperation in Testing Laboratory Accreditation

Several mechanisms are used to facilitate the acceptance of test data produced by laboratories in more than one country. In some cases, a laboratory in one country will buy or establish a subsidiary within the physical boundaries of another country. Test data can then be exchanged and accepted between the parent laboratory and its subsidiary. In other cases, two or more organizations located in different countries agree to accept each other's test data. Government authorities may also have bilateral or multilateral agreements for mutual acceptance of test data. For example, the U.S. National Institute of Standards and Technology's (NIST's) National Voluntary Laboratory Accreditation Program (NVLAP) has established bilateral agreements between the United States and the National Association of Testing Authorities in Australia, the Testing Laboratory Registration Council in New Zealand, and the Standards Council of Canada. Under these agreements, test results from laboratories accredited by each party are recognized by the other party to the agreement.

# 2.4 Importance of Laboratory Accreditation to International Trade

Laboratory accreditation has taken on increased significance as international recognition and acceptance of test data have assumed greater importance in the reduction of technical barriers to trade. As traded products become more complex, it is no longer possible to assess their quality or performance by mere inspection. Decisions are now generally based on test data, and laboratory accreditation provides some assurance of the technical proficiency and competence of a laboratory to assess a product's or service's conformance to a set of prescribed standards. The competence of laboratories, which perform testing within an evaluation and approval system, is vital in securing acceptance of their test results by other countries. Mutual acceptance of laboratory test results between countries can reduce unnecessary retesting and serve as a basis for increased opportunities for international trade.

The international General Agreement on Tariffs and Trade (GATT) has as one of its major components the Agreement on Technical Barriers to Trade (usually referred to as the Standards Code). The framers of the Standards Code, including the United States, recognized that activities, such as laboratory accreditation and the mutual acceptance of test results by signatories, can either expedite or seriously hinder the free flow of goods in international commerce. The Standards Code, however, does not obligate signatories to recognize test results or certification marks from another country. The Code established a mechanism to enable signatories to the Code to enter into bilateral negotiations to discuss the reciprocal acceptance of test results. One method for ensuring the acceptance of test data is the mutual recognition of the scheme or schemes that exist in each country



# Note:

Accreditation programs may not include all of the above criteria in their evaluation process. The choice of criteria depends on the degree and type of assurance sought by the accrediting body, the cost associated with the adoption of each criterion, and the complexity of the test method(s) included in the accreditation. There may also be differences between programs using the same technical criteria, but whose frequency and intensity of application varies. For example, proficiency testing may be required annually or monthly, for all test methods or only the most important ones. Depending on these factors, an on-site inspection may be a oneday inspection conducted by one assessor or a week-long inspection conducted by a team.

for the accreditation of testing laboratories. Assurance that there is an adequate laboratory accreditation scheme can provide another country with some degree of confidence in test results of laboratories accredited under that scheme. As multilateral trade negotiations continue, one goal is to broaden the scope of the Code in this important area.



# 2.5 Some Factors for Consideration

Not all laboratory accreditation programs (LAPs) are equally thorough, nor are all laboratory-accrediting bodies equally competent. The users of accreditation, accredited laboratories, and test data produced by accredited laboratories should be aware of the following factors when evaluating a laboratory's accreditation or accreditation process

- Standards and Test Methods Used
- Open Access to the System
- Conflicts of Interest
- Effective Quality System
- Staff Training, Experience, and Records
- Adequate Records
- Adequate Follow-up and Enforcement
- Lack of Recognition of Laboratory Accreditation Schemes
- Mutual Recognition Agreements
- Multiple Accreditations
- An Adequate Appeals System
- Lack of Failures
- Accreditation Costs

These factors may affect the ability of the accreditation process to provide assurance that an accredited laboratory is capable of producing accurate and precise test data.

## 2.5.1 Standards and Test Methods Used

The choice of standards and test methods used in a laboratory accreditation scheme has a significant impact on the scheme and the accuracy, representation, and reproducibility of the results. To test a product or service against a standard, a test procedure or method must be used. Test results can have value only if the method used to generate them is capable of producing consistently accurate and precise results.

Although avoiding all possible misinterpretations in the writing of a standard is almost impossible, many standards developers fail to test and adjust standards to accommodate problems encountered during implementation, particularly during testing situations. Conformance to characteristics specified in a standard may not be accurately assessable with any kind of practical test method.

Standards may not cover all essential characteristics of a product necessary to ensure a given level of quality or safety, or they may contain unnecessary specifications that are not based on well-documented research or information. Specification may be inadequate or set too low to ensure an acceptable level of product quality or safety. If such problems with test methods and standards are significant, the test result can be misleading or useless.



# 2.5.2 Open Access to the System

In general, participation in the accreditation process should not be conditional upon a laboratory's membership in any association or organization. It is usually not desirable for the accrediting body to have any relationship with the test laboratory that might influence the accreditation process. Laboratories holding membership in the accrediting organization might develop sufficient influence over the accrediting organization to affect the accreditation decision. Furthermore, unjustified fees, financial requirements, or other conditions for application, which restrict participation and are not relevant to the competency of the laboratory, should be avoided.

### 2.5.3 Conflicts of Interest

If the accreditation process is to be credible, the accrediting body and its assessors should be free from any outside influence, which might bias the results of the accreditation process. The body should have sufficient financial resources to allow it to refuse accreditation, should that prove necessary. No relationship should exist between the laboratory and the accrediting body or its assessors that could in any way influence the objectivity and outcome of the accreditation process.

# 2.5.4 Effective Quality System

The presence of an effective quality system in the accreditation scheme is important in maintaining confidence in the accreditation process. ISO/IEC Guide 54 notes that the system should be "appropriate to the type, range and volume of work performed." The system should be documented and should include "quality assurance procedures specific to each step of the accreditation process." Procedures for ensuring adequate feedback, taking corrective actions, and handling appeals should also be included. Such documentation should be available to the accreditation staff, and responsibility for the system should be assigned to a person having access to the highest management levels. The quality system should be periodically reviewed and revised, as needed, to ensure the continued effectiveness of the system.

# 2.5.5 Staff Training, Experience, and Records

Assessors should have the knowledge and experience necessary to perform all required assessments in the accreditation process, including detailed knowledge of the assessment criteria and the standards, test methods and equipment involved. Financial benefit accruing to the accrediting body from the training of assessors should be avoided to discourage the training of marginally qualified assessors. The accrediting body should also have a means of ensuring fair and equitable selection and assignment of assessors. Assessor reports and recommendations should be submitted without editing to the accrediting body. A proposed standard for selecting qualified assessors is currently under consideration by the ISO.

#### 2.5.6 Adequate Records

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The accrediting body should maintain adequate records on the data collected, findings, and reports related to all assessments performed; the qualifications, training, and experience of each assessor; the assessment procedures used; and the laboratories accredited. All documentation on a laboratory should be restricted to persons or organizations considered by the accrediting body as having a legal right to such records.

### 2.5.7 Adequate Follow-up and Enforcement

The accrediting body should have a mechanism in place to minimize the potential for fraud or deception on the part of a laboratory regarding its accreditation status or meaning of that status. This includes arrangements for periodic reassessments of each accredited laboratory to ensure that it continues compliance procedures that permit the swift withdrawal of accredited status from laboratories that fail to comply with the terms and requirements for accreditation, as well as procedures for notifying other interested parties of a change in accreditation status.

### 2.5.8 Lack of Recognition of Laboratory Accreditation Schemes

Lack of recognition or acceptance of a laboratory accreditation scheme by other parties can necessitate extensive retesting of a product or service at considerable expense in terms of both time and money. In some cases, lack of recognition results from inadequate knowledge or information about the program and the vested interests of others, rather than problems in the program itself. Lack of recognition can result in the need for a laboratory to obtain multiple accreditations for the same or essentially the same testing services, sometimes based on all or most of the same accreditation criteria.

For example, based on information collected by Charles Hyer, laboratories that want to be accredited and designated nationwide to conduct electrical safety-related testing of construction materials must gain the acceptance of at least 43 states, more than 100 local jurisdictions, the International Conference of Building Officials, the Building Officials and Code Administrators, the Southeastern Building Code Congress International, and a number of federal agencies, as well as several large corporations. Some federal agency LAPs have gained recognition by other agencies. These include the NVLAP—currently required by the Department of Housing and Urban Development, the Federal Communications Commission, the Federal Trade Commission, the Environmental Protection Agency, the Nuclear Regulatory Commission, and parts of the Department of Defense.

Additional agencies are likely to require NVLAP accreditation as new LAPs are established. Reports on laboratories that also test pesticides and environmental contaminants from the Food and Drug Administration's toxicology laboratory monitoring program are shared with the Environmental Protection Agency. In some cases, private sector LAPs are recognized and accepted by federal, state, and local government authorities for regulatory, procurement, or other purposes. Programs that are well accepted are usually more cost effective because the need for multiple and duplicative assessments is reduced.



## 2.5.9 Mutual Recognition Agreements

Lack of recognition can be overcome through mutual recognition agreements, in which two or more parties agree to recognize the competence of laboratories accredited by the other(s). Many problems may arise with mutual recognition agreements, however, including lack of clarity or the inclusion of poorly defined terms and responsibilities in the written agreement. One of the least understood problems involves the identity and authority of the signatories to the agreement. For example, two accrediting bodies can agree to recognize each other's laboratory accreditation system. If the acceptance body for the test data produced by the accredited laboratories (usually the agency with regulatory responsibility for the product or service) is not party to the agreement, it may not be willing to accept data generated from laboratories accredited under the other accrediting body's system. The value of any agreement is then questionable. This can be overcome if each accrediting body is willing to extend its own accreditation to a laboratory that has been accredited by the other party. Under this arrangement, however, each party may assume responsibility for, and the liability and risk associated with, the other party's work. As a result, the establishment of effective mutual recognition agreements is usually a very complex undertaking.

### 2.5.10 Multiple Accreditations

Laboratories involved in multiple types of testing may need to obtain accreditation from more than one agency or organization. For example, a laboratory may be accredited by one agency to test telecommunication products, by another to test small electric appliances, and by yet another to test PV products. As noted above, however, it is not uncommon for a laboratory to need multiple state and local government accreditations and designations to conduct the same type of testing.

LAPs are frequently narrow in their scope—designating or accrediting laboratories to test only a narrowly defined range of products or services within the agency's or organization's area of responsibility. The results of laboratory assessments from these programs are usually of only limited use to other agencies and organizations. A laboratory that offers a broad range of testing services may need multiple accreditations, which increases the laboratory's cost of doing business and possibly restricts entrance into additional testing areas.

# 2.5.11 An Adequate Appeals System

Disagreements among parties involved in an accreditation program may occasionally arise. Provision should be made within the program for an impartial appeals mechanism to handle disagreements that cannot otherwise be resolved. Procedural requirements should be in writing with minimal limitations on the timing of appeals, and on who may file.

### 2.5.12 Lack of Failures

If all applicants are accredited, the effectiveness of the accreditation program should be reviewed. It is possible that the accreditation program has been effective and unqualified testing laboratories have not applied. However, it is also possible that the accreditation program has not been effective in uncovering weaknesses in laboratory operations, and the program's methods and criteria need to be overhauled. Causes for the lack of failures should be investigated to determine whether the program is still effective.

# 2.5.13 Accreditation Costs

The costs involved in accreditation can be cause for serious concern for all laboratories, particularly for smaller laboratories or those that offer a broad range of testing services. Such costs must be balanced against the amount of new testing work likely to result.

Multiple accreditations may be required for laboratories to perform testing for different countries, or even for more than one state or local jurisdiction. Multiple accreditations may also be required for different products or testing fields, all of which can considerably increase total accreditation costs. These costs must ultimately be passed on to the users of the testing services.



# Chapter 3 Requirements for the Quality System of a Laboratory



The procedure that specifies how an accredited laboratory should perform its functions to conform to a high quality standard is referred to as the "quality assurance system" or "quality system." This chapter describes the specific requirements of the quality system of a laboratory.

The testing laboratory shall define and document its policies and objectives for, and its commitment to, good laboratory practices and the quality of testing services. The laboratory management shall ensure that these policies and objectives are documented in a quality manual and that they are communicated to, understood by, and implemented by all laboratory personnel engaged in PV component or system testing. The quality manual shall be updated periodically to ensure that it remains current; this responsibility will come under the authority and responsibility of the quality manager. The quality manual, including up-to-date referenced test procedures and operating documents, shall be available for use by the laboratory personnel.

# 3.1 Quality System

The laboratory shall establish and maintain a quality system appropriate to the type and scope of PV testing required for a certification and labeling program for PV components and systems. To ensure the credibility and reliability of test results produced by a laboratory, it is essential that a laboratory receive accreditation. Based on recent developments in the U.S. and international arenas, a new need for laboratories to perform PV system and component testing and certification has been identified. An essential part of this is developing standard laboratory procedures and achieving independent certification and approval.

This chapter represents a plan for a laboratory to apply for and obtain ISO 17025 certification for PV systems and component testing. The final result will be an "operations and quality assurance process," or "quality system." All elements of this system are listed below. The quality system documentation shall consist of four parts:

- Quality Manual.
- Standard Operating Procedures Manual.
- **Test Instrument Manual.**
- Testing Standards Manual.

The purpose of the *Quality Manual* will be to document well-defined policies and procedures associated with laboratory operations to ensure that the highest quality standards for testing, reporting, and other services are maintained. This manual will ensure that all requirements defined by the applicable standards, directives, and organizations are met. Laboratory staff member commitment to high quality and the standards dictated in the *Quality Manual* are key to achieving the stated objectives.

The Standard Operating Procedures Manual will include approved laboratory practices for maintaining a quality system. The Standard Operating Procedures Manual will include specific procedures to be followed and requirements and staff responsibilities for performing all tests conducted on PV or solar thermal systems and components. The requirements will include general laboratory practice, as well as case-specific procedures for the testing of systems and components.

The *Test Instrument Manual* will include information specific to the requirements for performing the inventory, operation, and regular calibration of the laboratory test equipment. Information in the manual will include equipment manufacturers' manuals, calibration records, and location of the equipment. Where applicable, the specific uses of the equipment will be identified and explained.

The *Testing Standards Manual* will include all internationally recognized PV test standards, recommended practices and guidelines, such as approved by the IEC. Where internationally accepted standards are not available, procedures or interim standards, such as the PV GAP, will be used. National standards, like those approved by the IEEE and other organizations applicable to PV systems and component testing, may be included in the *Testing Standards Manual*.

#### 3.1.1 Quality Manual

The laboratory's *Quality Manual* shall be specific to the laboratory physically involved in testing PV components and systems and shall therefore be unique to the laboratory; it shall not be a generic quality manual pertaining to a parent organization. The content, structure, and format of the manual shall reflect this uniqueness. An example of a test laboratory quality manual is included in **appendix 1**, which was developed by the Florida Solar Energy Center as a test laboratory for PV modules, components and systems, and solar thermal collectors and systems.

All copies of the manual shall be numbered, and a log shall be maintained of the recipient of each control copy. The manual shall be a *living document*, that is, each section shall be separately numbered, and each page shall contain the appropriate page number of that section and the following document control information: date of issue, authority, and amendment number. The minimum contents of the *Quality Manual* shall include the following:

- 1. A policy statement on quality, including objectives and commitments, that is prepared, issued, and endorsed by top management.
- 2. The organization and management structure of the laboratory, its place in any parent organization, and relevant organizational charts. The organizational charts shall include all positions and names, and be consistent with job descriptions and training records.
- 3. The responsibility, authority, and interrelation of all personnel who manage, perform, or verify work affecting the quality of tests and calibrations. These relationships should be further identified in a separate organizational chart.

<sup>•</sup> This material was obtained from PV GAP (1999a).





- 4. Procedures for control and maintenance of the quality system and related operations documentation. These procedures shall include the following, in addition to the requirements specified in the second item above:
- The procedures, responsibilities, and authorities for drafting, changing, approving, and issuing documents in the quality system, and documents for performing testing and calibration (test methods, calibration procedures, job orders, and travel).
- Procedures for preventing obsolete or superseded documents from being used.
- Complete historical files of all quality documents and the location of these files.
- A master list of all quality documents with current issue dates and identities of copy-holders (where relevant).
- The job descriptions of the management and key operating staff (listed in annex A of the sample quality manual in appendix 1). Also, job descriptions of all other operating and support staff, training records, and their office locations.
- The laboratory's approved signatories for test reports and certifications. The criteria for selecting the approved signatories shall be as specified in a model for a third-party certification and labeling program for PV components and systems.
- The laboratory's policy and reference procedures for achieving traceability of all measurements.
- Arrangements for reviewing all new work to ensure that the laboratory has the appropriate facilities and resources before commencing such work. The manual shall describe facilities and resources for such a review. The manual shall also describe policies and procedures to screen incoming test requests to determine whether it is within the laboratory's capacity to accept the new work. Evidence of this review shall be documented.
- The laboratory's scope of tests, listed in tables (whether in a body or in an appendix to the procedure manual). Test procedures will be covered in one table, and the calibration procedures in another. The documents pertaining to test and calibration procedures, respectively, shall be identified and their distribution noted.
- The procedures for handling test items. This policy shall describe the system of work flow through the laboratory and shall be supported by a flow chart indicating the key elements of the overall test program.
- Reference to major test and calibration equipment used in the laboratory. This reference shall be supported by a list in tabular form, of all such instrumentation. Information provided in the list shall include items required in the section on maintenance of records on equipment, reference materials, and reference instruments.
- Reference to procedures for the calibration, verification, and maintenance of instrumentation and equipment.
- Reference to current verification practices including interlaboratory comparisons and proficiency test programs (if made available for PV testing), use of reference materials and reference physical standards, and internal quality control, or procedures.



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- Procedures to be followed for feedback and corrective action whenever testing discrepancies are detected, or departures from documented policies and procedures occur.
- The laboratory management's policy and arrangements for permitting departures from documented policies and procedures, or from standard practices.
- Policy and procedures for resolution of complaints received from clients or other parties about the laboratory's testing activities.
- Procedures for protecting the confidentiality and proprietary rights of clients.
- Procedures for audit and review of the quality system, as described in section 3.2 of this document (Audit, Review, and Verification Processes).
- Procedures for training staff in the implementation and application of, and compliance with, the quality system and related operating procedures.
- Copies of or reference to procedures for the management of personnel, personnel records, and the office location of this information.
- If work is subcontracted, procedures to ensure that subcontractors are competent and comply with the requirements of this guide, as described in the section of appendix 1 entitled Subcontracting of Tests. (See also the section of appendix 2 entitled Subcontracting of Calibration or Testing.)
- Copies of or reference to procedures to ensure that outside support services and supplies are of adequate quality, according to the section in appendix 2 entitled Outside Support and Supplies.
- Copies of or reference to procedures for avoiding deterioration or damage to test and calibration items during storage, handling, preparation, and testing.
- Copies of or reference to procedures for the receipt and retention or safe disposal of test and calibration items, including all provisions necessary to protect the integrity of the laboratory.
- Copies of or reference to procedures to ensure that purchased equipment, materials, and services comply with specified requirements when no independent assurance of the quality of outside support services or supplies is available.

The purpose of this Quality Manual is to document well-defined policies and procedures associated with laboratory operations to ensure that the highest quality standards for testing, reporting, and other services are maintained. The sample outline in table 3.1 covers all requirements defined by the applicable standards, directives, and organizations. Laboratory staff member commitment to high quality and the standards dictated in the Quality Manual are key to achieving the stated objectives.



<sup>&</sup>lt;sup>2</sup> FSEC PV and Solar Thermal, Systems and Component Test Laboratory, Quality Assurance Standards and ISO 25 Certification, Florida Solar Energy Center Publication, 1998.

# 3.1.2 Standard Operating Procedures Manual

The Standard Operating Procedures Manual includes approved laboratory

practices for maintaining a quality system (see the sample outline in table 3.2). This document includes specific procedures and requirements for performing all tests conducted on PV systems and components, and the requirements of general laboratory practice, as well as case-specific procedures for testing systems and components.

# 3.1.3 Test Instrument Manual

The Test Instrument Manual includes information specific to the requirements for performing the inventory, operation, and regular calibration of the laboratory test equipment (see the sample outline in table 3.3). Information in this manual includes equipment manufacturers' manuals, calibration records, and location of test equipment. Where applicable, the specific uses of the equipment for PV testing are identified and explained.

# 3.1.4 Testing Standards Manual

The Testing Standards Manual should include all standards, recommended practices, and guidelines of the IEC, IEEE, and other organizations applicable to PV systems and component testing (see the sample outline in table 3.4). Where internationally accepted standards are not available, procedures or interim standards proposed by PV GAP are included. These standards are the basis for the PV systems and components.

# 3.2 Audit, Review, and Verification Processes

The laboratory shall conduct internal or contracted audits of its activities to verify that its operations continue to comply with the requirements of the quality system. Trained and qualified staff members shall carry out such audits who are, whenever resources permit, independent of the activity to be audited.

Audits shall be carried out not less than once a year. These audits shall include both general criteria (documents, records, and policies) and technical compliance (test methods and practices).

Where the audit findings cast doubt on the quality of the laboratory's test results, the laboratory shall



#### Table 3.1

#### Sample Outline for a Quality Manual

#### Organizational and Management Structure

- The Laboratory
- Photovoltaics Group
- Staff Assignments and Responsibilities

#### Quality Assurance Policy

- Commitments and Obligations
- Confidentiality, Impartiality, and Conflict of Interest Policy
- Test Database Management
- Record-keeping, Document, and File **Convention Control Policy**
- Reference Library Document Maintenance and Control Policy
- Quality Assurance Audit Policy
- Nonconformity, Complaint, and Corrective Action Policy

#### Equipment Received for Testing

- Procedures for Submitting Equipment for Testing
- Receipt, Inspection, and Archiving of Test Systems and Components
- Testing Flow Processes and Time Schedules
- Reporting Content and Format
- Approval and Certification Policy
- Test Sample Retention Policy
- Dispute Resolution Policy

#### Testing Methods and Procedures

- System
- Components

Test Equipment

- Equipment Inspection and Service Policy
- Calibration and Verification of Test Instruments and Equipment
- Dedicated Use of Equipment

# Facilities and Maintenance

- Safety Systems
- Environmental Systems
- Housekeeping Policy and Responsibilities

#### Health, Safety, and Environment Policy

Appendixes

- Laboratory Plans and Description
- Staff Vitae and Job Descriptions
- Personnel Qualified to Perform Specific Tasks
- Instruments Requiring Calibration
- Equipment Requiring Maintenance
- List of Procedures and Standards

take immediate corrective action. The laboratory shall immediately notify, in writing, any client whose work may have been affected, and shall provide a copy of all such information and correspondence to any product certification program body for which the testing is performed.

The objectives of these audits are to discover the following:

- Whether management objectives (as defined by the quality system) are being achieved.
- Whether designated duties are being carried out satisfactorily.
- Whether appropriate calibrations of equipment, or materials, or both, are being properly carried out, and whether the results are within the acceptable error limits for the quantities and properties being measured.
- Whether procedures described in the quality system are being followed.
- Opportunities for quality improvement.

The quality manager shall be responsible for ensuring that all components of the laboratory's activities are audited at least once a year on behalf of the management. The task of carrying out audits may be delegated to other staff with appropriate technical training and familiarity with the quality system. Additionally, the following requirements should be met:

- The laboratory shall have a planned schedule for the audits that includes all activities. Table 3.2
- The audit procedures shall be documented.
- The audits shall be carried out in accordance with the planned schedule and with the documented procedures.
- The results of the audits shall be documented.
- Effective corrective action shall be undertaken within a reasonable time frame with respect to all nonconforming items.
- A record of all completed corrective actions shall be maintained.

The quality system adopted to satisfy the requirements of this model shall be reviewed at least once a year by senior management to ensure its continuing suitability and effectiveness and to introduce any necessary changes or improvements. The management review shall include the following:

- Matters arising from the previous review.
- Reports of any formal second- or third-party assessments.
- Reports of internal audits done since the last management review, including any corrective actions required and taken.
- Results of participation in any interlaboratory comparisons or proficiency test programs, if available.
- Results of internal quality, data, and instrumentation checks or verification procedures.
- Details of any complaints from clients.

# Sample Outline for a Standard **Operating Procedures Manual**

#### Test Instruments and Equipment

- Instrument Labels
  - Instrument Calibration
  - Instrument Cross-checking

#### Inventory and Location

Equipment Received for Testing

- Procedures for Submitting Equipment for Testing
- Receipt, Inspection, Archiving and Labeling of Test Systems and Components
- Testing Flow Processes and Time **Schedules**
- Reporting Content and Format
- Approval and Certification Policy
- Test Sample Retention Policy

#### Test Procedures

- Stand-alone Systems
- Solar Home Systems
- Commercial PV Lighting Systems
- Vaccine Refrigeration Systems
- Water Delivery Systems
- Grid-connected Systems
- Hybrid Systems

#### Test Reports

Data Format and Content



- Staff training and cross-training (for both new and existing staff).
- Adequacy of resources (personnel, equipment).
- Future plans, new work requirements, new staff, and new equipment.

All audit and review findings and any corrective actions that arise from them shall be documented. The quality manager shall ensure that these actions are discharged within the agreed timetable. Corrective action shall be taken whenever evidence arises that the quality system is not functioning properly, for example, under the following circumstances:

- When there is a need to correct an immediate failure. This may require, as appropriate, retesting and withdrawing an invalid test report, and issuing a new test report.
- When there is a need to investigate the underlying cause of a failure. This may involve test personnel not being properly trained in the use of a new instrument or may involve the use of defective equipment found to be out of calibration.

In addition to periodic audits, the laboratory shall ensure the quality of the results provided to clients by implementing independent checks. These checks shall be reviewed and shall include, as appropriate, but not be limited to, the following:

- Internal quality control schemes using, whenever possible, statistical techniques (such as Spearman's rank correlation to discover reversals; x-y correlation coefficients between two measurements of an independent variable; or statistical process control charting, uncertainty analyses).
- Participation in proficiency testing or other interlaboratory comparisons, if made available for PV testing.
- Regular use of certified reference materials or reference instruments or both, in-house quality control using secondary reference materials, or reference test specimens or both, including accepted calibrated standards for the measurement of optical, electrical, thermal, and physical properties of items employed in the testing as detailed in the sections of appendix 2 entitled "Equipment and Reference Materials, Instruments, or Standards" and "Test and Calibration Methods."
- Replicate testing.
- Retesting of retained test items.
- Correlation of results for different characteristics of an item.

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#### able 3.3

Sample Outline for a Test Instrument Manual

# Environmental Measurement Instruments

- Solar Radiation Measurement
  - Thermopile Pyranometers
  - Silicon Pyranometers
  - Reference Cells
  - Reference Modules
- Wind Speed and Wind Direction Sensors

Temperature and Humidity Sensors

- Instruments to Measure Electrical Properties
  - Voltage, Current, and Power Transducers
  - Multimeters
  - Power Analyzers and kwh Meters
  - Current Shunts
  - Voltage Dividers
  - Oscilloscopes and Spectrum Analyzers
  - Chart Recorders
  - Elapsed Time Meters

Data Acquisition Systems and Equipment

- Power Supplies
- Battery Test Equipment
- Conductance and Load Testers
- Hydrometers
- Scales
- I-V Curve Tracers and Accessories
- Solar Simulator and Accessories
- Lighting Evaluation Equipment
- Illuminance Meters
- Photometers
- Computers and Accessories
- Environmental Chambers
- Audiovisual Equipment
- Manuals for Equipment Manufacturers
- Calibration Records
- Location and Inventory
- Specific or Dedicated Use of Equipment

#### Table 3.4 Sample Outline for a Testing Standards Manual

- Scope and Content
- Applicable Standards Organizations
- List of Standards
- Component Test Standards
- Systems Test Standards

# 3.3 Personnel Requirements



The laboratory shall have sufficient personnel with the necessary education, training, technical knowledge, and experience for their assigned functions. Job descriptions of all personnel involved in PV component or systems testing shall be prepared and shall include position title, minimum requirements for the position, responsibilities, reporting relationships, and any supervisory responsibilities.

The laboratory shall ensure that the training of its personnel is up to date. Procedures shall be developed to identify training needs, not only for training new personnel, but also for developing and maintaining the skills of existing personnel in all test techniques. Particular attention should be given to new or only occasionally used test methods, procedures, and techniques. Procedures for cross-training shall be developed and shall be implemented as needed.

The laboratory shall maintain records on the relevant qualifications, training, skills, and experience of the technical personnel. A list of all tests and calibrations that each staff member has been assessed for and found competent to perform shall be maintained. Cross-training records shall be kept up to date.

# 3.4 Laboratory Space and Facilities

Laboratory facilities shall include the provision of regular, essentially permanent, ample work space (indoor or outdoor, or both) for testing PV components and systems and for performing any necessary calibrations (table 3.5). Energy sources, lighting, heating, air conditioning, and ventilation shall be adequate to facilitate the correct performance of tests and the required internal calibrations.

The environment in which these activities are undertaken shall not invalidate the results or adversely affect the required uncertainty level of any measurement. Care shall be taken when such activities occur at sites other than a permanent laboratory facility.

The laboratory shall provide equipment for the effective monitoring, control, and recording of environmental conditions, as appropriate. Due attention shall be paid, for example, to dust, electromagnetic interference, humidity, mains voltage, temperature, and sound and vibration levels, as appropriate to the tests and calibrations performed.

Effective separation shall exist between neighboring areas in which there are incompatible activities. Access to and use of all areas affecting the quality of measurements or testing shall be defined and controlled through documented procedures.

Adequate measures shall be taken to ensure good housekeeping and safety in the laboratory and at any outdoor test sites.

The quality manual and related quality documentation shall state the laboratory's policies and operational procedures established to meet the requirements of this model.

Complete and detailed test and calibration procedures shall not be contained in the *Quality Manual*. The laboratory's specific requirements and requirements for test procedures as part of a certification and labeling program for PV components and systems shall be maintained in a separate test and calibration procedures manual or in separate manuals unique to the PV test laboratory.

Rules shall be developed and employed for the unique identification of all quality documentation, for changes to the documents, for distribution of the documents, and for the registration of copies issued. The control information required on all documentation in the quality system shall

### Sample Manual Outline: Quality System for a Photovoltaic Systems Test Laboratory 1. Quality Manual (QM)

- 1.1 Application and Scope of Quality Manual 1.2 Organizational and Management Structure
  - 1.2.1 The Center
  - 1.2.2 Photovoltaics Group
  - 1.2.3 Staff Assignments and Responsibilities
- 1.3 Quality Assurance Policy
  - 1.3.1 Commitments and Obligations
  - 1.3.2 Confidentiality, Impartiality, and Conflict of Interest Policy
  - 1.3.3 Test Database Management
  - 1.3.4 Record-keeping, Document, and File **Convention Control Policy**
  - 1.3.5 Reference Library Document Maintenance and Control Policy
  - 1.3.6 Quality Assurance Audit Policy
  - 1.3.7 Nonconformity, Complaint, and **Corrective Action Policy**
- 1.4 Equipment Received for Testing
  - 1.4.1 Procedures for Submitting Equipment for Testing
  - 1.4.2 Receipt, Inspection, and Archiving of Test Systems and Components
  - 1.4.3 Testing Flow Processes and Time **Schedules**
  - 1.4.4 Reporting Content and format
  - 1.4.5 Approval and Certification Policy
  - 1.4.6 Test Sample Retention Policy
  - 1.4.7 Dispute Resolution Policy
- 1.5 Testing Methods and Procedures
  - 1.5.1 Systems
  - 1.5.2 Components
- 1.6 Test Equipment
  - 1.6.1 Equipment Inspection and Service Policy
  - 1.6.2 Calibration and Verification of Test Instruments and Equipment
  - 1.6.3 Dedicated Use of Equipment
- 1.7 Facilities and Maintenance
  - 1.7.1 Safety Systems
  - 1.7.2 Environmental Systems

- 1.7.3 Housekeeping Policy and Responsibilities
  - 1.8 Health, Safety, and Environment Policy
  - 1.9 Appendices
    - 1.9.1 Laboratory Plans and Description
    - 1.9.2 Staff Vitae and Job Descriptions
    - 1.9.3 Personnel Qualified to Perform Specific Tests
    - 1.9.4 Instruments Requiring Calibration
    - 1.9.5 Equipment Requiring Maintenance
    - 1.9.6 List of Procedures and Standards
- 2. Standard Operating Procedures Manual (SOPM)
  - 2.1 Application and Scope of Standard Operating **Procedures Manual**
  - 2.2 Test Instruments and Equipment
    - 2.2.1 Instrument Labels
    - 2.2.2 Instrument Calibration
    - 2.2.3 Instrument Cross-checking
    - 2.2.4 Inventory and Location
  - 2.3 Equipment Received for Testing
    - 2.3.1 Procedures for Submitting Equipment for Testing
    - 2.3.2 Receipt, Inspection, Archiving, and Labeling of Test Systems and Components
    - 2.3.3 Testing Flow Processes and Time Schedules
    - 2.3.4 Reporting Content and format
    - 2.3.5 Approval and Certification Policy
    - 2.3.6 Test Sample Retention Policy
    - 2.3.7 Dispute Resolution Policy
  - 2.4 Test Procedures
    - 2.4.1 Stand-alone Systems
      - 2.4.1.1 Solar Home Systems
      - 2.4.1.2 Commercial Pv Lighting Systems
      - 2.4.1.3 Vaccine Refrigeration Systems
      - 2.4.1.4 Water Delivery Systems
    - 2.4.2 Grid-connected Systems
    - 2.4.3 Hybrid Systems
  - 2.5 Test Reports
    - 2.5.1 Data format and Content

(Continued on following page)





3. Test Instrument Manual (tim)	3.2.3 Data Acquisition Systems and
3.1 Scope and Content of Test Instrument Manual	Equipment
3.2 Classification and List of Test Instruments and	3.2.4 Power Supplies
Equipment	3.2.5 Battery Test Equipment
3.2.1 Environmental Measurement	3.2.5.1 Conductance and Load Testers
Instruments	3.2.5.2 Hydrometers
3.2.1.1 Solar Radiation Measurement	3.2.5.3 Scales
3.2.1.1.1 Thermopile Pyranometers	3.2.6 I-V Curve Tracers and Accessories
3.2.1.1.2 Silicon Pyranometers	3.2.7 Solar Simulator and Accessories
3.2.1.1.3 Reference Cells	3.2.8 Lighting Evaluation Equipment
3.2.1.1.4 Reference Modules	3.2.8.1 Illuminance Meters
3.2.1.2 Wind Speed and Wind Direction	3.2.8.2 Photometers
Sensors	3.2.9 Computers and Accessories
3.2.1.3 Temperature and Humidity	3.2.10 Environmental Chambers
Sensors	3.2.11 Audio-visual Equipment
3.2.2 Electrical Properties Measurement	3.3 Manuals for Equipment Manufacturers
Instruments	3.4 Calibration Records
3.2.2.1 Voltage, Current, and Power	3.5 Location and Inventory
Transducers	3.6 Specific Or Dedicated Use Equipment
3.2.2.2 Multimeters	4. Testing Standards Manual (TSM)
3.2.2.3 Power Analyzers and Kwh Meters	4.1 Scope and Content of Testing Standards
3.2.2.4 Current Shunts	Manual
3.2.2.5 Voltage Dividers	4.2 Applicable Standards Organizations 4.3 List of Standards
3.2.2.6 Oscilloscopes and Spectrum	
Analyzers 3.2.2.7 Chart Recorders	<ul><li>4.4 Component Test Standards</li><li>4.5 Systems Test Standards</li></ul>
3.2.2.8 Elapsed Time Meters	4.5 Systems lest standalus

include a unique identification of the document, the revision number, the date of issue, and the person authorizing the issuance of the revision so that the identity of the controlling document at any time is clear.

# Chapter 4 Test Procedures for Photovoltaic Modules, Batteries, and Charge Controllers

The primary objective of testing PV modules, balance of system (BOS) components (including batteries, charge controllers, inverters, DC to DC converters, trackers, loads, and others), and small PV systems is to procure reliable and well-performing PV systems that result in better system availability leading to improved system economics. The increased cost effectiveness and reliability of PV systems will further enhance consumer confidence and wider utilization of PV renewable technology, which could accelerate the socioeconomic development in developing countries in harmony with the preservation of global environments.

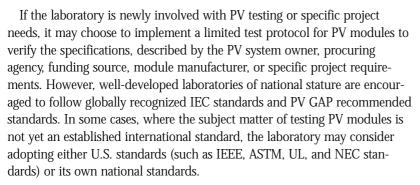
For developing countries to realize the full potential or major benefits of PV technology for the betterment of living standards, it is preferable to manufacture PV products indigenously and also to implement high-quality testing of domestic PV products locally. A majority of developing countries, however, may not have the state-of-the-art technical knowledge, well-trained staff, or the sophisticated equipment required for high-quality testing of PV products and small systems. The next two chapters address these aspects.

In the previous two chapters of this training manual, detailed information has been provided for PV testing laboratories to establish and install well-recognized and internationally accepted quality systems in their laboratories, such as those based on ISO 17025, and also to develop and obtain accreditation for their laboratories to test and certify PV modules, BOS components and small PV systems. Complementary to the previous two chapters, this and the following chapters describe the specific test procedures, preferably internationally recognized, for high-quality testing and certification of PV modules, batteries, charge controllers, stand-alone inverters, DC fluorescent lights, and small PV systems.

Depending on the domestic needs, type of PV applications employed, and the laboratory's own capabilities, the testing laboratory may elect to conduct well-defined, limited PV testing for functionality tests or verification of performance specifications, or it may plan to implement extensive testing of PV products to cover the entire gamut of testing for performance, mechanical and electrical stress, durability, extreme environmental exposure, and accelerated aging conditions. In the latter case, as much as possible the test procedures should conform to international or national standards. This chapter briefly describes the test procedures for verifying specifications and testing PV products extensively.



# 4.1 Photovoltaic Modules



### 4.1.1 Tests for Verification of Module Specifications

This subsection describes the tests, sampling plan, and test sequence to be used for verifying PV module specifications. These specifications were developed for solar home systems procured for the project assisted by the World Bank–Global Environment Facility (GEF).

The manufacturer will permit a representative from the testing laboratory to randomly select six modules for each model of PV modules from its stock. The samples will be sealed and shipped to the laboratory for testing.

To guarantee that each step of the test is independent and the whole test will be done correctly according to a standard sorting strategy, six modules of each model of PV module will be required to complete the whole test cycle. The six modules will be sorted and tested as shown in **figure 4.1** (see also table 4.1).

The test items are similar to the tests described in IEC Standard 61215 (1993) and are listed here:

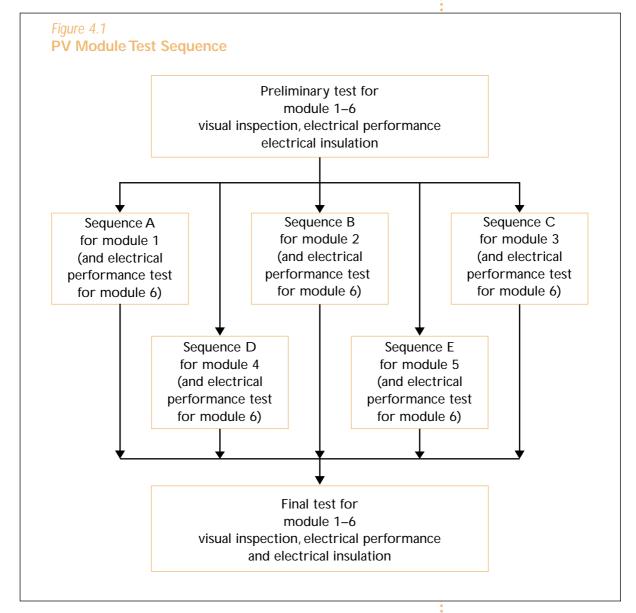
- 10.1: Visual Inspection.
- 10.2: Electrical Performance at Standard Test Conditions (STC) that is, 25° C module temperature, 1,000 W/m<sup>2</sup> irradiance and air mass 1.5 solar spectral distribution.
- 10.3: Electrical Isolation at 500 volts DC.
- 10.8: Outdoor Exposure Test, 60 kWh/m<sup>2</sup> total irradiance.
- 10.10: Ultraviolet (UV) Exposure Test (optional).
- 10.11: Thermal Cycling, -40±2°C to +85±2°C for 50 cycles.
- 10.12: Humidity Freeze Cycling, -40±2°C to +85±2°C at 85±5% RH for 10 cycles.
- 10.13: Damp Heat, 85±2°C, RH 80% to 90%, for 1,000 hours.
- 10.14: Robustness of Terminations.
- 10.15: Twist Test, Deformation Angle Less than or Equal to 1.2°.
- 10.16: Mechanical Load Test, 2,400 Pascals (3x wind gusts of 130 km/h) for One Hour Front and Back.
- 10.17: Hail Impact Test, 25 mm Ice Balls Striking at a Velocity of 23 m/sec.

*Pass criteria.* The test modules shall be considered to have passed the qualification tests if the random sample of six modules meets all of the following requirements:



- Each visual inspection should show no major defects.
- Each electrical performance test should show power of 90 percent or greater of the original baseline (initial performance) or post-annealing performance test.
- No module should exhibit any open circuit or ground fault during the tests.
- Electrical isolation tests should show no arcing and no leakage current in excess of 100 mA/m<sup>2</sup> of module area, or10 mA for the entire module, whichever is greater.

If two or more modules do not meet any of these requirements, the test modules shall be considered not to have passed the qualifications. If one out of five test modules (excluding module six used for baseline comparison) fails any test, two other modules of the same type and model should be procured and run through the entire relevant test sequence. If any of those two modules also fail, the test modules shall be judged not to have





passed the qualifications. However, if both the substitute modules pass the whole test sequence, the modules shall be judged to have passed the qualification requirements.

### 4.1.2 PV Module/Cell Standards

A laboratory that plans to conduct extensive testing of PV modules to meet the needs of a fast-growing domestic market or broad-based government and international programs is encouraged to adopt international standards, including IEC standards and PV GAP recommended standards. The existing IEC standards are listed here, and a hard copy of each of the pub-

lished IEC PV standards is included in Appendix 4 of this manual. PV GAPrecommended standards PV RS-1, PV RS-2, and PV RS-3 are also listed below and included in Appendix 3.

The U.S. PV module and cell test standards IEEE, ASTM, and UL are also very rigorous and comparable to IEC standards in their testing quality, effectiveness, and detail. These are also listed here for consideration of being adopted by the testing laboratory, especially when the international standards on the particular test subject are not yet available.

#### International Electrotechnical Commission Standards

- 1. IEC 61836: 1997, Solar Photovoltaic Energy Systems—Terms and Symbols.
- 2. IEC 60891: 1987, Procedures for Temperature and Irradiance Corrections to Measured I-V Characteristics of Crystalline Silicon Photovoltaic (PV) Devices. Amendment No. 1 (1992).
- 3. IEC 60904-1: 1987, Photovoltaic Devices-Part 1: Measurements of PV Current-Voltage Characteristics.
- 4. IEC 60904-2: 1989, Photovoltaic Devices—Part 2: Requirements for

**1** These standards may be purchased from the International Electrotechnical Commission, 3 rue de Varembé, Geneva, Switzerland. Tel: (41-22) 919-0211; fax: (41-22) 919-0300; Email: inmail@iec.ch; Web site: http://www.iec.ch.

#### Table 4.1 Test Sequence for PV Modules

	No. of	
No. Test	modules	Standard
Initial test		
1 Visual inspection	6	IEC 61215, test 10.1
2 Electrical performance	6	IEC 6215, test 10.2
3 Electrical isolation	6	IEC 61215, test 10.3
Sequence A		
4 Thermal cycling	1	IEC 61215, test 10.11
5 Visual inspection	1	IEC 61215, test 10.1
6 Electrical performance	1	IEC 61215, test 10.2
7 Electrical isolation	2	IEC 61215, test 10.3
8 Twist test	1	IEC 61215, test 10.15
Sequence B		
9 Humidity freeze cycling	1	IEC 61215, test 10.12
Sequence C		
10 Outdoor exposure test	1	IEC 61215, test 10.8
11 Visual inspection	1	IEC 61215, test 10.1
12 Electrical performance	1	IEC 61215, test 10.2
13 Electrical isolation	2	IEC 61215, test 10.3
14 Mechanical load	1	IEC 61215, test 10.16
Sequence D		
15 Ultraviolet (UV) exposure to		IEC 61215, test 1010
16 Visual inspection	1	IEC 61215, test 10.1
17 Electrical performance	1	IEC 61215, test 10.2
18 Electrical isolation	2	IEC 61215, test 10.3
19 Hail impact test	1	IEC 61215, test 10.17
Sequence E		
20 Damp heat	1	IEC 61215, test 10.13
21 Visual inspection	1	IEC 61215, test 10.1
22 Electrical performance	1	IEC 6215, test 10.2
23 Electrical isolation	2	IEC 61215, test 10.3
24 Robustness of terminations	s 1	IEC 61215, test 10.14
Sequence F		
25 Baseline comparison	1	
Final test		
26 Visual inspection	6	IEC 61215, test 10.1
27 Electrical performance	6	IEC 6215, test 10.2
28 Electrical isolation	6	IEC 61215, test 10.3

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Reference Solar Cells.



- 5. IEC 60904–3: 1989, Photovoltaic Devices—Part 3: Measurement Principles for Terrestrial Photovoltaic (PV) Solar Devices with Reference Spectral Irradiance Data.
- 6. IEC 60904–5: 1993, Photovoltaic Devices—Part 5: Determination of the Equivalent Cell Temperature (ECT) of Photovoltaic (PV) Devices by the Open-Circuit Voltage Method.
- 7. IEC 60904–6: 1994, Photovoltaic Devices—Part 6: Requirements for Reference of Solar Modules.
- 8. IEC 60904–7: 1995, Photovoltaic Devices—Part 7: Computation of Spectral Mismatch Errors Introduced in the Testing of Photovoltaic Devices.
- 9. IEC 60904–8: 1995, Photovoltaic Devices—Part 8: Guidance for Spectral Measurement of Spectral Response of a Photovoltaic (PV) Device. Second edition (1998).
- 10. IEC 60904–9: 1995, Photovoltaic Devices—Part 9: Solar Simulator Performance Requirements.
- 11. IEC 60904–10: 1998, Photovoltaic Devices—Part 10: Linearity Measurement Methods.
- 12. IEC 61215: 1993, Crystalline Silicon Terrestrial PV Modules—Design Qualification and Type Approval.
- 13. IEC 61345: 1998, UV Test for Photovoltaic (PV) Modules.
- 14. IEC 61646: 1996, Thin Film Silicon Terrestrial PV Modules—Design Qualification and Type Approval.
- 15. IEC 61701: 1995, Salt Mist Corrosion Testing of Photovoltaic (PV) Modules.
- 16. IEC 61721: 995, Susceptibility of a Module to Accidental Impact Damage (Resistance of Impact Test).
- 17. IEC 61730 Ed. 1.0: Safety Testing Requirements for PV Modules. Draft.
- IEC 61849 Ed. 1.0: Design Qualifications and Type Approval of PV Modules for Marine Environments. Draft.
- 19. IEC 61853 Ed. 1.0: Power and Energy Rating of Photovoltaic (PV) Modules, Draft.

# PV GAP Recommended Standards

- 20. PV RS-1: 1998, PV Stand-Alone Systems—Design Qualification and Type Approval.
- 21. PV RS-2: 1999, Crystalline Silicon Terrestrial Photovoltaic (PV) Module Blank Detailed Specification—Qualification Approval under the IEC Quality Assessment for Electronic Components (IECQ).
- 22. PV RS-3: 1999, Thin Film Terrestrial Photovoltaic (PV) Module Blank Detailed Specification—Qualification Approval under the IEC Quality Assessment for Electronic Components (IECQ).

# Institute of Electrical and Electronic Engineers (IEEE) Standards@

- 23. IEEE 1262: 1995 Recommended Practice for Qualification of Photovoltaic (PV) Modules. April 1996.
- P 1513: 1999, Recommended Practice for Qualification of Concentrator Photovoltaic (PV) Receiver Section and Modules. Draft, July 1999.
- 25. IEEE P1479: 1999, Recommended Practice for Evaluation of Photovoltaic (PV) Module Energy Production. Draft, July 1999.

## American Society for Testing and Materials (ASTM) Standards®

- 26. 1328–94: Terminology Relating to Photovoltaic Solar Energy Conversion.
- 27. 927–91: Specification for Solar Simulation for Terrestrial Photovoltaic Testing.
- 28. E 948–95: Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells under Simulated Sunlight.
- 29. E 973M-96: Test Method for Determination of the Spectral Mismatch Parameter between a Photovoltaic Device and a Photovoltaic Reference Cell.
- 30. E 1021–95: Test Methods for Measuring Spectral Response of Photovoltaic Cells.
- 31. E 1036M-96: Test Methods for Electrical Performance of Non-Concentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells.
- 32. E 1038–98: Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls.
- 33. E 1039–94: Test Method for Calibration of Silicon Non-Concentrator Photovoltaic Primary Reference Cells under Global Irradiation.
- 34. E 1040–98: Specification for Physical Characteristics of Non-Concentrator Terrestrial Photovoltaic Reference Cells.
- 35. E 1125–94: Test Method for Calibration of Primary Non-Concentrator Terrestrial Photovoltaic Reference Cells Using a Tabular Spectrum.
- 36. E 1143–94: Test Method for Determining the Linearity of a Photovoltaic Device Parameter with Respect to a Test Parameter.
- 37. E 1171–97: Test Method for Photovoltaic Modules in Cyclic Temperature and Humidity Environments.
- 38. E 1362–95: Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells.
- 39. E 1462–95: Test Methods for Insulation Integrity and Ground Path Continuity of Photovoltaic Modules.
- 40. E 1524–98: Test Methods for Saltwater Immersion and Corrosion Testing of Photovoltaic Modules.

These Standards may be procured from the Institute of Electrical and Electronic Engineers Standards Department, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855–1331, U.S.A. Telephone: (800) 678-IEEE or (732) 981–0060; E-mail: customer.service@ieee.org.

• These standards may be obtained from ASTM, 1916 Race Street, Philadelphia, PA 19103–1187, U.S.A. Telephone: (215) 299–5400; fax: (215) 977–9679.



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- 41. E 1596–94: Test Methods for Solar Radiation Weathering of Photovoltaic Modules.
- E 1597–94: Test Method for Saltwater Pressure Immersion and Temperature Testing of Photovoltaic Modules for Marine Environments.
- 43. E 1799–96: Practice for Visual Inspections of Photovoltaic Modules.
- 44. E 1802–96: Test Methods for Wet Insulation Integrity Testing of Photovoltaic Modules.
- 45. E 1830M-96: Test Methods for Determining Mechanical Integrity of Photovoltaic Modules.
- 46. E-44 203 R5: Test Method for Photovoltaic Array Wet Insulation Resistance, Main Committee Ballot. July 1999.
- E-44 131 R1: Test methods for Electrical Performance of Concentrator Terrestrial Photovoltaic Module and Arrays under Natural Sunlight. Under revision.
- 48. E-44 200 R9: Test Methods for Electrical Performance and Spectral Response of Multijunction Photovoltaic Cells and Modules. Under revision.
- 49. E 927: Specification for Solar simulation for Terrestrial Photovoltaic Testing. Under revision.
- 50. E 1021: Test Methods for Measuring Spectral Response of Photovoltaic Cells, under revision.

#### Underwriters Laboratories Standards

51. UL 1703: Standard for Safety of Flat-Plate Photovoltaic Modules and Panels, August 1986.

# 4.2 Photovoltaic Batteries

As for the PV modules, two levels of testing are applicable to PV batteries. A start-up laboratory, getting involved with the initial stages of PV testing, may decide to implement limited test protocol for PV batteries to verify the specifications, described by the PV system owner, procuring agency, funding source, module or battery manufacturer, or specific project requirements. The laboratories of national stature, however, are encouraged to follow globally accepted IEC standards and PV GAP–recommended standards.

# 4.2.1 Tests for Verification of Battery Specifications

This subsection describes the test procedure for batteries used at the Florida Solar Energy Center.

Initial cycle tests and other measurements are conducted on all batteries to quantify their capacity and other parameters related to determining the performance, physical characteristics, and cycle life of the battery. The batteries are put in a temperature-regulated water bath designed to maintain the temperature of the batteries at 25°C during the tests. Charge and dis-

This UL standard is available from Global Engineering Documentation, 7730 Carondelet Avenue, Suite 401, Clayton, MO 63105, U.S.A. Telephone: (800) 854–7179. charge cycles are conducted on the batteries at the prescribed rates and regulation voltages for the intended system application to determine each battery's usable capacity and system autonomy rating for the battery storage system.



Each test includes the measurement of voltage, current, and battery temperature. The data are usually measured at 15-second intervals and recorded at user-defined intervals (usually 6-minute periods). In addition, the minimum and maximum values of selected voltage channels are recorded on the same interval.

*Initial cycle procedure.* Each battery is subjected to a cycle test sequence designed to obtain information on battery performance under varying charge and discharge conditions. Details of the charge and discharge conditions for each battery and each cycle are based on battery type, capacity, charge-discharge rate and desired array to load conditions.

At the beginning of the cycle test sequence, each battery is given an initial charge with identical charging conditions used for each battery of the same type (flooded or valve-regulated). The purpose of the initial charge is to fully recharge the batteries prior to the cycle tests, as well as to quantify their initial state of charge. This is called a boost charge.

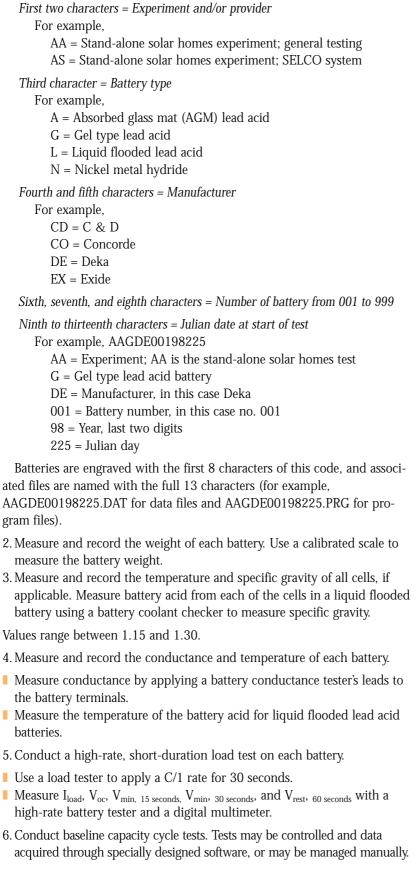
The charging is conducted with independent power supplies connected to each battery, using a current-limited to constant-voltage charging method with a 12-hour float period at the regulation voltage. The current-limited charge rate is generally set at a C/35 charge and discharge rate. The regulation voltages are consistent for each battery of the same type, and selected based on best estimates and discussion with manufacturer's representatives when applicable. In most cases, the regulation voltages are 14.1 V (2.35 V per cell) for the valve-regulated batteries, and 14.4 V (2.40 V per cell) for the flooded battery types.

After the initial boost charge, two or three additional discharge-charge cycles are conducted to determine baseline capacities and consistency among batteries of the same type. The discharges are performed using a resistive load usually set to a nominal C/35 discharge rate. All discharges are automatically terminated when the battery terminal voltage drops to 10.5 V (1.75 V per cell). The charge cycles following the first three discharges are conducted with independent power supplies, generally at a nominal C/35 rate constant current to a predefined regulation voltage.

After the initial discharge-charge cycles, a number of additional cycles are conducted on each battery to examine the effects of varying charge-discharge rate and charge regulation voltage on battery performance. For the discharges, the termination voltage is 10.5 V (1.75 volts per cell), regardless of the rate.

Upon receipt, each battery will undergo the following seven-step procedure:

1. Identify and label each battery. Upon arrival, condition each battery according to the manufacturer's instructions, if applicable. Mark each battery with a code that consists of eight characters, plus a five-digit date, as follows:



- Boost charge at C/35 rate to V<sub>Regulation, 12-hour float.</sub> Record total Ah and Ah to regulation.
- Pause testing for 4 hours.
- Discharge (C/35 rate to 1.75 volts per cell). Record total Ah and Ah to low-voltage disconnect (LVD = 11.4V).
- Pause testing for 4 hours.
- Recharge at C/35 rate to V<sub>Regulation</sub>, 12-hour float. Record total Ah and Ah to regulation, and compute overcharge.
- 7. Repeat at same discharge and recharge conditions.

Laboratory test conditions and the difference from operation of actual PV systems. The test conditions developed for this evaluation were chosen to exemplify operating parameters of typical PV systems using batteries. While actual PV system charging and discharge conditions are not simulated for these tests, the chosen conditions represent some of the norms and extremes of the actual operating conditions of PV systems.

The range of charge and discharge rates used for the tests are also typical of those common in small stand-alone PV systems. Charge rates in fielded PV systems are generally higher than discharge rates, and there may be considerable variation in the magnitude and duration of the charge, as well as in the average daily depth of discharge. The 12-hour float period was selected based on battery manufacturer recommendations (where available) and is conservatively longer than actual regulation periods found in operating PV systems. This ensures complete battery recharging and accurate capacity measurements.

The selection of charge regulation voltages used in the tests is based on consideration of manufacturers' data, when available, and typical values used by PV system designers and charge controller manufacturers. Often, the battery manufacturers recommend regulation or *float* voltages much lower than required to fully recharge the battery in a limited period. The general practice of PV system designers has been to use a higher regulation voltage to allow more power to be applied to the battery during and after charge regulation. However, using a higher regulation set point for some batteries while increasing the overcharge percentage does not significantly improve performance and may contribute to detrimental overcharging and premature battery failure. In some cases, the use of a higher regulation voltage has a notable effect on increasing capacity and charge acceptance.

The 100 percent depth of discharge used in the cycle tests is selected to exercise all batteries to the limits of their performance, and to provide data for comparison with manufacturers' ratings. Although a complete 100 percent discharge is not typical in fielded PV systems, many systems use controllers that allow a maximum depth of discharge up to 90 percent. In most cases, the average daily depth of discharge in PV systems is between 10 percent and 30 percent. Under these circumstances, the battery recharge efficiency would be lower than in these tests, because of the inefficiencies in charging a battery from 90 percent to 100 percent state of charge.



# 4.2.2 PV Battery Standards

International PV battery standards are grossly lacking at present. No published IEC or PV GAP standard is currently available, and only one IEC battery standard is a work in progress, which is listed below. However, six well-written, technically proficient, and high-quality IEEE standards exist for PV batteries, which are also listed below. The testing laboratories are encouraged to adopt these IEEE or their own national standards in the interim for PV batteries, until standards recommended by the IEC and PV GAP are established.

## IEC PV Battery Standards

1. TC82–1 Ed. 1.0: Photovoltaic Electricity Storage Systems, Proposed Work Item (PWI).

## Institute of Electrical and Electronics Engineers PV Battery Standards

- 2. IEEE 937–1987: Recommended Practice for Installation and Maintenance of Lead Acid Batteries for Photovoltaic (PV) Systems. March 1987.
- 3. IEEE 1145–1990: Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic (PV) Systems. November 1990.
- 4. IEEE 1013–1990: Recommended Practice for Sizing of Lead-Acid Batteries for Photovoltaic (PV) Systems. December 1990.
- 5. IEEE 1144–1996: Recommended Practice for Sizing of Industrial Nickel-Cadmium Batteries for Photovoltaic (PV) Systems. 1996.
- 6. IEEE 1361: Guide for the Selection, Test and Evaluation of Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems. Draft, July 1999.

# 4.3 Photovoltaic Charge Controllers

This section describes the test procedures for PV charge controllers used for stand-alone PV systems. No international standards (IEC or PV GAP) exist. Also IEEE, ASTM, and NEC standards are currently unavailable. Only one UL standard addresses a test procedure for charge controllers; this standard is listed in this section.

# 4.3.1 Tests for Verification of Charge Controller Specifications

Since international and national standards for PV charge controllers are virtually nonexistent, this subsection describes the details of the test procedure to verify specifications of charge controllers used for stand-alone PV systems. These specifications were developed for the project assisted by the World Bank–Global Environment Facility involving procurement of solar home systems. These test procedures are applicable to the charge controllers for small PV systems, that is, 1 kWp or smaller in size.



**Table 4.2** lists the items for testing PV charge controllers. Following is a description of the test methods:

1. Appearance and documentation

a. Appearance

*Technical requirements*: No physical damage (including damages from shipping and handling), carton damage, moisture penetration, or loose components.

*Test method:* Visually inspect the controller for any physical damage, including damage from shipping and handling. Also check the controller for carton damage, moisture penetration, and loose components.

b. Labels

Technical requirements: Clear labels with the following information:

- Manufacturer name and model.
- Serial number.
- Voltage and current ratings.
- PV array, battery and load connection points, and polarity.

*Test method:* Visually inspect the controller to verify that all the labels listed under technical requirements are included, also indicating the connection points and polarity of the PV array, battery and load.

## c. Documentation

Technical requirements: The following documents should be included:

- Technical requirements and ratings.
- Safety warnings.
- Installation instructions.
- Operating instructions.
- Troubleshooting instructions.
- Information on serviceable parts.
- Warranty.

*Test method:* Check whether all the documents listed under technical requirements are included with the charge controller.

# 2. Adjustment of set points

Technical requirements:

- (a) High-voltage disconnect and reconnect voltages and low-voltage disconnect and reconnect voltages should be preset at factory in accordance with battery characteristics.
- (b) Battery must be checked if it has different charging modes at different states of charge.
- (c) Average ambient temperature of the location of the battery's installation should be taken into account when choosing set points.
- Table 4.2 PV Charge Controller Test Items No. Test item Appearance and documentation Appearance 1 Label Documentation 2 Adjustment of set points 3a Array high-voltage disconnect (HVD) and reconnect: on-off controller Array high-voltage disconnect (HVD) and reconnect: 3b PWM controller 4 Load low-voltage disconnect (LVD) and reconnect 5 Temperature compensation (optional test) 6 No-load consumption (quiescent current) 7 Voltage drop 8 Vibration durability 9 Protection (a) Protection against load, and any internal short circuit (b) Protection to avoid reverse discharge from battery to PV array at niaht (c) Battery reverse polarity protection (d) Lightning and surge protection 10 Overvoltage protection
  - 11 Overcurrent protection



Test method:

- (a) Measure the voltage set points with a voltmeter to see whether they have been preset to correct values.
- (b) Check to see whether the charge controller has different charging modes.
- (c) Check whether the charge controller has the temperature compensation option.
- 3. Array high-voltage disconnect (HVD) and reconnect

a. ON-OFF controller

*Technical requirements:* Charge controller should have the capability to prevent battery overcharge (HVD) and reconnect when the battery is partially discharged. The recommended HVD and reconnect voltages for ON-OFF type charge controllers are as follows:

Flooded lead-antimony battery:

HVD: 14.6–14.8V; reconnect: >13.7V Flooded lead-calcium battery:

HVD: 14.4–15.5V; reconnect: 13.6–14.5V

Sealed valve-regulated lead-acid battery:

HVD: 14.2-14.4V; reconnect: >13.6V

*Test method:* Using the test set-up as shown in **figure 4.2**, adjust the voltage of the DC power supply to the battery nominal voltage (V-2), and increase it gradually. The HVD value is obtained on the DC power supply when the charge controller switches off the connection between the PV input and battery input (or short-circuits the PV array for a shunt-type controller). Lower the voltage of the DC power supply, and the reconnect voltage will be determined when the controller causes the PV input to be reconnected to the battery.

b. PWM controller

*Technical requirements:* For a pulse width modulated (PWM) type charge controller, there is no specific reconnect voltage. The recommended HVD voltages for PWM charge controllers are as follows:

Flooded lead-antimony battery:

14.4–14.8V Flooded lead-calcium battery: 14.0–14.4V Sealed valve-regulated lead-acid (VRLA) gel battery: 14.0–14.2V

Sealed valve-regulated lead-acid (VRLA) AGM battery: 14.1–14.4V

*Test method:* Replace the variable resistor in the set-up of **figure 4.3** with a bipolar power supply to simulate the battery, and adjust its output to the nominal charge controller voltage. Operate the DC power supply in a current source mode, and adjust its output current to the rated value of the charge controller. Gradually increase the voltage of the bipolar power supply. When it almost reaches HVD, the charging current indicated by the ammeter A will start to decrease. The HVD value is obtained when the charging current indicated by the ammeter A drops to zero. Vary the current output of the DC power supply, and repeat the entire procedure



# Note:

The set point values are for 12-volt nominal battery. Batteries with other nominal voltages will have set point values in same ratio. with charging currents ranging from 10 percent to 125 percent of the rated current. For all charging currents, the HVD should be in the range described in the technical requirements.



If a bipolar power supply or a battery simulator is not available, this test can be done by using a real battery as shown in **figure 4.4**. Adjust the output current of the DC power supply to the rated value. (The power supply should be operating in a current source mode.) The battery voltage will increase because of charging by the current source and when it almost reaches the HVD point, the charging current will start to decrease. The HVD value is obtained when the charging current indicated by the ammeter A drops to zero. Vary the output current of the power supply, and repeat this test with charging currents ranging from 10 percent to 125 percent of the nominal charging currents. For all charging currents, the HVD values should be in the range specified in the technical requirements.

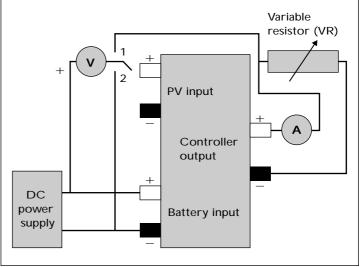
4. Load low-voltage disconnect (LVD) and reconnect

Technical requirements: When battery voltage drops during discharging to the LVD point (1.8–1.9V per cell for lead acid battery) at the rated load current, the load should be disconnected from the battery. When the battery voltage increases during charging to the load reconnect value, the load should be reconnected automatically.

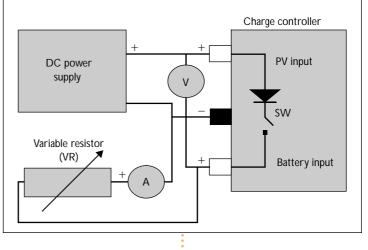
*Test method:* Using the test set-up as shown in figure 4.2, first adjust the DC power supply output voltage at the nominal voltage of the battery V2.

Adjust the output current of the charge controller to the rated value with the variable resistor (VR). Then, decrease the voltage of the DC power supply gradually till the controller switches off the load connection automatically by indicating zero current through the ammeter A, and the LVD value is obtained. Increase the voltage of the DC power supply until the battery is connected to the load again as indicated by the current through the ammeter A, and the load reconnect voltage is determined. Vary the variable load resistor and repeat this test for different load currents ranging from 10 percent to 125 percent of the rated load current.

# Figure 4.2 Test for HVD (ON–OFF controller) and LVD, and Test for Voltage Drop When Discharging



#### Figure 4.3 Test for Voltage Drop When Charging and Tests for Overvoltage and Overcurrent Protection



Quality Improvement of Photovoltaic Testing Laboratories in Developing Countries

For all load currents, the LVD values should be in the range specified in the technical requirements.



5. Temperature compensation (optional test)

*Technical requirements:* If battery temperature compensation option is specified with the charge controller, it should be verified for its effect on

the set points. The temperature coefficient value should be in the range of -3 to -7 mV/°C /cell.

*Test method:* For this test, the temperature sensor can be placed in a controllable temperature chamber and the procedure described under item 3 and item 4 should be repeated. From the measurements at various chamber temperatures, a plot of HVD versus temperature can be obtained. The temperature coefficient value should be in the range of -3 to -7 mV/°C /cell.

6. Quiescent current

*Technical requirements:* The charge controller's self-consumption current should not exceed 1 percent of the rated charge current.

*Test method:* Using the test set-up as shown in **figure 4.5**, measure the current drawn by the charge controller, while both the PV input and load output are disconnected.

7. Voltage drop

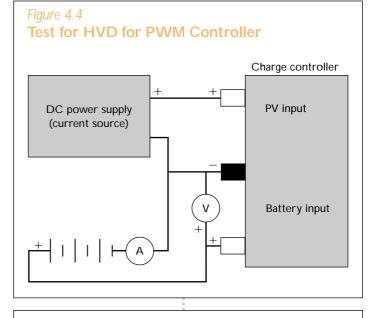
*Technical requirements:* The voltage drop between the PV array and battery during charging, and the voltage drop between the battery and load during discharging, should each be within 5 percent of the nominal voltage of the charge controller.

## Test method:

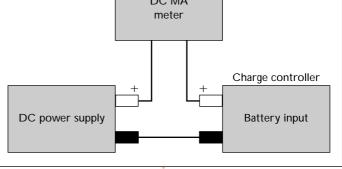
- (a) Using the test set-up as shown in figure 4.3, adjust the charging current to its maximum rated value, and measure the voltage drop V between the DC power supply and battery terminals.
- (b) Using the test set-up as shown in figure 4.2, adjust the discharge current to its maximum rated value, and measure the voltage drop V-1 under discharge condition between the battery input and controller output terminals. If the switching component is in negative circuit, the voltage drop should also be measured between the negative terminals.

• Temperature compensation and lightning protection are optional for temperate climates and low lightning areas, respectively.

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# Figure 4.5 Test for Quiescent Current (self consumption)



#### 8. Vibration durability

*Technical requirements:* No damage is caused to the charge controller by the vibrations, which are tested in the range of 10–55 Hz, 0.35mm, 3-axis directions for 30 minutes.

*Test method:* Set the charge controller to vibrations of 10–55 Hz, 0.35mm, at 3-axis directions for 30 minutes. Then, check the charge controller to verify that no mechanical damage or other malfunction has occurred.

9. Protections functions

#### a. Short circuit protection

*Technical requirements:* The charge controller must avoid any damage to itself and connected equipment in the case of an accidental short circuit at its load terminals or an internal short circuit.

*Test method:* Using the test set-up as shown in figure 4.2, remove the ammeter A and short the charge controller output terminals by reducing the variable resistor VR to zero, or remove the variable resistor and short the output terminals, then verify that no damage to the charge controller or power supply occurs.

b. Reverse discharge protection

*Technical requirements:* The charge controller must avoid any reverse discharge from battery to PV array at night.

*Test method:* Using the test set-up as shown in **figure 4.6**, start with the maximum value of the variable resistor and the DC power supply adjusted to nominal battery input voltage. Then, gradually reduce the variable resistor to zero, and verify that there is no reverse current flow indicated by the ammeter A.

c. Battery reverse polarity protection

*Technical requirements:* The charge controller should have protection against connecting the battery in reverse polarity.

*Test method:* Connect the charge

controller battery input terminals to DC power supply in reverse polarity for one hour, and verify that the controller or the power source is not damaged.

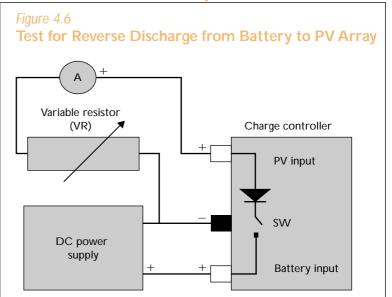
#### d. Lightning protection

*Technical requirements:* The charge controller should have protection to avoid damage from lightning. This protection is needed only in areas with excessive lightning. <sup>(6)</sup>

• Temperature compensation and lightning protection are optional for temperate climates and low lightning areas, respectively.

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*Test method:* Visually check the type and ratings of the surge arrestors to ensure that they are capable of absorbing the expected surge energy from lightning at the location.



10. Overvoltage protection

*Technical requirements:* The charge controller should withstand overvoltage up to 1.25 times the nominal open circuit voltage of PV array for a duration of at least one hour.

*Test method:* Using the test set-up as shown in figure 4.3, adjust the voltage of the DC power supply to 1.25 times the nominal PV array open circuit voltage. Also adjust the variable resistor VR to obtain the rated charge current. Continue the operation in this mode for one hour, and verify that no damage has occurred to the charge controller.

11. Overcurrent protection

*Technical requirements:* The charge controller should withstand overcurrent up to 1.25 times the maximum rated charge current for at least one hour.

*Test method:* Using the test set-up as shown in figure 4.3, adjust the voltage of the DC power supply to the nominal PV array operating voltage. Also adjust the variable resistor VR to obtain 1.25 times the maximum rated charge current. Continue the operation in this mode for one hour, and verify that no damage has occurred to the charge controller and no excessive heat is generated.

# 4.3.2 PV Charge Controller Standards

Currently there are no internationally approved charge controller standards, either by IEC or recommended by PV GAP. Working Group 6 (WG6) of IEC Technical Committee 82 (TC 82) is drafting IEC standards for PV stand-alone charge controllers, as listed below. A well-written, technically proficient, and sufficiently detailed charge controller standard has been drafted and approved by the UL of the United States. This standard, UL 1741, primarily specifies the test procedure for safety of charge controllers and inverters, and is also listed below.

## IEC Charge Controller Standards (Work in Progress)

IEC 62109, Ed 1.0: Electric Safety of Static Inverters and Charge Controllers for Use in Photovoltaic (PV) Power Systems. Draft.

## Underwriters Laboratories (UL) Charge Controller Standard

UL 1741: 1999, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems; Underwriters Laboratories; Northbrook, Illinois; May 1999.

# Chapter 5 Test Procedures for Photovoltaic Inverters, DC Fluorescent Lights, and PV **Systems**

n this chapter, the test procedures for PV balance of system (BOS) components and PV systems are continued from the previous chapter. Specifically, this chapter describes the test procedures for PV inverters, DC fluorescent lights, and PV systems.

# 5.1 Photovoltaic Inverters

Like charge controllers, international standards (IEC and PV GAP) currently do not exist for inverters. Also IEEE, ASTM, and NEC standards are currently not available.

# 5.1.1 Tests for Verification of Stand-Alone **Inverter Specifications**

Since international and national standards for PV inverters are not yet established, this subsection describes the test procedure for verification of specifications of inverters used for stand-alone PV systems. These specifications were also developed for the project assisted by the World Bank–Global Environment Facility involving procurement of Solar Home Systems, and are applicable to inverters for small PV systems, that is, 1 kWp or less. The items for testing PV inverters are listed in table 5.1, followed by description of the test method for each item.

## 1. Appearance and documentation

#### a. Appearance

Technical requirements: No physical damage (including damage from shipping and handling), carton damage, moisture penetration, and loose components.

Test method: Visually inspect the inverter for any physical damage, including damage from shipping and handling. Also check the inverter for carton damage, moisture penetration, and loose components.

#### b. Labels

Technical requirements: Clear labels with the following information:

- Manufacturer name and model.
- Serial number.
- Input and output voltage and current ratings.
- Battery and load connection points and polarity.





Test method: Visually check inverter to verify that all the labels listed
under technical requirements are included, and that they indicate the
connection points and polarity of the battery and load.

c. Documentation

*Technical requirements:* The following documentation should be included: 1. Technical specifications and ratings, 2. Safety warnings, 3. Installation instructions, 4. Operating instructions, 5. Troubleshooting instructions, 6. Information on serviceable parts, and 7. Warranty.

*Test method:* Check to be sure all documents listed under technical requirements are included with the inverter.

## 2. Efficiency versus power level

*Technical requirements:* Inverter efficiency should be higher than 80 percent, when the output power level is above 75 percent of the rated power level.

*Test method:* Using the test set-up with a variable resistive load as shown in figure 5.1, measure the inverter efficiency as

 $\eta = \frac{AC \text{ Power Output}}{DC \text{ Power Input}} = \frac{Wac}{Vdc.Idc}$ 

Increase the AC power output from 10 percent to 100 percent of the rated power to obtain the plot of inverter efficiency versus output power. The inverter efficiency should be higher than 80 percent for all output power levels above 75 percent of the nominal power.

# 3. Load (output power) capability

#### Technical requirements:

The inverter can operate safely at an ambient temperature of 25°C for at least (a) four hours at full rated output power, (b) one minute at 125 percent of the rated output power, and (c) two seconds at 150 percent of the rated output power (to simulate high-surge currents because of starting of motors).

*Test method:* Using the test set-up as shown in figure 5.1 at 25°C ambient temperature, adjust the load to provide full rated output power and

Table	e 5.1		•	
Sta	nd-Alone P	V Inverter Test Ite	ems	
No.	Test item			
1	Appearance	and documentation	Appearance	
			Label	
			Documentation	
2	Efficiency vs.	power level		
3	Load (output	t power) capability		
4	Input voltage	e range and frequency	verification	
5	Voltage harm	nonics		
6	Noise			
7	Quiescent cu	urrent		
8	Vibration du	rability		
9	Protection	(a) Low-voltage pro	tection	
	functions	(b) Output overcuri	rent protection	
		(c) Short circuit pro	otection	
		(d) Reverse polarity	protection	
		(e) Lightning protec	tion	

maintain this power level for four hours. The inverter should operate safely and not reach temperatures high enough to result in fire, to damage any materials used, or to activate the operation of any protective device. Repeat this test at 125 percent of the rated output power for one minute, and then at 150 percent of the rated output power for two seconds. Verify the inverter's safe operation under both of these conditions as done previously (at rated power for four hours).



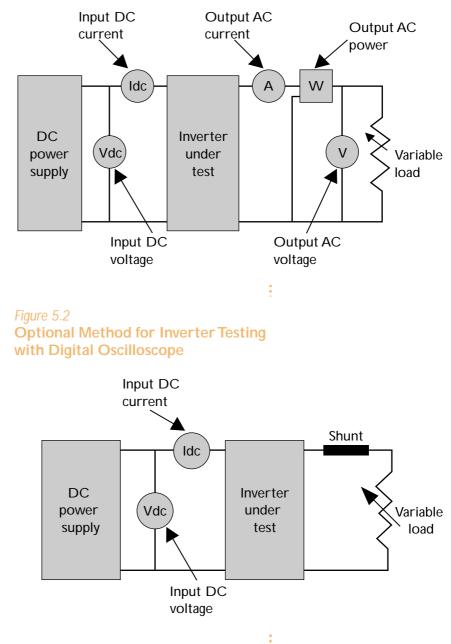
## 4. Input voltage range and frequency verification

Technical requirements:

- (a) The inverter should operate normally when the input DC voltage is in the range of 90–120 percent of the nominal input voltage. During the normal operation of the inverter, its AC output voltage must remain in the range of 220 volts ± 10%.
- (b) Inverter output operating frequency should be in the range of 50 Hz  $\pm$  5%.

Test method: Using the test set-up as shown in figure 5.1, keep the output power constant at half rated power and vary the input DC voltage from 90 percent to 120 percent of the nominal input voltage, while also measuring the inverter output frequency with an oscilloscope or a meter placed across the shunt (figure 5.2). Repeat this test at different output power levels ranging from 10 percent to 100 percent of the rated power. For all power levels, the inverter should meet the technical requirements, as described for items 4 and 5.

# Figure 5.1 Inverter Testing



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#### 5. Voltage harmonics

*Technical requirements:* For a sine-wave inverter, the maximum total harmonic distortion in the output voltage should not exceed 5 percent of the fundamental component at the full rated output power of the inverter.

*Test method:* This test should be conducted only for sine-wave inverters. Using a harmonic analyzer, measure the total harmonic distortion in the output voltage at different power levels. At any power level it should not exceed 5 percent of the fundamental component at the full rated power.

#### 6. Noise

*Technical requirements:* Audio noise produced by the inverter should be less than 65 dB at a distance of 3 meters, when the inverter is operating.

*Test method:* Measure the inverter noise at a distance of 3 meters from the inverter at half and full rated power, and verify that it is below 65 dB.

## 7. Quiescent current

*Technical requirements:* Inverter self-consumption current should not exceed 3 percent of the rated input current.

*Test method:* Using the test set-up as shown in figure 5.1 and, with the load disconnected, measure the DC input current drawn by the inverter at different DC input voltages from 90 percent to 120 percent of the nominal input voltage. Verify that the current drawn at no load is within 3 percent of rated input current for all conditions.

#### 8. Vibration durability

*Technical requirements:* No damage is caused to the inverter by the vibrations, tested in the range of 10–55 Hz, 0.35 mm, 3-axis direction for 30 minutes.

*Test method:* Subject the inverter to vibrations as stated in the technical requirements. Check the inverter to verify that no mechanical damage or malfunction has occurred.

#### 9. Protection functions

a. Low-voltage protection

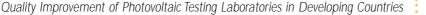
*Technical requirements:* Inverter should shut down automatically to protect the battery when the input voltage is lower than 90 percent of the rated value (1.8 volts per battery cell).

*Test method:* Start with the DC power supply voltage at the inverter nominal input voltage, and gradually decrease the power supply voltage. Check whether the inverter shuts down automatically when its input voltage falls below 90 percent of the rated value.

b. Output overcurrent protection

*Technical requirements:* Inverter should shut down automatically if the output power exceeds 150 percent of the rated power.

Test method: Using the test set-up as shown in figure 5.1, adjust the load





to provide the full rated AC power. Then increase the load gradually, and verify that the inverter stops operating as the load increases above 150 percent of the rated power.



c. Short circuit protection

*Technical requirements:* If the inverter output is shorted, a circuit breaker in the inverter output circuit should trip or a fuse should blow to protect the inverter from any damage.

*Test method:* Using the test set-up as shown in figure 5.1, short the inverter AC output by reducing the variable load resistance to zero, or remove the load and short the inverter output terminals. The circuit breaker should trip or the fuse should blow, but no damage to the inverter or other hazard should occur.

d. Reverse polarity protection

*Technical requirements:* If the polarity of the inverter DC input connections is reversed, the inverter should not get damaged.

*Test method:* With the DC power supply voltage output adjusted to its minimum, connect the output terminals of the power supply in reverse polarity to the inverter DC input. Then, increase the power supply voltage gradually to the nominal input voltage of the inverter, and maintain this voltage for at least one hour. Verify that no damage to the inverter or power supply occurs.

e. Lighting protection

*Technical requirements:* The inverter should have protection to avoid damage from lightning (required only in the area of excessive lightning).

*Test method:* Visually check the type and rating of the surge arrestors to ensure that they are capable of absorbing expected surge energy from lightning at the location of the inverter.

# 5.1.2 PV Inverter Standards

At present there are no internationally approved PV inverter standards, either by IEC or recommended by PV GAP. Working Group 6 (WG6) of IEC Technical Committee 82 (TC 82) is drafting IEC standards for PV inverters as listed below. A well-written, technically proficient, and sufficiently detailed PV inverter charge controller standard has been drafted and approved by the UL of the United States. This standard, UL 1741, primarily specifies the test procedure for safety of charge controllers and inverters, and is also listed below.

# IEC Inverter Standards (Work in Progress)

- 1. IEC 62109, Ed 1.0: Electric Safety of Static Inverters and Charge Controllers for Use in Photovoltaic (PV) Power Systems. Draft.
- 2. IEC 62116, Ed 1.0: Testing Procedures—Islanding Prevention Measures for Power Conditioners Used in Grid Connected Photovoltaic (PV) Power Generating Systems. Draft.

Lightning protection is optional for low lightning areas.

#### Underwriters Laboratories (UL) Inverter Standard

UL 1741: 1999, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems. Underwriters Laboratories; Northbrook, Illinois; May 1999.

# 5.2 DC Fluorescent Lights

The international standards (IEC and PV GAP) for PV-powered DC fluorescent lights do not exist at present. Also IEEE, ASTM, and NEC standards are currently not available.

This subsection describes the test procedure for verification of specifications of DC fluorescent lights used for stand-alone PV systems. These specifications were also developed for the project assisted by the World Bank–Global Environment Facility involving procurement of solar home systems, and they are applicable to DC-powered fluorescent lights for stand-alone PV systems.

The test items for DC fluorescent lights are listed in **table 5.2**, followed by the test procedures.

#### 1. Appearance and labels

#### a. Appearance

*Technical requirements:* No physical damage (including damage from shipping and handling), carton damage, moisture penetration, and loose components.

*Test method:* Visually inspect the fluorescent light for any physical damage, including damage from shipping and handling. Also check the carton for damage, moisture penetration, and loose components.

#### b. Labels

Technical requirements: Clear labels with the following information:

- Manufacturer name and model number.
- Serial number.
- Voltage and wattage ratings.
- Polarity.
- Date of manufacture and batch number.

*Test method:* Visually inspect the light to verify that all the labels listed under the technical requirements are included, and that they indicate the connection points and polarity. Verify that the labels cannot be removed after being polished by a wet cloth for 15 seconds.

#### **DC Fluorescent Lights Test Items** No. Test item Appearance and labels Appearance 1 Labels Documentation 2 Lamp socket and holder 3 Luminous efficiency 4 Lamp operating voltage 5 Minimum operating frequency 6 Electrical waveform and crest factor 7 Protection functions and quiescent current 8 Vibration durability 9 Lamp lifetime 10 Insulation resistance 11 Fire and pressure resistance



## 2. Lamp socket and holder

*Technical requirements:* The socket of the lighting fixture should meet the requirements of the international standard, "Technical Requirements of Lamp Holders for Tubular Fluorescent Lamps and Starter-Holders." The lamp socket electrical parts should not be exposed during normal operation (that is, hands and fingers should not be able to come in contact with electrical parts of the lamp socket). The size of the socket and holder should meet the requirements of IEC 61 standard.

*Test method:* Measure the size of the socket and holder with a ruler or other measuring instrument, and verify that they meet the requirements of the standard in IEC 61.

## 3. Luminous efficiency

Technical requirements:

- (a) After 100 hours of conditioning, the luminous efficiency of the fluorescent light should not be less than 35 lumens per watt (L/W) without lamp cover and reflectors at the nominal input voltage of the fluorescent light and an ambient temperature of 25°C.
- (b) The luminous efficiency of the fluorescent light should not be less than 80 percent of its rated value throughout the voltage range of 90–120 percent of the nominal voltage.

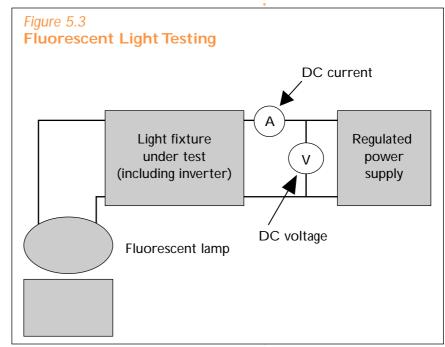
#### Test method:

(a) Using the test set-up as shown in **figure 5.3**, operate the fluorescent light for 100 hours for normal usage conditioning. Then, with the lamp cover and reflector removed, measure its luminance and the input power required at the nominal voltage and at an ambient temperature of 25°C, and determine its luminous efficiency as follows:

Efficiency = Luminance/Vdc.Idc

The efficiency should be 35 L/W or greater.

 (b) Vary the input voltage of the fluorescent light from 80 percent to 130 percent of the nominal voltage, and verify that the luminous efficiency is 80 percent or greater than its rated value for all voltages in the range of 90–120 percent of the nominal voltage.





#### 4. Lamp operating voltage



*Technical requirements:* Minimum operating voltage when the lamp starts should be at least 90 percent of the nominal voltage, and the lamp should be capable of continuous operation between 90 percent and 120 percent of the nominal voltage.

*Test method:* In the previous test for luminous efficiency, also check that the minimum striking voltage at which the lamp will turn on is less than or equal to 90 percent of the nominal voltage, and verify that the maximum voltage for at least four hours of continuous operation without damage to the lamp or fixture is at least 120 percent of the nominal voltage.

#### 5. Minimum operating frequency

*Technical requirements:* The minimum operating frequency of the fluorescent lamp should be 20 kHz.

*Test method:* Measure the operating frequency at the lamp terminals with an oscilloscope for input voltage to the fixture ranging from 90 percent to 120 percent of its nominal voltage. The frequency should be greater than 20 kHz for all voltage conditions.

## 6. Electrical waveform and crest factor

Technical requirements:

- (a) Electrical waveform at the lamp terminals must be symmetrical in time to within 10 percent.
- (b) The maximum crest factor (ratio of peak to root mean square voltage at the lamp terminals) should be no more than 2.0.

*Test method:* In the previous test for operating frequency, also record the electrical waveform at the lamp terminals with the oscilloscope, and verify that the waveform is symmetrical within 10 percent and that the crest factor is below 2.0 over the lighting fixture input voltage range of 90–120 percent of the nominal voltage.

## 7. Protection functions and quiescent current

#### a. Lamp open circuit protection

*Technical requirements:* The lighting fixture should be protected against damage when operating under open circuit conditions (for example, when the lamp is removed or has failed).

*Test method:* Remove the lamp from the socket, and apply the nominal voltage to the fixture. Check the operation for at least four hours to ensure that no damage to the fixture or lamp occurs and that no excessive heat is generated.

#### b. Quiescent current

*Technical requirements:* The current drawn by the fluorescent light when operating with a failed or removed lamp should be limited to less than 20 percent of the nominal current consumption of the light.

*Test method:* Measure the current drawn by the fluorescent light with the lamp removed. It should be less than 20 percent of the nominal current consumption. If possible, repeat this test with a failed lamp in the socket.

The current drawn should be limited to 20 percent of the nominal current consumption. After the test, the lighting fixture should operate normally.



c. Reverse polarity protection

*Technical requirements:* The lighting fixture and lamp should be protected against reverse polarity, or the fluorescent light as a whole should be protected from damage if reverse polarity is applied.

*Test method:* Using the test set-up as shown in the figure, adjust the regulated power supply to the nominal voltage of the fluorescent light. Connect the lighting fixture terminals to the power supply in reverse polarity for one hour, and verify that no damage occurs to the lamp, lighting fixture, or power supply.

## 8. Vibration durability

*Technical requirements:* No damage is caused to the fixture or the lamp by the vibrations, tested in the range of 10–55 Hz, 0.35mm, 3-axis directions for 30 minutes.

*Test method:* Put the fluorescent light to vibrations of 10–55 Hz, 0.35 mm, at 3-axis directions for 30 minutes. Then check that no mechanical damage or malfunction has occurred to the fixture or the lamp.

## 9. Lamp lifetime

*Technical requirements:* Fluorescent lights must provide a minimum lamp lifetime of 1,000 hours. The switching lifetime (ON-OFF cycles) of the lamp must be at least 1,000 cycles.

*Test method:* Operate the fluorescent light with a DC power supply for 1,000 hours, during which the power supply voltage should be automatically varied between 90 percent and 120 percent of the nominal voltage of the light. During each hour, the lamp should be automatically turned off for a brief period (one minute or less) to simulate ON-OFF cycling of the lamp. No failure of the lamp should occur during 1,000 hours of operation.

## 10. Insulation resistance

*Technical requirements:* For the fluorescent lamps with metal covers, the insulation resistance between the cover and the lamp terminals should meet IEC 598–1 requirements.

*Test method:* For the fluorescent lamps with metal casings, measure the insulation resistance between the metal casing and the lamp terminals at about 1,000 volts with a high-pot tester. The insulation resistance value should comply with the standard in IEC 598–1.

# 11. Fire and pressure resistance

## a. Fire test

*Technical requirements:* Insulation materials should comply with heat and fire resistance requirements. After the fire test, the self-burning time of

the insulation material should not exceed 30 seconds. Any flame should burn out within 30 seconds after the fire source is removed. A thin paper under the insulation material should not burn by fallen burning debris from the insulation material.



*Test method:* Put fire for 10 seconds at the place where the highest temperature is most likely to occur in the insulation material during operation, and verify that the flame on the insulation material burns out within 30 seconds after the removal of the fire source. Also, check that a thin paper under the insulation material does not burn from the fallen debris of the insulation material. (For the insulation material of the lights, use a 650° heated fiber to test its fire and heat resistance.)

b. Ball pressing test

*Technical requirements:* After ball pressing test, the mark should be less than 2 mm.

*Test method:* Press the insulation material with a steel ball (5 mm in diameter) with 20 N pressure. Check the press mark one hour after the test, and verify that the mark is smaller than 2 mm.

# 5.3 Photovoltaic Systems

It is recommended that the laboratories planning to conduct testing of PV systems to meet the needs of a fast-growing domestic market or broadbased government and international programs adopt international standards, including IEC standards and PV GAP recommended standards. The existing IEC standards are listed here, and a hard copy of each of the published IEC PV standard is included in Appendix 4 of this manual. PV GAP-recommended standard PV RS-1 is also listed below and included in appendix 3.

The U.S. PV system test standards are drafted by the Standards Coordinating Committee 21 for Photovoltaics (SCC 21) of IEEE and approved by the IEEE Standards Board. These standards are also very rigorous and comparable to IEC standards in their quality, effectiveness, and detail. They are listed here for consideration of being adopted by the testing laboratory, especially when the international standards on the particular test subject are not yet available.

## IEC Systems Standards

- 1. IEC 61173: 1992 Over Voltage Protection for Photovoltaic (PV) Power Generating Systems.
- 2. IEC 61194: 1993 Characteristic Parameters of Stand-Alone Photovoltaic (PV) Systems.
- 3. IEC 61277: 1995 Guide: General Description of Photovoltaic PV) Power Generating Systems.
- 4. IEC 61702: 1995 Rating of Direct Coupled Photovoltaic (PV) Pumping Systems.
- 5. IEC 61724: 1998 Photovoltaic System Performance Monitoring— Guidelines for Measurements, Data Exchange and Analysis.
- 6. IEC 61725: 1997 Analytical Expression for Daily Solar Profiles.

7. IEC 61727: 1995 Photovoltaic (PV) Systems—Characteristics of the Utility Interface.



- 8. IEC 61829: 1995 Crystalline Silicon Photovoltaic (PV) Array—On-Site Measurement of I-V Characteristics.
- 9. IEC 61683: PV Systems—Power Conditioners—Procedures for Measuring Efficiency.
- 10. IEC 62124, Ed. 1.0: PV Stand-Alone Systems—Design Qualification and Type Approval, Draft.

#### PV GAP Systems Standards

PV RS-1: 1998 Photovoltaic Stand-Alone Systems—Design Qualifications and Type Approval.

#### Institute of Electrical and Electronics Engineers Systems Standards

- 1. IEEE 928: Recommended Criteria for Terrestrial PV Power Systems.
- 2. IEEE 1374: 1999 Guide for Terrestrial Photovoltaic (PV) Power System Safety.
- 3. IEEE 929-2000: Recommended Practice for Utility Interface of Photovoltaic (PV) Systems. April 2000.
- 4. IEEE PAR 1373: Recommended Practice for Field Test Methods and Procedures for Grid-Connected Photovoltaic (PV) Systems. Draft, August 1999.
- 5. IEEE PAR 1479: Recommended Practice for the Evaluation of Photovoltaic (PV) Module Energy Production. Draft, July 1999.
- 6. IEEE 1526: Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic (PV) Systems. Draft, 1999.

## NEC Systems Standards

(U.S.) National Electrical Code 1999 (NEC 99) Article 690. National Fire Protection Association; Quincy, Massachusetts; September 1998.

# Chapter 6 International Developments and Best Practices



hree bodies responsible for international standardization are the IEC, the ISO, and the International Telecommunications Union (ITU). These groups work closely together and occupy adjacent premises in Geneva, Switzerland.

The IEC, through more than 100 technical committees, prepares international standards for the electrotechnical field and is the parent to several autonomous certification schemes. To be certified under any one of these schemes, the laboratory needs to be audited by a recognized independent conformity auditor. One internationally recognized conformity auditor is the International Electrotechnical Commission Quality Assessment System for Electronic Components (IECQ).

ISO and ITU address all other fields—some jointly with IEC. ISO, however, also has a special committee for developing jointly what are called ISO/IEC internationally accepted guides, many of which are fundamental to the activity of conformity assessment. Referring to relevant ISO/IEC guides can identify the requirements for a testing laboratory. Note, however, that the ISO/IEC itself does not engage in any audit certification to any standard. Certification to ISO or IEC standards are made by recognized conformity auditors.

# 6.1 International Electrotechnical Commission

The IEC has global responsibility for the standardization of, among other things, PV components and systems, and the operation of product certification schemes. It provides a forum for the preparation and implementation of consensus-based voluntary international standards by facilitating international trade in its field and helping to meet expectations for an improved quality of life.

Founded in 1906, the IEC is the world organization that prepares and publishes international standards for all electrical, electronic, and related technologies. The IEC was founded as a result of a resolution passed at the International Electrical Congress held in St. Louis, Missouri (USA), in 1904. The membership consists of more than 50 countries, including the world's major trading nations and a growing number of industrializing countries. IEC central offices are located in Geneva, Switzerland.

There are two forms of active participation in the IEC's work. Full membership entitles countries to full participation in international standardization activities. Full members are national committees, each having equal voting rights. Associate membership allows for limited participation of countries with limited resources. Associate members have observer status and can participate in all IEC meetings. They have no voting rights. On becoming a member of the IEC, each national committee agrees to open access and balanced representation from all private and public electrotechnical interests in its country. The whole organization of the IEC is designed to ensure that the national committees play a leading part in all decisionmaking of the commission. This enables the widest degree of consensus on standardization work to be reached at an international level. It is up to the national committees to align their policies accordingly at the national level.

# 6.2 IEC Mission Statement

The IEC's mission is to promote, through its members, international cooperation on all questions of electrotechnical standardization and related matters, such as the assessment of conformity to standards, in the fields of electricity, electronics, and related technologies.

The IEC charter embraces all electrotechnologies, including electronics, magnetics and electromagnetics, electroacoustics, telecommunications, and energy production and distribution, as well as associated general disciplines, such as terminology and symbols, measurement and performance, dependability, design and development, safety, and the environment.

To further its mission, the IEC commission has developed the following objectives:

- Meet the requirements of the global market efficiently.
- Ensure worldwide use of its standards and conformity assessment schemes.
- Assess and improve the quality of products and services covered by its standards.
- Establish the conditions for the interoperability of complex systems.
- Increase the efficiency of industrial processes.
- Contribute to the improvement of human health and safety.
- Contribute to the protection of the environment.

The IEC is one of the bodies recognized by the World Trade Organization (WTO) and entrusted by it to monitor the national and regional organizations agreeing to use the IEC's international standards as the basis for national or regional standards as part of the WTO's Technical Barriers to Trade Agreement.

The IEC is organized using technical committees (TC). TC 82 is tasked with developing PV-related standards. Current projects include those listed in **table 6.1**.

# 6.3 IEC Quality Assessment System for Electronic Components

The IECQ is the IEC's Quality Assessment System for Electronic Components that is used to perform conformity audits. Typically these audits are to IEC standards for the electronics component industry. Since few conformity auditors are familiar with PV components or PV systems, the IECQ has an agreement with PV GAP to work with the PV community.

Quality Improvement of Photovoltaic Testing Laboratories in Developing Countries

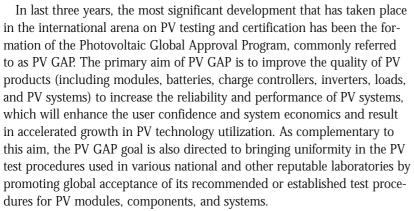




# Table 6.1 Current IEC Projects on PV Standards

Project	Language code	Stage code
EC 60904–9 Ed. 2.0	E	ANW
mendment to IEC 60904–9 (1995) to take into account thin-film silico	n	
EC 61683 Ed. 1.0	E	CDIS
hotovoltaic systems—Power conditioners—Procedure for measuring e	fficiency	
EC 61723 Ed. 1.0	В	PWI
afety guidelines for grid connected photovoltaic (PV) systems mounted	on buildings	
EC 61728 Ed. 1.0	E	PWI
afety test procedures for utility grid-connected photovoltaic inverters		
EC 61729 Ed. 1.0	E	PWI
quipment and safety specifications for direct coupled PV-pumping syste	ms	
EC 61730 Ed. 1.0	E	ANW
afety testing requirements for PV modules		
EC 61836–2 Ed. 1.0	E	ANW
olar photovoltaic energy systems—Terms and symbols—Part 2		
EC 61849 Ed. 1.0	E	ANW
Design qualification and type approval of photovoltaic (PV) modules for		
EC 61853 Ed. 1.0	E	ANW
ower and energy rating of photovoltaic (PV) modules		
EC 62078 Ed. 1.0	E	ANW
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# 6.4 PV GAP



PV GAP is a global, PV industry–driven organization that strives to promote and maintain a set of quality standards and certification procedures for the performance of PV products and systems, to ensure high quality and reliability. While individual components, such as the PV modules, can carry warranties of 20 years, the need for greater consistency in combining appropriate components into properly designed and maintained systems is critical to the continued success of the industry.

At present, few PV product and system standards exist. This means that many manufacturers, especially those in developing countries, have no guidelines on how to produce reliable products, how to install them in systems, and how to service them. Furthermore, the lack of approved testing laboratories makes product testing difficult for manufacturers.

A PV quality assurance program is needed to ensure the high quality of PV products and installations globally. A PV quality seal is also needed to identify those products and systems that are manufactured and installed to this international standard. The PV GAP was initiated to provide this resource.

# 6.5 Achieving the PV GAP Mission

For PV GAP to achieve its goal (or mission), the following needs should be met:

- Globally accepted PV standards. To promote the global acceptance of the IEC and other international standards, and, when such standards do not exist for PV modules, components, or systems, to develop recommended standards (RSs) by reviewing and utilizing existing national or regional standards.
- Acceptance of reciprocity between testing laboratories. To develop a list of acceptable testing laboratories worldwide, including those in the developing countries. An important goal is to achieve global acceptance of reciprocity between PV testing laboratories.
- Reference manual. While there are many national and regional handbooks in existence, it is essential to establish one globally accepted reference manual for PV systems.



- Approval and certification program. PV GAP's approval and certification program is based on the ISO/IEC system. Since all conformity auditors are not familiar with PV components and PV systems, the IECQ (IEC's Quality Assessment System for Electronic Components) will be used as the primary conformity auditor. The IEC's offices are in Geneva, Switzerland. In addition, PV GAP will recognize other conformity auditors to certify laboratories and manufacturers as the requirements are developed.
- PV GAP quality seal. To establish a "quality seal" for PV components and systems to be awarded to companies and manufacturers that are approved or certified.

PV GAP has planned to meet these needs as follows:

- *Centralized organization.* PV GAP is organized as a not-for-profit organization under the control of the global PV industry. Its central, coordinating office is in Geneva, Switzerland.
- *Global standards.* PV GAP will list the following global standards:
  - IEC standards developed for PV.
  - Other International standards applicable to PV.
  - PV recommended standards.
- Accredited testing laboratories.
  - PV GAP will utilize globally accepted requirements for the approval of testing laboratories.
  - PV GAP will maintain a list of testing laboratories fulfilling the requirements.

A laboratory's capabilities are assessed according to the applicable standards (for example, ISO 17025). If the laboratory fulfills all the requirements, it will receive accreditation from a certification body to perform all the tests for which it passed the accreditation process. The role of the testing laboratory is to test PV components and systems according to established international standards, either according to an IEC standard or according to a PV GAP "Recommended Standard."

The approved testing laboratories are as follows:

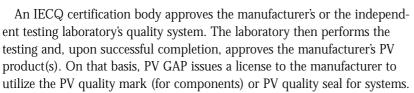
- Independent organizations that have the proper equipment, personnel, traceability, and so forth to perform tests prescribed by the standard(s).
- PV manufacturing companies' departments that have the proper equipment, personnel, traceability, and so forth to perform tests prescribed by the standard(s).

# 6.6 Certification

PV GAP has several responsibilities, including coordination of the worldwide effort to ensure PV system reliability and certification of the components and systems, using the internationally recognized IECQ, which is operated by the IEC based in Geneva, Switzerland.



# 6.7 Certification Process



# 6.8 PV Quality Mark and Seal

Manufacturers, distributors, and installers that are approved under the PV GAP system will be licensed to use and display a distinctive mark or seal. The PV quality mark is applied to all PV components and products approved by PV GAP. PV GAP also has a solar quality seal, which it uses to indicate that the PV system and installation, as a whole, is up to its certification standard.

# 6.9 PV GAP and the IEC/IECO

PV GAP has developed a professional, collaborative relationship with the IEC, based on that organization's long-standing international reputation for quality and the technical interests it holds in common with the goals of PV GAP.

# 6.10 PV GAP Membership Information

To become a member of PV GAP, the association or organization must accept the principles of PV GAP. These principles include adherence to the quality standards defined by PV GAP and the IECQ and a code of professional conduct. Until December 31, 1998, members were accepted on a temporary basis after they had signed a declaration that they were planning to obtain certification. Since that date, members are accepted only after they receive certification.

The standing committees of PV GAP include the following:

Standards Committee.

- Committee to Monitor Testing Laboratories.
- Committee on the Reference Manual.
- Licensing and Disciplinary Committee.
- Oversees the licensing and enforcement of the PV GAP seal.
- Oversees issues related to the use of the PV GAP seal.
- Manages adherence to the principles of PV GAP.
- Ensures payment of the annual subscription.
- Evaluates the performance of the licensed certification body.

# 6.10.1 Membership Benefits

The primary benefit of membership is the market advantage enjoyed by members' products and systems. Domestic and international funding and



development groups will specify the use of products that meet the PV GAP requirements, for projects receiving loans or grant funds. Displaying the PV GAP quality seal on its products or in relation to its services provides a significant marketing advantage, as conferred by the international recognition of product and service quality.



In addition, members have access to the following:

- PV GAP information services.
- PV GAP publications: licensed organizations, standards, approved testing laboratories, updated reference manual.
- News bulletins.
- Standards lists, testing laboratories lists, PV GAP publications.

The Executive Board of PV GAP consists of the following people:

- Chairman: Dr. P. Varadi; P/V Enterprises, USA.
- Secretary: Mr. R. Kay (acting); IECQ, Switzerland.
- Treasurer: Mr. M. Real; Alpha Real, Switzerland.

Board members include the following people:

- Mr. Y. Baba; JEMA, Japan.
- Mr. J. Bonda; EPIA, Belgium.
- Dr. R. DeBlasio; NREL, USA.
- Dr. H. Forest; SEIA, USA.
- Dr. C. Gay; USA.
- Prof. R. Hill; Newcastle Photovoltaic Applications Centre, UK.
- Ms. S. McDade; UNDP, USA.
- Dr. H. Ossenbrink; JRC; Ispra, Italy.
- Ms. L. Schaeffer; USA.
- Mr. H. Shimizu; JQAO, Japan.

Following are the Advisory Board members:

- Mr. S. Chalmers; PowerMark, USA.
- Mr. P. Helm; WIP, Germany.
- Prof. Dr. J. Luther; Fraunhofer Institut, Germany.
- Mr. E. Lysen; NOVEM, the Netherlands.
- Mr. A. Schmitt; EDF, France.
- Mr. A. K. Vora; ISPMA, India.
- Prof. A. Zervos; National Technological University; Athens, Greece.

Here is how to contact PV GAP: PV GAP Secretariat c/o IEC Central Office 3 rue de Varembé P.O. Box 131 CH-1211 Geneva 20 Switzerland Tel: (41–22) 919–0216 Fax: (41–22) 919–0300 TX: 414121 iec ch URL: http://www.pvgap.org

# 6.10.2 PV GAP Certification and Membership

Two agreements with PV GAP include requirements to mark individual PV components and complete small PV systems. The foremost agreement is between PV GAP and the manufacturing organization. The secondary agreement is between PV GAP and the testing laboratory.

Manufacturing/PV GAP Agreement: The requirements for this agreement include the following:

- Proof of certification to ISO 9000 and ISO 65 by either the IECQ or a recognized third party conformity auditor.
- Proof of compliance of a component or a small PV system to PV RS-1, PV RS-2, or PV RS-3 by an independent testing laboratory that is recognized by PV GAP.
- Payment of fees to PV GAP.
- Consent to the bylaws of PV GAP.

Laboratory–PV GAP Agreement: The requirements for this agreement include the following:

- Proof of accreditation to ISO 17025 and ISO 65 by either the IECQ or a recognized third party conformity auditor.
- Proof of compliance to test components or small PV systems to PV RS-1, PV RS-2, or PV RS-3 by either the IECQ or a recognized third party conformity auditor.
- Payment of fees to PV GAP.
- Consent to the bylaws of PV GAP.

When a manufacturer has complied with the PV GAP requirements, the manufacturer may then apply and display the PV GAP mark of the products and literature of the tested product or system. The manufacturer is the only organization authorized to apply the PV GAP mark.

Providing quality systems is only a part of what is required to install reliable, long-life small PV systems in rural areas. All the components need to be in place, including maintenance spare parts, operations and maintenance training, and financing.

# 6.11 PV GAP Recommended Standards

Presently there are three PV GAP recommended standards (RS):

- RS-1 Photovoltaic Stand-Alone Systems—Design Qualifications and Type Approval
- RS-2 Crystalline Silicon Terrestrial Photovoltaic (PV) Module Blank Detailed Specification—Qualification Approval under IECQ
- RS-3 Thin-Film Terrestrial Photovoltaic (PV) Module Blank Detailed Specification under IECQ.

These are interim standards that will be superseded by international standards as they are approved. The three standards are included in Appendix 3 of this manual.



# 6.12 PV GAP Laboratory Accreditation



This subsection addresses the requirements for an independent testing laboratory to become PV GAP certified. The process starts when the laboratory contacts the national supervising inspectorates (NSIs) and identifies an IECQ conformity auditor or another conformity auditor recognized by the NSIs.

NSI Central Office 3 rue de Varembé P.O. Box 131 CH 1211 Geneva 20 Switzerland Telephone: (41–22) 919–0216 Fax: (41–22) 919–0300 E-mail: rk@iec.ch

Then, the laboratory needs to make arrangements with the selected auditor to have its facility approved, in accordance with IECQ Rules of Procedure QC-001002–3 Clause 2, Revision 1998, ISO 17025, and with the PV GAP interim test procedures. These guides set out the general requirements that a laboratory must demonstrate to be recognized as competent to carry out PV GAP tests.

Following are the primary requirements for becoming a PV GAP–authorized laboratory:

- The laboratory must operate an accredited or audited ISO 17025 Quality Plan based on documents such as the following:
- ISO/DIS 17025: General Requirements for the Competence of Testing and Calibration Laboratories.
- ISO/IEC Guide 65: General Requirements for the Bodies Operating Product Certification Systems.

The conformity auditor needs to follow ISO/IEC Guide 62, General Requirements for Bodies Operating Assessment and Certification of Quality Systems, and ISO/IEC Guide 58, General Requirements for Bodies Operating Assessment of Testing and Calibration Laboratories.

- (2) The laboratory must be accredited or audited to certify PV devices to international standards.
- (3) The laboratory must be accredited or audited to test PV systems to the PV GAP test methods:
- IEC-QC 001002–3, Clause 2, and document CMC/427/DIS. Approval of Independent Testing Laboratories.

In addition, TC 82, Solar Photovoltaic Energy Systems, is the IEC committee responsible for providing the product standards needed for the IECQ's approval for PV GAP. Recommended standards for the solar PV field are also listed by PV GAP. These include the PV GAP recommended standards:

- PV GAP Recommended Standard PV RS-1, January 1998 PV Stand-alone Systems: Design Qualification and Type Approval.
- PV GAP Recommended Standard PV RS-2, 1999 Crystalline Silicon Terrestrial Photovoltaic (PV) Module Blank Detailed Specification-

Qualification Approval under the IECQ. This document includes the relevant requirements of IEC-61215 Crystalline Silicon Terrestrial Photovoltaic (PV) Modules Design Qualification and Type Approval.

PV GAP Recommended Standard PV RS-3, 1999 Thin-Film Terrestrial Photovoltaic (PV) Module Blank Detailed Specification-Qualification approval under the IECQ. This document includes the relevant requirements of IEC-61646 Thin Film terrestrial Photovoltaic (PV) Module s Design Qualification and Type Approval.

These three PV GAP recommended standards are included in Appendix 3 of this manual.

(4) The laboratory must stay current.

Staying current requires that the laboratory be self audited at least twice a year and be audited by an independent external conformity auditor at least once a year.

- (5) The laboratory must complete the PV GAP application.
- (6) The laboratory must pay the fees.

Upon approval, the certified laboratory will be entitled to the following:

- Listing in the IECQ register of Approvals QC 001005 published twice per year and distributed worldwide.
- Listing also on the CODUS (Sheffield, UK) on-line QA database.
- To use the PV quality mark or seal in advertising.

The manufacturer of the product or system is the only organization that can be authorized to apply the PV GAP quality mark to the product. The laboratory testing is a part of that process.



# Chapter 7 Staff Training and Development

taff training and development are critical and integral parts of operating a PV testing laboratory. Effective staff training requires not only effective trainers but also materials based on effective instructional design. The purpose of this chapter is to present a proven methodology on how to design, develop, and implement an instructional program, and how to evaluate the program. The method uses an instructional design and development procedure developed by Darryl L. Sink & Associates of Monterey, California.

The instructional development model is shown in the flow diagram of figure 7.1. It is a multistep method that begins with a needs analysis and ends with an evaluation of the program.

The materials presented in this chapter are based largely on the Instructional Developer Workshop: A Guide for the Professional Instructional Developer, with the permission of the following company:

Darryl L. Sink & Associates 60 Garden Court. Suite 101 Monterey, California 93940

## 7.1 Training Programs for Staff Development

Effective organizations give high priority to the continuous development of staff capabilities through training. This is especially true for a PV testing laboratory that will be evaluating state-of-the-art components and systems. Staff of the PV testing laboratory will be involved in both offering and receiving training. The nature and scope of these training programs should be based on needs analyses. It is recommended that training programs offered by the testing laboratory use the methodology outlined in this chapter, and include analysis, design, development, and evaluation.

## 7.2 Instructional Development **Methodology**

The following sections briefly describe the methodology involved in the process of developing training programs.

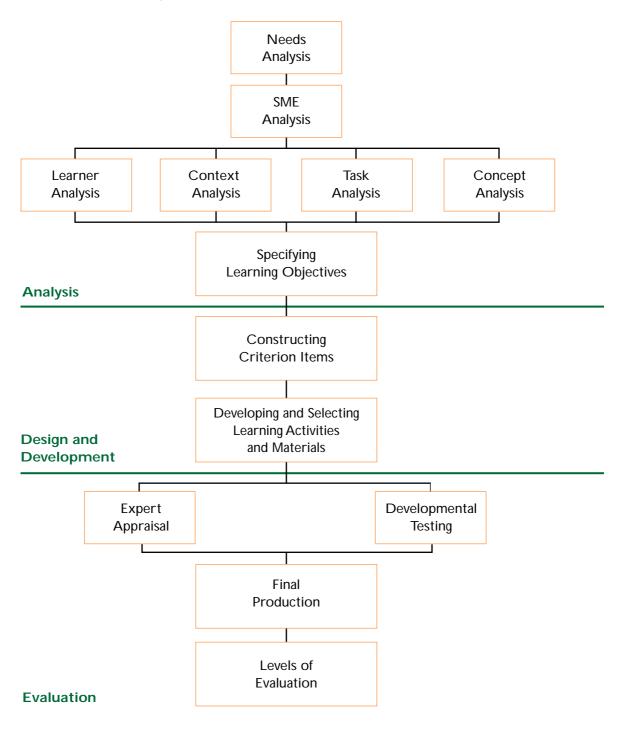
### 7.2.1 Needs Analysis

The needs analysis is the first step in a systematic approach to the development of training materials and programs.

Conducting a needs analysis helps to identify differences in knowledge, skills, and attitudes that can be met through training and educational experiences and distinguishes them from inappropriate policies and procedures,



Figure 7.1 Instructional Development Model



motivational strategies, or management styles.

people and provide input themselves.



The instructional designer provides the process for collecting and analyzing information gathered from all those affected by the training. Management and subject matter experts provide access to the appropriate

7.2.2 Subject Matter Expert Analysis

The objective of this analysis is to obtain complete and accurate input from subject matter experts.

The subject matter expert analysis is conducted as soon as it is certain that training is needed. It involves working with people to gain the necessary and sufficient content to train the target audience.

The subject matter experts should have sufficient breadth and depth to their experience and knowledge to clearly articulate what the audience needs to know and do.

### 7.2.3 Learner Analysis

The purpose of the learner analysis is to design training based on the characteristics of the target audience. The learner analysis tailors the training program to the needs, abilities, and preferences of the target population and to their specific requirements. The nature of the target population influences the design of the training program and materials. Conducting a learner analysis avoids producing training that is inappropriate for the audience.

Learner characteristics affect the design and selection of the following:

- Language and terminology.
- Prerequisites.
- Learning activities.
- Participant materials.
- Learner feedback and evaluation.
- Format for instructional materials.
- Training schedule.
- Media and instructional equipment.

First-hand interviews and observations of the learners are the most reliable and revealing sources of information. Interviews with others who have relevant information (for example, management and subject matter experts) may also be useful.

### 7.2.4 Context Analysis

Context analysis is used to identify and describe those environmental factors that affect the design of training programs. Performing context analysis avoids producing training that will not work in the intended learning environment, and maximizes the potential for success of the program. Environmental factors affect the following:

- Media selection.
- Learning activities.
- Participant materials and leader guides.

- Learner and course evaluation.
- Packaging and production of training materials.
- Training schedule.

The instructional designer performs the context analysis by consulting with management and subject matter experts.

#### 7.2.5 Task Analysis

The task analysis is conducted after the needs analysis. The needs analysis identifies problems and the need for solutions. The task analysis specifies goals in terms of tasks and breaks them down into their subparts. Performing the task analysis enables the instructional designer to describe the task, identify the entry levels for the training program, and sequence the instruction. When the learning task is understood as clearly as possible, all important content is included, and unnecessary content is excluded.

The instructional designer observes the tasks being performed, interviews the subject matter experts along with others who may have significant input, and verifies the analysis with the subject matter experts. When it is a cognitive task, the instructional designer must rely heavily on subject matter experts and any literature available to conduct the analysis.

### 7.2.6 Concept Analysis

The instructional designer is often called upon to provide training that teaches concepts. Concept analysis can be used to clarify the concept's definition, systematically sort out examples of the concept, and identify critical and variable attributes. Attributes are used to suggest the nature of examples to be used during instruction. Concept analysis is performed early in the instructional development process. It is conducted as a part of the analysis phase prior to the specification of objectives.

Information gathered in a concept analysis can be used to do the following:

- Identify and refine the subject matter content.
- Specify learning objectives.
- Develop criterion test items.
- Specify examples and nonexamples.
- Design learning activities and instructional materials.

The instructional designer performs the concept analysis by consulting with subject matter experts.

### 7.2.7 Specifying Learning Objectives

Specifying objectives is the major outcome of the analysis phase in the systematic design of instruction. The objectives should match the instructional task and the characteristics of the target audience. Objectives are written after the analyses have been completed.

Good objectives help the instructional developer select learning materials and activities, and evaluate the students. Likewise, clearly stated objectives help students identify what to study and how they will be evaluated.



### 7.2.8 Constructing Criterion Items



Criterion items establish whether or not the objectives of the training have been accomplished. A criterion item is a question or activity that requires the students to indicate in a clear, direct way their attainment of the learning objective.

Criterion items are best developed immediately after the learning objectives have been developed and before any writing or design begins. This process is very dynamic because objectives may be revised as tests are constructed. Most importantly, the final criterion items should match the objectives.

Subject matter experts can often think of questions more easily than they can think of objectives. Subject matter experts can be a big help in constructing meaningful tests that measure the attainment of the objectives. Whether the subject experts or the designer writes the tests, it is the designer's responsibility to make sure any criterion-referenced test matches the objectives.

## 7.2.9 Design Documents and Blueprints

Design documents present an overview of the instructional program that shows how all the training elements fit into the delivery system. This provides a big picture of the training. Blueprints are more specific and show the sequence of events and details of each component of instruction.

The design document is usually produced as soon as the objectives are specified. The blueprint comes later when the developers have decided on the topics and activities that will be contained in the course.

Instructional design documents and blueprints are effective tools for developing successful training programs. The blueprint can be used to do the following:

- Provide a framework for developing course materials.
- Communicate details of the training program.
- Document the training program.

### 7.2.10 Developing and Selecting Learning Activities and Materials

Developing learning activities and materials begins after the learning objectives and criterion items have been developed. The criterion test items should be constructed before the development of the materials and activities for two reasons:

- 1. By knowing how the students' performance will be measured, the instructional developer has a better idea of where the design should lead the student.
- 2. The criterion items are often used as the guidepost for writing the materials and activities.

To increase the effectiveness of the instructional program, it is necessary to apply principles of design, develop appropriate instructional strategies, select media wisely, and write in an efficient and effective manner. The five most important principles of effective instruction that should be included in the training are as follows:



- Provide an advance organizer that illustrates the purpose and overview of the training.
- Include relevant practice of the skills and knowledge to be learned.
- Incorporate continuous feedback from the students in response to what they have learned.
- Avoid the inclusion of any and all irrelevant materials.
- Make the training interesting.

Developing materials that suit the learning task, the preference of the learners, the style of the trainer, and the situational constraints requires a broad-based knowledge of strategies and techniques on the part of the instructional designer and the cooperation of the subject matter experts and the trainer.

### 7.2.11 Expert Appraisal

As part of the evaluation phase, expert appraisal is sought as soon as the prototype instructional materials have been created. The information obtained from experts is used to revise instructional materials before developmental testing is conducted.

By seeking out the advice of experts, the developer receives useful feedback on the conceptual adequacy and technical quality of the instructional program. This information will be helpful in implementing the program, and includes feedback on the relevance of the objectives, theoretical soundness of the content, adequacy of definitions and explanations, proper use of technical terms, and appropriateness of examples. Experienced trainers can suggest further improvements on the usability of the instructional package, adequacy of packaging, availability of media equipment, and flexibility of usage. Media specialists can suggest improvements on the technical quality of production.

### 7.2.12 Development Testing

Another important part of the evaluation process is developmental testing, which typically begins after expert appraisal. Developmental testing is the part of formative evaluation in which feedback is obtained from tryouts with representative members of the target population. The purpose of this testing is not to grade the trainee, but rather to make the materials instructionally and motivationally more effective. Tryouts are initially conducted individually, with the developer working alongside the trainee who works through the materials. The subject matter experts are available for any technical difficulty.

### 7.2.13 Final Production

As formative evaluation is completed for each important component, final production is completed. Generally, final production occurs after two to three test-revision-test cycles. Creating the final version of an instructional program slowly evolves during formative evaluation. Careful attention to detail throughout this stage allows for a coordinated effort in completing all the components of the program in a timely manner.



### 7.2.14 Levels of Evaluation

As many as four levels of evaluation are used to evaluate the effectiveness of training programs. These levels are as follows:

- 1. Learners are evaluated during and at the end of instruction to measure their reaction to the training.
- 2. Learners are evaluated during and at the end of instruction to measure how well they achieved the learning objectives of the training program.
- 3. Learners are evaluated once they are working on the job and applying the training. This evaluation measures whether the training is being applied on the job as it was intended and prescribed.
- 4. The final level of evaluation measures the impact of the training on the overall operation and success of the organization.

Evaluation levels 1 and 2 are conducted immediately after the instruction is over. Levels 3 and 4 are conducted some time after the training has been completed. The results of the evaluation are used to improve the training program's effectiveness.

## 7.3 Training for Certification

To ensure the credibility and reliability of test results produced by the laboratory, the laboratory will develop a plan to apply for and obtain ISO 17025 certification for testing. This task will be headed by laboratory project team members, and staff training should be an important part of the plan.

The approach will be to develop a laboratory operations and quality assurance process, or quality system, and to train staff appropriately on its implementation. The quality system proposed for the test laboratory will consist of four parts:

Volume 1, Quality Manual Volume 2, Standard Operating Procedures Manual Volume 3, Test Instrument Manual

Volume 4, Testing Standards Manual

The purpose of Volume 1, Quality Manual, will be to provide welldefined policies and associated procedures to all members of the testing laboratory so as to ensure that the highest quality standards for products and services are maintained. This manual will be designed to ensure that all requirements defined by the applicable standards, directives, and organizations are met. All laboratory staff will be trained on the objective and commitment to quality, and trained to achieve the stated objective.

The outline in **table 7.1** for the proposed Quality Manual will be used to map staff training.

Volume 2, Standard Operating Procedures Manual, will include approved laboratory practices for maintaining a quality system. Specific procedures will include requirements for performing all tests required for the solar home system (SHS) and related components. General laboratory practices to be included in the Standard Operating Procedures Manual are as follows:

- Instrument labels.
- Instrument calibration.
- Instrument cross-checking.
- Standards control and maintenance.
- Control module handling and storage.
- Correspondence records and filing.
- Filename convention.
- Instrument manuals.
- Laboratory notebooks.
- Module mounting for tests and storage.
- Receiving inspection, labeling, and connection of test leads.
- Reference cell handling and use.
- Shipping.
- Test instrument receipt, inspection, and labeling.
- Test reports.
- Test sequence visual inspection.
- Thermocouple use.

Volume 3, Test Instrument Manual, will include information specific to the requirements for operating and maintaining calibration of the laboratory test equipment. This information will be in large part developed from equipment manufacturers' manuals, and application-specific procedures required for qualification tests on SHSs.

Volume 4, Testing Standards Manual, will include all standards, recommended practices, and guidelines of the IEC, IEEE, and other organizations applicable to SHS qualification testing. At present, IEC standards do not exist for PV systems and many major components, and are only under preliminary development in IEEE. Where internationally accepted standards are not available, interim standards for the PV Global Accreditation Program (GAP) will be used in the Testing Standards Manual.

To conclude this task, the laboratory will prepare an action plan to achieve ISO 17025 certification. This plan will include a schedule, milestones, budgets, equipment needs, and other services necessary for ISO 17025 certification, including training. The success of this effort will rely heavily on compliance with the quality system process also developed under this work.

The laboratory will define and document its policies and objectives for, and its commitment to, good laboratory practices and the quality of testing services. The laboratory management will ensure that these policies and objectives are documented in a Quality Manual

## Table 7.1

#### **Outline for a Quality Manual**

1. Photovoltaic Test Laboratory (PTL) Quality Assurance Manual

#### 2. Organization and Management Structure

- 3. Quality Assurance Policy
  - Title Page 3.1.
  - Calibration and Verification of Test 3.2. Instruments and Equipment
  - Client Complaint Response Policy 3.3.
  - Confidentiality and Undue Influence 3.4. Policy
  - 3.5. Quality Assurance Manual Content and Format Policy
  - PTL Document and File Convention and 3.6. **Control Policy**
  - 3.7. Library Document Maintenance and **Control Policy**
  - Equipment Inspection and Service Policy 3.8.
  - **General Testing Policy** 3.9.
  - 3.10. Housekeeping Policy
  - 3.11. Laboratory Personnel and Training Policy
  - 3.12. Logbook Policy
  - 3.13. Quality Assurance Audit Policy
  - 3.14. Record Retention Policy
  - 3.15. Report Reissue Policy
  - 3.16. Sample Retention Policy
  - 3.17. Test Procedures Policy
  - 3.18. Verification of Results Policy
  - 3.19. Departure from Policy
  - 3.20. Accommodations and **Environment Policy**
  - 3.21. Computer Use Policy
  - 3.22. Certificates and Reports Policy
  - 3.23. Subcontract of Testing Policy
  - 3.24. Outside Support and Supplies Policy
  - 3.25. Nonconformity, Complaint, and Corrective Action Policy
- 4. Appendices
  - Laboratory Plans 4.1
  - 4.2 PTL Staff Vitae
  - 4.3 Job Descriptions
  - Personnel Qualified To Perform 4.4 **Specific Tests**
  - 4.5 Instruments Requiring Calibration
  - Equipment Requiring Maintenance 4.6
  - List of PTL Procedures 4.7
  - 4.8 **Employee Agreements**
  - Exhibits 4.9
  - 4.10 NCAR (Nonconformity, Complaint, and Corrective Action Request) Form



and communicated to, understood by, and implemented by all laboratory personnel engaged in PV component and system testing. Effective staff training is a key element in obtaining certification and maintaining quality system operation.



# Appendix 1. Florida Solar Energy Center Quality Manual

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# Foreword

## **Quality Policy Statement**

The Florida Solar Energy Center (FSEC), including its administrators, managers, and staff, believe that quality is the primary means to continue to make a positive contribution to the field of renewable energy and to maintain a credible international status, and so have agreed to make quality a priority. To this end, the FSEC expects high quality within the organization and from those organizations and individuals with which it does business.

By implementing a quality plan, the FSEC expects to provide its customers with testing services that meet recognized international standards, that are traceable and reproducible, and that are recognized internationally. Solar equipment testing and certification is one of the primary reasons for the existence of the Florida Solar Energy Center. Florida State statutes require the FSEC to maintain testing and certification capability. The solar industry in Florida and throughout the world depends on the FSEC to maintain an independent test laboratory status and be capable of conducting consistent tests of high accuracy and quality, meeting all requirements of the appropriate standards. It is a policy of the FSEC to maintain this capability.

The Florida Solar Energy Center has pledged to continue the commitment of human and physical resources to provide the highest possible quality in its testing of solar energy equipment.

David L. Block, Director Florida Solar Energy Center 12/16/99

# 1. Scope

This quality manual specifies the quality system of the Florida Solar Energy Center (FSEC) Test Laboratories. It is intended to apply to the photovoltaic test laboratory and the solar thermal test laboratory. Both laboratories are engaged in testing solar components and solar systems. The quality system at the FSEC is designed to meet the requirements of ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories.* The FSEC capability extends to testing only; calibrations for external clients are not performed.

# 2. References

The references listed below and those listed in section 5.4 of this document constitute elements of the FSEC quality system. The most recent editions of the referenced documents apply.

- ISO/IEC DIS 17025, General Requirements for the Competence of Testing and Calibration Laboratories
- ISO/IEC Guide 2, General Terms and Their Definitions Concerning Standardization and Related Activities
- VIM 1993, International Vocabulary of Basic and General Terms in Metrology

## 3. Terms and Definitions

The terms and definitions given in the above reference document apply to this document and to the Florida Solar Energy Center quality system.

## 4. Management

## 4.1 Organization and Management

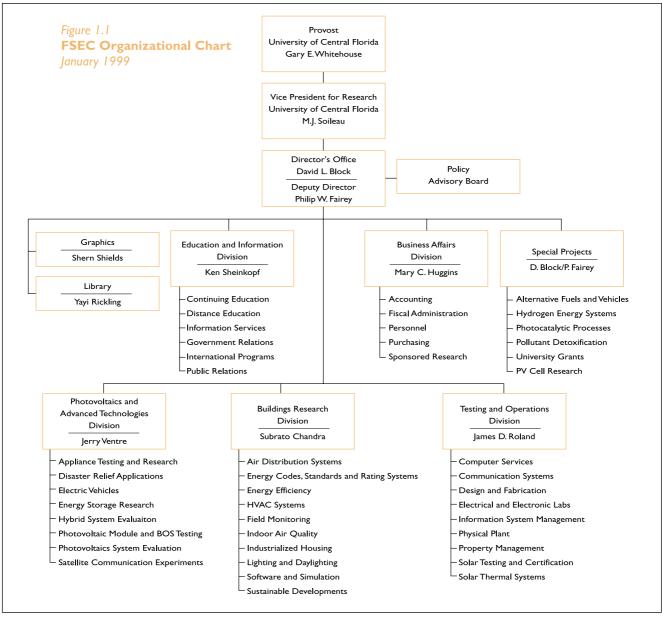
### 4.1.1 Laboratory Organization and Control

In a major step toward promoting the greater use of solar energy, the Florida legislature created the Florida Solar Energy Center (FSEC) as a part of the State University System of Florida. The FSEC reports to the Board of Regents through the University of Central Florida.

The FSEC was established to serve as a nucleus for solar energy activities in the state, including:

- Education
- Solar project demonstration
- Solar equipment testing
- Technical information dissemination
- Design and development of solar energy systems
- Solar energy research

The FSEC is a nonteaching research institute within the State University System. As such, it does not manufacture or market solar equipment and has no conflicting affiliations with solar manufacturing or marketing organizations. No conflict of interest exists that would make test personnel unable to render impartial technically sound and objective advice and judgments. All employees are required to report any outside employment, business activity, and potential conflict of interest.



The organization structure of the FSEC is shown in **figure 1.1**. Five divisions, organized according to general areas of responsibility, carry out the center's functions. The smooth operation of the center requires constant interaction and support among the divisions.

Solar equipment testing and certification is one of the primary reasons for the existence of the Florida Solar Energy Center. Florida State Statutes require test and certification capability to perform these functions.

The test and certification program at the FSEC is within the Testing and Operations Division and is under the supervision of its director. James D. Roland is responsible for day-to-day management of center test activities, including planning, scheduling, technical direction of tests, certification of results, and test report preparation. No test activities are subcontracted. Laboratory management personnel include the following:

David L. Block, Ph.D., P.E. Director, FSEC Philip Fairey Deputy Director, FSEC Gerard Ventre, Ph.D., P.E. Director, Photovoltaics and Advanced Technology Division

James D. Roland Director, Testing and Operations Division

Jim Huggins Program Director

Gobind Atmaram, Ph.D. Principal Engineer, Photovoltaics Program

Craig Maytrott, Quality Manager, Testing and Operations Division

Laboratory points of contact are Gobind Atmaram for the photovoltaic program and Jim Huggins for the solar thermal program.

The Quality Manager has a major responsibility for the quality program. He has access to the highest level of FSEC management on any issue that effects the quality and integrity of the test laboratories.

### 4.1.2 Business Dependence

Individual test clients contribute less than 0.1 percent of the FSEC budget. The State of Florida provides funding for the FSEC. Additional funds are obtained through research, development, and test contracts with Federal and State agencies and private companies.

### 4.1.3 Laboratory Experience

The FSEC submitted full and detailed information on its thermal collector performance testing programs, including equipment, personnel, methods, and support facilities, to the study team from the Air Conditioning and Refrigeration Institute under their contract to the Department of Energy to qualify or certify testing laboratories. The report, *Laboratories Technically Qualified to Test Solar Collectors in Accordance with ASHRAE Standard* 93–77 (W. J. Niessing, November 1978, NBSIR 78–1535) verifies the FSEC's compliance with ASHRAE standards. Other organizations that have accredited the FSEC include the following:

- The Solar Rating and Certification Corporation (SRCC)
- The State of California under the TIPSE program
- The State of New Mexico
- International Association of Plumbers and Mechanical Officials

The FSEC has had extensive experience in testing solar collectors for certification and rating, and in monitoring solar hot water systems for research, as well as in research, development, and testing of other types of solar equipment and systems.

The FSEC has been testing and evaluating photovoltaic systems for the last 15 years. This experience has been used to develop complete test procedures and methods. The FSEC has also participated with the National Renewable Energy Laboratory (NREL) and Power Mark Corporation (the U.S. PVGAP representative) to develop and validate the prototype test procedure. In addition, NREL has also drafted *Interim Test Methods and Procedures for Determining the Performance of Small Photovoltaic Systems* (draft of December 23, 1998). The FSEC is on the evaluation team for this document and has performed system evaluations using the Interim Test Methods and Procedures.

## 4.1.4 Confidentiality and Proprietary Rights

The FSEC can conduct research and tests on proprietary and confidential equipment. However, most solar thermal collector tests at the FSEC are for the purpose of certification under the Florida certification systems. In these cases, the data are not considered confidential and can be requested by other parties under the Florida

Public Records Law. Universities and the FSEC are granted a specific exclusion under Florida Statute 240.241 which states in part "...Materials that relate to methods of manufacture or production, potential trade secrets, potentially patentable material, actual trade secrets, business transactions, or proprietary information received, generated, ascertained, or discovered during the course of research conducted within the state universities shall be confidential and exempt from the provisions of S119.07(1)...." This exemption allows the FSEC to conduct confidential tests on proprietary equipment not under test for certification.

All equipment to be tested, test data, and reports are treated in such a manner as to maintain confidentiality. When equipment is delivered to the FSEC, it is immediately assigned a number, and a decal is affixed to the device. No identification is needed beyond the assigned decal number. As data are collected, they are maintained in a confidential file and made available only to the test engineers and to the client. Upon completion of the test, the data and test report are either filed in nonconfidential files for certification tests or in confidential files for proprietary tests. No information is disseminated on the tests, even within the FSEC, without a "need to know."

## 4.2 Quality System

The provisions of this quality manual define and constitute the FSEC Quality System. The FSEC management is fully supportive of the Quality System and has implemented policies and procedures to ensure maintaining the highest levels of laboratory performance.

All documentation of the Quality System is under the control of the Quality Manager. It is his responsibility to maintain the latest revision of all documents including this document. It is also his responsibility to ensure that all appropriate test laboratory personnel are knowledgeable of and understand the relevant requirements.

## 4.3 Document Control

The FSEC maintains a library of all documents relative to the quality system including international standards, test standards, test procedures and calibration procedures. Examples include relevant ISO standards, ASHRAE, ASTM, and internal FSEC procedures. A listing of documents is given in section 5.4.

The document library listing is included on a computer database and is available to any FSEC employee. The centralized library is under the control of the Quality Manager. It is his duty to maintain current all documents. The Quality Manager and the Test Engineer shall review the complete documentation library at least once per year. It is also the Quality Manager's duty to ensure all appropriate personnel receive training in the requirements of the standards and procedures they use.

The Quality Manager shall issue to each accredited test laboratory at the FSEC a test procedure manual(s). This manual shall be maintained as a quality document, and copies shall be made available to the testing personnel. It shall contain the following:

#### A. Standards

- 1. Applicable International Standards
- 2. Applicable FSEC Standards
- 3. Other applicable standards
- B. Calibration Control Documents
  - 1. Equipment Lists
  - 2. Requirements
  - 3. Procedures
  - 4. Authorized Personnel
- C. Testing Control Documents
  - 1. Forms
  - 2. Procedures

#### 3. Examples

Testing and Operations test reports are under the control of the Director, Testing and Operations. Procedures for review and approval of test data are described in section 5.10.3, Organization and Management, of this document.

The training program, as described in Human Resources, shall be implemented for all new employees engaged in testing. This has been an effective program for training technical personnel to conduct the thermal performance, reliability, and durability test. Copies of all applicable standards and test procedures are readily available to testing personnel.

## 4.4 Request and Contract Review

Each request for a test is reviewed by the Test Engineer, the Office Manager, and the Laboratory Division Director. The great majority of solar thermal tests are performed under a set of prescribed standard procedures that are well known. These tests lead to an FSEC approval for certification. The initial review for this type of test is brief and perfunctory.

Any nonstandard test is carefully reviewed by the technical staff members and management to determine if the FSEC has the capability, if new procedures or equipment is needed and if it is a test our laboratory should perform.

## 4.5 Subcontracting of Tests

The Florida Solar Energy Center does not normally subcontract tests. Laboratory clients of the FSEC submit items primarily for certification tests or for other tests for which the FSEC has capability. The FSEC is required by state statute to establish and maintain capability for certification tests to the state standards.

If for some reason subcontracting is required in the future, the requirements of ISO 17025, Paragraph 4.5, shall be met.

## 4.6 Purchasing Services and Supplies

As part of the University of Central Florida and the State of Florida, the FSEC follows the purchasing regulations of the university and the state. The regulations and procedures are extensive and detailed in procedure manuals.

When purchasing equipment, materials or services that affect testing, the FSEC's internal procedures also apply. These procedures require that the test engineer and one other qualified technical person review the purchase document. The second reviewer may be a principal investigator, the quality manager or a division director. This review shall be done with awareness of the test requirements to ensure that all quality requirements are met. All purchase records are maintained at the FSEC and at the University of Central Florida.

Equipment records are maintained at the FSEC. Operations and maintenance manuals and calibration certificates are maintained in the Quality System library under the control of the Quality Manager.

## 4.7 Service to the Client

The FSEC maintains communication with test clients who are also free to contact any employee. Prior to testing and often during testing, FSEC laboratory personnel consult with the test clients. For nonstandard tests, the FSEC consults with the client in designing a test.

As a public institution, the FSEC is obliged to meet with any interested client or potential client.

## 4.8 Complaints

Complaints are initially referred to the test engineer for consideration. Response is made to the complaint based on consultation with other staff members. If the answers or actions provided are not acceptable to the test client the complaint shall be referred to the FSEC Certification Review Board. This board is comprised of FSEC employees not directly associated with the testing of the item in question. Board members are appointed by the Center's Director. After due consideration the Board will make a decision. Their decision will be final. This process is formalized in FSEC Document, GP-6–80, section 3.1.8.

## 4.9 Control of Nonconforming Testing

Whenever nonconforming testing is identified, the work is immediately stopped and a review initiated. The review committee shall include, as a minimum, the test engineer, Quality Manager, and Laboratory Director. The cause of nonconformance shall be examined and corrective action taken. Decisions shall be made and recorded preceding resumption of tests, repeat of tests, notification to the client, and so forth. The Quality Manager must approve the resumption of testing.

## 4.10 Corrective Action

Whenever a discrepancy in testing is found the following process shall occur. The Program Director and Quality Manager are notified of the discrepancy. The Test Engineer determines if data was affected, how much data was effected, what tests were affected, and how to correct the data if possible. Any affected test clients are notified. All this information is presented to the Program Director who makes a decision as to a course of action. The decision is passed on to the test client and the Test Engineer carries it out. Better test methods, training, and/or documentation are investigated to prevent reoccurrence of problem. If a test client disagrees with the actions taken they may file a complaint as described in section 4.8.

If the discrepancy or nonconformance appears to be a general problem, a special audit shall be requested by the Quality Manager.

## 4.11 Preventive Action

The test laboratory team members are always encouraged to look for improvements and to identify any problems. The laboratory test group meets together once per week to review test progress, new test requirements and any concerns with procedures or equipment. Any problems are corrected immediately, if possible, or referred to someone for further study.

## 4.12 Records

The FSEC has an established system for retention of records. All written records are maintained indefinitely. Each test conducted generates a set of records from the receiving inspection through to the final test report. All observation, inspections and measurements are recorded and retained and identified to the specific test.

## 4.13 Internal Audits

Review of testing results may occur at any time. At a minimum, the Program Director and one other Testing and Operations Division engineer shall review each test report. The purpose of the review is to check the reasonableness of the results and to look for any errors in the data. Any necessary corrections shall be made before the test report is released to the client.

Audits of testing activities will be conducted at the request of the Center Director or the Quality Manager at least once per year. A competent party chosen from outside the Testing and Operations division shall conduct the audit. The audit shall include a review of relevant documentation, calibration procedures, testing procedures, personnel proficiency, observation of test performance, and all other elements of the quality system.

The results of an audit shall be given in written form to the Center Director, Quality Manager, Program Director and Division Directors. Any necessary corrective actions shall be documented. The Quality Manager shall insure that these actions are discharged within a reasonable time scale. Corrective action shall be taken if discrepancies are found which cast doubt on the validity of published test results and the affected parties shall be notified immediately in writing.

## 4.14 Management Review

The test laboratory management reviews shall be conducted annually. The annual review shall be conducted with specific objectives of reviewing the test workload, personnel resources, equipment resources, results of audits, any feedback from clients. The laboratory personnel shall be specifically surveyed for their comments on any relevant subjects.

Management at the FSEC is sufficiently close to the test operations, that ongoing reviews solve most problems prior to the annual reviews.

# 5. Technical Requirements

## 5.1 General

There are many facets to the FSEC's Quality System. They are documented individually and completely in the following sections. Factors affecting the quality, correctness and reliability of the tests performed by the laboratory include contributions from:

- Personnel (5.2)
- Accommodations and environmental conditions (5.3)
- Test methods and model validation (5.4)
- Equipment (5.5)
- Measurement traceability (5.6)
- Sampling (5.7)
- Handling of test items (5.8).

## 5.2 Personnel

Since inception of the solar collector test program at the FSEC, several people have been trained in the performance of tests, and an effective training program has been developed. Establishment of personnel competence to conduct tests is based on direct supervisory evaluation over a period of time.

Supervision of tests and analysis of tests is limited to graduate engineers who have undergone an on-the-job training program. Complete familiarity with the applicable test procedure, in-house procedures, equipment capabilities and equipment operations are required before an employee can supervise tests. Additional training on characteristics of solar collectors including review of past tests and examination of the tested collectors is required before an individual is judged competent to interpret test results. A supervisory evaluation is made. Even after an individual is competent to analyze results, the FSEC procedure of a double review of test data and the test report is continued.

#### 5.2.1 Training Program

An effective training program for test personnel has been developed over the past fifteen years at the Florida Solar Energy Center. The program is heavily oriented toward on-the-job training but does include some class-room work as well. A typical training program for a new technician/test operator in the solar thermal test laboratory is described here:

It is important for the trainee to understand the objective of the test program before getting enmeshed in the details of equipment and procedures. For this reason, training begins with classroom instruction in the characteristics of solar collectors and the meaning of the instantaneous efficiency curve. Thermal performance, incident angle modifier and thermal response time are all thoroughly explained and discussed. Materials used for this part of the training include the ASHRAE 93 and 96 test method, FSEC procedures GP-5–80 and GP-6–80, solar collectors, and FSEC-developed visual aids. The trainee is expected to become completely familiar with the ASHRAE 93 and 96 test methods. Additional materials are available in the library for the interested trainee. The classroom training has been conducted by the test manager. Any of the test engineers are also capable of performing the training.

On-the-job training begins with a description of the test stands and instrumentation. Operation of the mechanical portion of the system (pumps, heat exchanger, tracking mechanism, and so forth) is demonstrated. Operational modes of the test stands are somewhat complex and the student requires several test periods before becoming proficient at setting up and operating the system to collect the thermal performance test data. During this time, observation and assistance by a test engineer insures operation and continuing training.

The trainee is also introduced to the instruments used to make test measurements. The level of instruction on instruments varies and is dependent upon whether the trainee is expected to maintain the equipment or only to operate it. The operator trainee is taught how to use the equipment and make any required adjustments. The technician is expected to learn the operation and maintenance of the equipment. Certain calibration procedures are also taught. An example of the latter case is calibration of the temperature sensors.

Test operations are taught by trainee observation of actual test operations and by trainee trial under close supervision of a test engineer. The trainee is not free to independently attempt tests until a supervisory evaluation has been completed. A test engineer is always available for consultation with the test operator even after the training program.

Test operations includes instruction in setting up and operating the mechanical system, the data logger, and the computer system. Also included are instructions on assessing reasonableness of the raw data measurements so that any malfunctions may be recognized and corrected. During this phase of training, the earlier classroom instruction on the ASHRAE 93 and 96 test methods are reinforced to ensure that the test constraints are met.

The last phase of training is intended to give the trainee a complete grasp of the entire test process. The data processing is explained and demonstrated. A set of test data collected by the trainee is carried through to the final test report form.

### 5.2.2 Professional Development

The Florida Solar Energy Center has several specific programs which assure continuing professional development for center personnel. Among these are:

- a. Continuing Education: Center staff members are provided up to six academic hours per semester for continuing education at any of the nine state universities of Florida.
- b. Seminars, Workshops, and Conferences: Center personnel attend various seminars and workshops as participants and as attendees.
- c. Committee Participation: The FSEC supports work on various solar related committees. Center members are active on ASHRAE, ASME, ASTM, IEEE, and other solar committees. FSEC personnel have been very active in developing national solar standards and test methods through committees of IREC, SRCC, and IEEE.
- d. Professional Societies: All of the Center personnel are active within their technical area, most of multiple memberships in ISES, ASHRAE, AMSE, IEEE, ISA, ASTM, and others.
- e. Library: The FSEC maintains an extensive technical library with an emphasis on energy related documents and periodicals.

#### 5.2.3 Job Descriptions

Each position at FSEC has a specific job description and job classification. Whenever an employee terminates, the new employee advertisement includes the job description. Job descriptions are included in Annex A of this manual. Résumés of employees are included in Annex B.

## 5.3 Accommodation and Environmental Conditions

The Florida Solar Energy Center is situated on 15 acres of land on the campuses of Brevard Community College, Cocoa, and the University of Central Florida, Brevard. Structures on the site consist of an office building, a laboratory building with conditioned low-bay space and unconditioned high-bay space, and a central energy plant. The site provides ample space for indoor and outdoor solar test facilities and building expansions.

The solar thermal device test facility occupies a portion of the FSEC grounds. The present facility consists of four mobile tracking platforms, two fluid conditioning carts, one meteorological cart and high bay space to receive, inspect, test and store collectors and solar systems, a conditioned facility for testing solar systems, an indoor solar simulator, a partial meteorological station located on top of the office building and a complete meteorological station located 1.5 miles away.

FSEC's photovoltaic testing facilities include separate shipping and receiving, receiving inspection, environmentally controlled storage area, controlled-access, full-solar view outdoor exposure and test areas, environmentally controlled, class A flash solar simulator, storage battery test facility, rotating-mirror Goniophotometer, various solar and electrical /electronic monitoring instruments and specialized photovoltaic I-V curve tracers and power trackers.

The indoor solar thermal device and photovoltaic test facilities are controlled-access, environmentally controlled (when required) and separated from the office building and shop/ facilities areas to prevent damage and influences from unauthorized personnel and interfering operations such as welding, spray painting and sandblasting.

The specific solar thermal and photovoltaic tests to be performed contain requirements on the upper and lower limits of certain environmental parameters, such as direct normal solar radiation, diffuse solar radiation, wind speed. These limits are detailed in the appropriate ASHRAE, ASTM, IEC, IEEE, ISO, and UL standard or procedure. These parameters are electronically monitored, recorded and reviewed to ensure that the test data was taken while the environmental conditions were within these prescribed limits.

Library-FSEC maintains a extensive technical library with an emphasis on energy related documents and periodicals. When FSEC relocated to Cocoa the FSEC library joined with Brevard Community College and University of Central Florida in a joint-use library.

## 5.4 Test and Calibration Methods Including Sampling

#### 5.4.1 General

FSEC uses the appropriate solar thermal and photovoltaic test methods and procedures as listed in table 5.4.1–1. On exception, FSEC will not follow every aspect of an international or national standard or procedure when either requested by the client or a nonstandard product can not be tested according to the unmodified standard or procedure. Deviations shall be documented, technically justified, authorized and accepted by the client. See sections 5.4.3, 5.4.4, and 5.4.5 for more detail.

FSEC maintains its own Document Control System which contains a copy of all the international and national standards and procedures listed in **table 5.4.1–1**.

Also maintained by the Document Control System are all relevant equipment user's manuals and handling and preparation procedures.

All of the above listed documents (instructions, standards, manuals and reference data) are maintained under original and revised document control and are readily available in copy-only checkout form to personnel from a central location.

The sampling procedure followed by FSEC is covered in section 5.7.

#### 5.4.2 Selection of Methods

Depending on the specific solar thermal or photovoltaic standard product to be tested and the individual client's testing requirements, an appropriate international or national standard or procedure, or combination thereof, shall be selected from table 5.4.1. The latest edition of a standard or procedure shall be used unless it is not appropriate or possible to do so. In such a case, the test report shall indicate that a previous or older test standard or procedure was used, along with the justification.

If a partial, modified, expanded, new or custom test standard or procedure is requested, the request will be evaluated by the Division Director, the Quality Manager and the appropriate test engineering staff to determine the validity, difficulties, limits, conditions and complications of the specific request. A determination will be made if the test should be performed as requested. This determination, along with the limits and conditions, shall be forwarded to the client for approval. Additionally, suggestions of options to the special request may be given to the client for consideration. The client shall then approve and authorize FSEC to proceed with testing

as directed by special request. Any deviations from the complete standard or procedure shall be clearly and completely documented in a specific section of the final test report.

FSEC calibrates some of its own test instruments for in-house use only. These calibrations are performed using the complete and unmodified methods published by the appropriate international or national technical society. Only qualified personnel equipped with adequate resources and calibrated test instrument are used for these calibrations.

### 5.4.3 Laboratory-Developed Methods

Introduction of test methods developed by FSEC for its own use, when no appropriate test method was available. These test methods have been developed by qualified personnel equipped with sufficient facilities, instrumentation, hardware and software to produce a repeatable test sequence which provides technically valid results.

Two examples of solar test methods developed by FSEC include "Simplified Solar Domestic Hot Water System and Component Test Protocols-Draft 1.5: 10/7/1999" and "Test Facility for Photovoltaic Powered Pumps-FSEC 7/2/1993." In each case, a test method was required and none existed for a nonstandard or new product. The first procedure was developed by SRCC, NREL, FSEC and several colleges and has been validated. The second method was developed by FSEC and shall be validated as described in section 5.4.5.

### 5.4.4 Nonstandard Methods

Nonstandardized test methods, as well as standardized test methods, shall be subject to agreement with the client and shall include a clear specification of the client's requirements and the purpose of the test. The methods developed shall be validated appropriately prior to use, and shall be available for examination by the client or other authorized recipient.

### 5.4.5 Validation of Methods

FSEC shall validate nonstandardized method, laboratory-developed methods; standardized methods used outside their intended range and amplifications of standard methods to confirm that the methods are fit for the intended use. FSEC shall document the test method, the validation procedure, the results and include a statement as to whether the method is fit for the intended use.

The validation procedure used shall be at least one of the following:

- calibration using reference standards or reference materials,
- comparison of results achieved with other methods,
- interlaboratory comparison,
- systematic assessment of the factors influencing the results, or
- assessment of the uncertainty of the results based on scientific understanding of the theoretical principals

The client's needs shall be addressed for relevancy by confirming the range and accuracy of the procedure used for validation.

Applicability of the current, unmodified laboratory-developed or nonstandardized test methods shall be checked annually with an expert knowledgeable of currently installed solar systems.

### 5.4.6 Best Measurement Capability

FSEC does not offer calibration services.

### 5.4.7 Estimation Uncertainty of Measurement

FSEC has performed root-sum-square statistical calculations of the uncertainties of measurement associated with the sensors, translators, signal conditioners, analog-to-digital converters and frequency counters that com-

# Table 5.4.1-1FSEC Standards and Procedures (page 1 of 6)

Organization	Document number	Date	Description	Primary	Secondary
ASHRAE	96–1980	1989	Methods of testing to determine the thermal performance of unglazed flat-plate, liquid-type solar collectors		
	93-1986	1986	Methods of testing to determine the thermal performance of solar collectors		
	95–1987	1988	Methods of testing to determine the thermal performance of solar domestic water heating systems		
	125–1992	1992 draft	Method of testing thermal energy meters for liquid streams in HVAC systems		
ASTM	E 816	1981	Standard method for calibration of secondary reference pyrheliometers and pyrheliometers for field use		
	E 824	1981	Standard method for transfer of calibration from reference to field pyranometers		
	E 892	1987	Standard tables for terrestrial spectral irradiance at air mass 1.5 for a 37° tilted surface	e	1
	E 927	1991	Standard specification for solar simulation for terrestrial photovoltaic testing		1
	E 941	1992	Standard test method for calibration of reference pyranometers with axis tilted by the shading method		
	E 973	1991	Standard test method for determination of the spectral mismatch parameter between a photo-voltaic device and a reference cell		1
	E 1036	1996	Standard test methods for electrical perform- ance of nonconcentrator terrestrial photovoltai modules and arrays using reference cells	c	
	E 1038–98	1998	Standard test method for determining resist- ance of photovoltaic modules to hail by impac with propelled ice balls	t	
	E 1171–97	1998	Standard test methods for photovoltaic module in cyclic temperature and humidity environme		1
	E 1362		Standard test method for calibration of noncor centrator photovoltaic secondary reference cell		1
	E 1492	1995	Standard test methods for insulation integrity and ground path continuity of photovoltaic modules		
	E 1830M	1996	Standard test method for determining mechanical integrity of photovoltaic modules [metric]		

# Table 5.4.1-1FSEC Standards and Procedures (page 2 of 6)

Organization	Document number	Date	Description	Primary	Secondary
FSEC	FSEC- GP-5–80	1985	Test methods and minimum standards for certifying solar collectors		
	FSEC- GP-6–80	1985	Operation of the collector certification program		
	FSEC- GP-7–80	1985	Florida standard practice for design and installation of solar domestic water and pool heating systems	<b>1</b>	
	FSEC- GP-8–80	1985	Operations of the Florida Standards program for solar domestic water and pool heating systems		
	NREL/TP- 520–27031	1999	Procedures for determining the performance of stand-alone photovoltaic systems		
	PV-3		Testing requirements for a certification and labeling program for photovoltaic modules		
ISO	ISO 9059	1990	Solar Energy-Calibration of field pyrhelio- meters by comparison to a reference pyrheliometer		
	ISO 9060	1990	Solar Energy-Specification and classification of instruments for measuring hemispherical solar and direct solar radiation	1	
	ISO 9459-1	1993	Solar heating-Domestic water heating systems Part 1: Performance rating procedure using indoor test methods	_	
	ISO 9459–2	1995	Solar heating-Domestic water heating systems Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems	_	
	ISO 9459–3	1997	Solar heating-Domestic water heating systems Part 3: Performance test for solar plus supple- mentary systems		
	ISO 9488	1999	Solar energy-Vocabulary		
	ISO 9553	1997	Solar energy-Methods of testing preformed rubber seals and sealing compounds used in collectors		
	ISO 9806-1	1994	Test methods for solar collectors-Part 1: Thermal performance of glazed liquid heating collectors including pressure drop	<b>1</b>	
	ISO 9806-2	1995	Test methods for solar collectors-Part 2: Qualification test procedures		
	ISO 9806-3	1995	Test methods for solar collectors-Part 3: Thermal performance of unglazed liquid heating collectors (sensible heat transfer only) including pressure drop		

# Table 5.4.1-1FSEC Standards and Procedures (page 3 of 6)

Organization	Document number	Date	Description	Primary	Secondary
ISO	ISO 9808	1990	Solar water heaters-Elastomeric materials for absorbers, connecting pipes and fittings– Method of assessment		
	ISO 9845	1992	Solar energy–Reference solar spectral irradianc at the ground at different receiving conditions- Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5.		
	ISO 9846	1993	Solar energy–Calibration of a pyranometer using a pyrheliometer		
	ISO 9847	1992	Solar energy–Calibration of field pyrano- meters by comparison to a reference pyranometer		
	ISO/TR 9901	1990	Solar energy field pyranometers– Recommended practice for use		
	ISO/TR 10217	1989	Solar energy water heating systems– Guide to material selection with regard to internal corrosion		
	ISO/TR 12596	1996	Solar heating–Swimming pool heating systems; dimensions, design and installation guidelines		
	ISO/DIS 9495	1997 draft	Solar energy–Transparent covers for collectors- Aging test under stagnation conditions	-	1
	ISO/DIS 17025		General requirements for the competence of testing and calibration laboratories.		
	Guide 28	1982	General rules for a model third-party certifica- tion system for products		
	ISO/ TC 180/ SC 4 N 165	1990	Solar energy–Heating systems for swimming pools-Part 1: Design and construction.		
	ISO/ TC 180/ SC 4 N 167	1990	The heating of swimming pools.		
	ISO/ TC 180/ SC 4 N 168	1990	Australian Standard-Solar heating systems for swimming pools.		
	ISO/IEC Guide 7	1994	Guidelines for drafting of standards suitable for use for conformity assessment.		
	ISO/IEC Guide 22	1996	General criteria for supplier's declaration of conformity.		
	ISO/IEC Guide 23	1982	Methods of indicating conformity with standards for third party certification systems.		
	ISO/IEC Guide 27	1983	Guidelines for corrective action to be taken by a certification body in the event of misuse of it mark of conformity		1

# Table 5.4.1-1FSEC Standards and Procedures (page 4 of 6))

Organization	Document number	Date	Description	Primary	Secondary
ISO	ISO/IEC Guide 28	1982	General rules for a model third-party certification system for products.		
	ISO/IEC Guide 43–1	1997	Proficiency testing by interlaboratory comparisons–Part 1: Development and operation of proficiency testing schemes.	1	
	ISO/IEC Guide 43–2	1997	Proficiency testing by interlaboratory comparisons-Part 2: Selection and use of proficiency testing schemes by laboratory accreditation bodies.		
	ISO/IEC Guide 53	1988	An approach to the utilization of a suppliers quality system in third party product certification.		1
	ISO/IEC Guide58	1993	Calibration and testing laboratory accreditati systems-General requirements for operation and recognition.	on	1
	ISO/IEC Guide 60	1994	ISO/IEC Code of good practice for conforminassessment	ty	
	ISO/IEC Guide 61	1996	General requirements for assessment and accreditation of certification/registration bod	ies.	
	ISO/IEC Guide 62	1996	General requirements for bodies operation assessment and certification/registration of quality systems.		1
	ISO/IEC Guide 65	1996	General requirements for bodies operation product certification systems.		
	ISO/IEC 17020	1998	General criteria for the operation of various to of bodies performing inspection.	ypes	
	ISO/IEC TR 17020	1998	General requirements for bodies providing accreditation of inspection bodies.		
	ISO/IEC Draft Guide 66	1998	General requirements for bodies operating assessment and certification/registration of environmental management systems (EMSs)		
	ISO/IEC 61836	1997	Solar photovoltaic energy systems-terms and symbols		
	ISO/IEC 60891	1987	Procedures for temperature and irradiance corrections to measured I-V characteristics o crystalline silicon photovoltaic (PV) devices	f	
	ISO/IEC 60904-1	1987	Photovoltaic devices–Part 1: Measurements of PV current-voltage characteristics	of 🖊	
	ISO/IEC 60904–2	1989	Photovoltaic devices–Part 2: Requirements for reference solar cells	1	
	ISO/IEC 60904–3	1989	Photovoltaic devices–Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradian	ce data	1

# Table 5.4.1-1FSEC Standards and Procedures (page 5 of 6)

Organization	Document number	Date	Description	Primary	Secondary
ISO	ISO/IEC 60904–5	1993	Photovoltaic devices–Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open- circuit voltage method		
	ISO/IEC 60904–6	1994	Photovoltaic devices–Part 6: Requirements for reference of solar modules		
	ISO/IEC 60904–7	1995	Photovoltaic devices–Part 7: Computation of spectral mismatch error introduces in the testing of photovoltaic devices		1
	ISO/IEC 60904–8	1995	Photovoltaic devices-Part 8: Guidance for spectral measurement of spectral response of a photovoltaic (PV) device; Second edition (1998)		
	ISO/IEC 60904–9	1995	Photovoltaic devices-–Part 9: Solar simulator performance requirements		
	ISO/IEC 60906–10	1998	Photovoltaic devices–Part 10: Linearity measurement methods		
	ISO/IEC 61215	1993	Crystalline silicon terrestrial PV modules– design qualification and type approval		
	ISO/IEC 61345	1998	UV test for photovoltaic (PV) methods		
	ISO/IEC 61646	1996	Thin film silicon terrestrial PV modules– design qualification and type approval		
	ISO/IEC 61701	1995	Salt mist corrosion testing of photovoltaic modules		
	ISO/IEC 61721	1995	Susceptibility to a module to accidental impact damage (resistance of impact test)		
	ISO/IEC 61173	1992	Overvoltage protection for photovoltaic power generating systems		
	ISO/IEC 61194	1993	Characteristic parameters of stand-alone photovoltaic systems		
	ISO/IEC 61277	1995	Guide: General description of photovoltaic power generating systems		
	ISO/IEC 61702	1995	Rating of direct coupled photovoltaic pumping systems	g	
	ISO/IEC 61724	1998	Photovoltaic system performance monitoring- guidelines for measurements, data exchange and analysis		
	ISO/IEC 61725	1997	Analytical expression for daily solar profiles		
	ISO/IEC 61727	1995	Photovoltaic systems–Characteristics of the utility interface		
	ISO/IEC 61829	1995	Crystalline silicon photovoltaic array-on-site measurement of IV characteristics	~	

### Table 5.4.1-1 FSEC Standards and Procedures (page 6 of 6)

Organization	Document number	Date	Description	Primary	Secondary
SRCC	Standard 100	1995	Methodology for determining the thermal performance rating for solar collectors		
	Document OG-100	1995	Operating guidelines for certifying solar collectors		
	Document OG-300	1997	Operating guidelines and minimum standards for certifying		
	Document OG-400	1996	Guidelines for certifying compliance with minimum standards for solar swimming pool heating systems		
UL	UL 174	1991	Standard for Safety: Household electric storage tank water heaters		
	UL 1703	1993	Standard for Safety: Flat-plate photovoltaic modules and panels		
VIM	Second Edition	1993	International vocabulary of basic and general terms in metrology		

prise the data acquisition system. Even prior to these calculations, measures have been taken to minimize instrumentation errors. These include constant temperature ovens for the instrumentation to minimize temperature related instrumentation drift, redundant and difference measurements of critical temperature sensors, and historical logs and comparisons of pyranometer files to detect long term trends.

### 5.4.8 Control of Data

Data is monitored in real time prior to actual test data collection to verify test parameter stability. Test data is monitored in a tabular and graphic manner in real time during data collection to ensure data bounds are not exceeded. In addition to the visual monitoring of the real time data, special software is used to automatically verify that predetermined upper and lower test limits are not exceeded. Positive indications are made of data outside of bounds to alert the test engineer that the data being collected is no good. Data is again checked prior to a collected data point being included in the final test report data set. One more data check is performed during final review of the selected data prior to final report release.

## 5.5 Equipment

FSEC owns and maintains all the necessary measurement and test equipment required for the correct performance of tests specific to:

- solar thermal device testing,
- photovoltaic module testing and
- I mall stand-alone photovoltaic system performance determination.

Equipment and its software has been selected and maintained such that it is capable of meeting or exceeding the accuracy required for the test specifications. **Table 5.5–1** contains the vital information necessary to describe FSEC's test equipment. It contains unique identification, brief description, manufacturer's name, model, serial number, current location, record of manufacturer's instruction manual, record of maintenance and repair, last calibration date, and next calibration due date.

# Table 5.5.1-1Laboratory Test Equipment (page 1 of 6)

FSEC ID Number	Nomenclature	Manufacturing model number	Manufacturing serial number	Instruction manual	Calibration frequency
FS043972	Meteorological system		451	yes	N/A
FS069420	Anemometer micro response	Qualimetrics 2030	1953	yes	annual
FS069371	Anemometer micro response	Qualimetrics 2030	1971	yes	annual
FS070103	Sonic anemometer		x2744	yes	annual
S070104	Sonic anemometer		x2744	yes	annual
S069370	Wind vane micro response	Qualimetrics 2020	2458	yes	annual
S069419	Wind vane micro response	Qualimetrics 2020	2478	yes	annual
S067328	Wind vane micro response	Qualimetrics 2020	1470	yes	annual
	Precipitation gauge calibrator	Qualimetrics 60103		yes	annual
S068237	Barometer		N/A	yes	N/A
	Precipitation gauge wind screen	Qualimetrics 6410		yes	N/A
	Platinum temperature probe	Qualimetrics 4470-A		yes	annual
	Dew point thermistor probe	Qualimetrics 5320		yes	annual
	Humidity calibration chamber	Qualimetrics 5150-A		yes	3 to 6 months
	Wind speed module pulse input	Qualimetrics 1222		yes	annual with wind speed sensor
	Wind direction module	Qualimetrics 1240-A		yes	annual with wind direction sensor
	Temperature module platinum resistance sensor	Qualimetrics 1420-A, 1421-A		yes	annual
	Relative humidity module	Qualimetrics 1500 1501		yes	annual with relative humidity sensor
	Dew point temperature module thermistor input	Qualimetrics 1540 1541		yes	annual
	Event accumulator module	Qualimetrics 1600 1601		yes	annual
	Barometric pressure module	Qualimetrics 1705 1706, 1705–001		yes	annual
	Frequency meter	International Microtronics Corp.		yes	annual
	Digital thermometer	Fluke 2100A	30043	yes	annual
	Digital thermometer	Omega 2175A	818017	yes	annual

# Table 5.5.1-1Laboratory Test Equipment (page 2 of 6)

FSEC ID Number		Manufacturing model number	Manufacturing serial number	Instruction manual	Calibration frequency
	Digital multimeter	Fluke 8060A	4285007	yes	annual
	Digital multimeter	Fluke 8060A	3259025	yes	annual
	Digital multimeter	Fluke 8060A	3620907	yes	annual
	Multipoint digital thermometer	Fluke 2166A		yes	annual
	Voltage standard	Fluke, 335D	23000	yes	annual
	HP function	Hewlett Packard 3455A	1622A06258	yes	annual
	Microprocessor-based temperature/process controller	Omega	M1303/0493	yes	N/A
	Power control	Payne Engineering 18TB		yes	N/A
FS069169	Monometer/ calibrator kit	D1025H01		yes	annual
	RIS supercal	RIS CL-6000		yes	annual
FS069193	Pressure converter 200 psig	A0109J001		yes	N/A
FS067090	IV curve tracer	DS-100	1031097	yes	annual
	Thermocouple simulator/calibrator	1120	25960	yes	annual
FS068803	Temperature Bath	Hart Scientific	7011	yes	N/A
FS032480	Scale Toledo Spinks	31564		yes	annual
FFS069836	Scale general	PORTA TRONIC 820	801238R	yes	annual
FS067126	Cyclops 33F thermometer	20001290			
	Thermometer, Brooklyn -1 to 11°C in 0.01° division	22626	20761	yes	Reference Standard
	Thermometer, Brooklyn 9 to 21°C in 0.01° division	22628-AS-D7-FC	93321	yes	Reference Standard
	Thermometer, Brooklyn 19 to 31ºC in 0.01º division	22630-AS-D7-FC	90841	yes	Reference Standard
	Thermometer, Brooklyn 29 to 41ºC in 0.01º division	22632-AS-D7-FC	93322	yes	Reference Standard
	Thermometer, Brooklyn 39 to 51ºC in 0.01º division	22634	96569	yes	Reference Standard
	Thermometer, Brooklyn 49 to 61ºC in 0.01º division	22636	23071	yes	Reference Standard
	Thermometer, Brooklyn 59 to 71ºC in 0.01º division	22638	96568	yes	Reference Standard
	Thermometer, Brooklyn 69 to 81ºC in 0.01º division	22640	0N330	yes	Reference Standard
	Thermometer, Brooklyn 79 to 91ºC in 0.01ºdivision	22642-AS-D7-FC	4N621	yes	Reference Standard
	Thermometer, Brooklyn 89 to 101°C in 0.01° division	22644-D7-AS-FC	28521	yes	Reference Standard

# Table 5.5.1-1Laboratory Test Equipment (page 3 of 6)

FSEC ID Number	Nomenclature	Manufacturing model number	Manufacturing serial number	Instruction manual	Calibration frequency
	Thermometer, Brooklyn 99 to 111ºC in 0.01º division	22650-AS-D7-FC	36540	yes	Reference Standard
	Thermometer, Brooklyn 15 to 40°C in 0.05° division	3527-RM-FC	02921	yes	Reference Standard
FS069796	Eppley total ultraviolet radiometer	TUVR	31717	yes	annual
FS021820	Eppley pyrheliometer (normal incidence)	NIP	14305E6	yes	annual
FS021817	Eppley pyrheliometer (normal incidence)	NIP	14306E6	yes	annual
FS068270	Eppley pyrheliometer (normal incidence)	NIP	19042E6	yes	annual
FS034950	Eppley pyrheliometer (normal incidence)	NIP	21606E6	yes	annual
FS067391	Eppley pyrheliometer (normal incidence)	NIP	26690E6	yes	annual
	Eppley pyrheliometer (normal incidence)	NIP	23826E6	yes	annual
FS040229	Eppley precision infrared radiometer (pyrgeometer)	PIR	24291F3	yes	annual
FS068327	Eppley precision infrared radiometer (pyrgeometer)	PIR	27877F3	yes	annual
FS068324	Eppley precision infrared radiometer (pyrgeometer)	PIR	27878F3	yes	annual
FS068496	Eppley precision infrared radiometer (pyrgeometer)	PIR	28397F3	yes	annual
FS068530	Eppley precision infrared radiometer (pyrgeometer)	PIR	28591F3	yes	annual
FS068531	Eppley precision infrared radiometer (pyrgeometer)	PIR	28592F3	yes	annual
FS040210	Eppley precision infrared radiometer (pyrgeometer)	PIR	188F3	yes	annual
FS068532	Eppley precision infrared radiometer (pyrgeometer)	PIR	28593F3	yes	annual
FS069549	Eppley precision spectral pyranometer	PSP	31204F3	yes	annual
FS035260	Eppley precision spectral pyranometer	PSP	21683F3	yes	annual
FS021759	Eppley precision spectral pyranometer	PSP	14317F3	yes	annual
FS048052	Eppley precision spectral pyranometer	PSP	15284F3	yes	annual
FS024342	Eppley precision spectral pyranometer	PSP	15839F3	yes	annual

# Table 5.5.1-1Laboratory Test Equipment (page 4 of 6)

FSEC ID Number	Nomenclature	Manufacturing model number	Manufacturing serial number	Instruction manual	Calibration frequency
FS039725	Eppley precision spectral pyranometer	PSP	23900F3	yes	annual
FS048458	Eppley precision spectral pyranometer	PSP	8728F3	yes	annual
FS021772	Eppley precision spectral pyranometer	PSP	14392F3	yes	annual
FS021764	Eppley precision spectral pyranometer	PSP	14322F3	yes	annual
FS021763	Eppley precision spectral pyranometer	PSP	14321F3	yes	annual
FS021762	Eppley precision spectral pyranometer	PSP	14320F3	yes	annual
FS021761	Eppley precision spectral pyranometer	PSP	14319F3	yes	annual
FS021759	Eppley precision spectral pyranometer	PSP	14317F3	yes	annual
FS021760	Eppley precision spectral pyranometer	PSP	14318F3	yes	annual
FS048051	Eppley precision spectral pyranometer	PSP	16297F3	yes	annual
FS028453	Eppley precision spectral pyranometer	PSP	16944F3	yes	annual
	Eppley precision spectral pyranometer	PSP	17349F3	yes	annual
FS025846	Eppley precision spectral pyranometer	PSP	18273F3	yes	annual
	Eppley precision spectral pyranometer	PSP	18678F3	yes	annual
FS068269	Pyranometer #8–48		19139	yes	annual
FS035001	Eppley precision spectral pyranometer	PSP	21586F3	yes	annual
FS035041	Eppley precision spectral pyranometer	PSP	21587F3	yes	annual
FS029243	Eppley precision spectral pyranometer	PSP	19884F3	yes	annual
FS068269	Eppley black and white pyranometer	PSP	19139	yes	annual
FS026851	Eppley precision spectral pyranometer	PSP	19241F3	yes	annual
FS029242	Eppley precision spectral pyranometer	PSP	19883F3	yes	annual
FS030566	Eppley precision spectral pyranometer	PSP	20653F3	yes	annual

# Table 5.5.1-1Laboratory Test Equipment (page 5 of 6)

FSEC ID Number	Nomenclature	Manufacturing model number	Manufacturing serial number	Instruction manual	Calibration frequency
FS030566	Eppley precision spectral pyranometer	PSP	20653F3	yes	annual
FS033266	Eppley precision spectral pyranometer	PSP	21063F3	yes	annual
FS033267	Eppley precision spectral pyranometer	PSP	21065F3	yes	annual
FS033268	Eppley precision spectral pyranometer	PSP	21066F3	yes	annual
FS035261	Eppley precision spectral pyranometer	PSP	21682F3	yes	annual
FS035041	Eppley precision spectral pyranometer	PSP	21587F3	yes	annual
FS035002	Eppley precision spectral pyranometer	PSP	21581F3	yes	annual
FS035001	Eppley precision spectral pyranometer	PSP	21586F3	yes	annual
FS035260	Eppley precision spectral pyranometer	PSP	683	yes	annual
FS037371	Eppley precision spectral pyranometer	PSP	23615F3	yes	annual
FS037372	Eppley precision spectral pyranometer	PSP	23616F3	yes	annual
FS037373	Eppley precision spectral pyranometer	PSP	23617F3	yes	annual
FS039723	Eppley precision spectral pyranometer	PSP	23891F3	yes	annual
FS039724	Eppley precision spectral pyranometer	PSP	23892F3	yes	annual
FS039725	Eppley precision spectral pyranometer	PSP	23900F3	yes	annual
FS040239	Eppley precision spectral pyranometer	PSP	24182F3	yes	annual
FS040238	Eppley precision spectral pyranometer	PSP	24183F3	yes	annual
FS040237	Eppley precision spectral pyranometer	PSP	24184F3	yes	annual
FS040235	Eppley precision spectral pyranometer	PSP	24185F3	yes	annual
FS040284	Eppley precision spectral pyranometer	PSP	24269F3	yes	annual
FS040285	Eppley precision spectral pyranometer	PSP	24270F3	yes	annual

## Table 5.5.1-1Laboratory Test Equipment (page 6 of 6)

FSEC ID Number	Nomenclature	Manufacturing model number	Manufacturing serial number	Instruction manual	Calibration frequency
FS029242	Eppley precision spectral pyranometer	PSP	883	yes	annual
FS029243	Eppley precision spectral pyranometer	PSP	884	yes	Annual
FS040235	Eppley precision spectral pyranometer	PSP	24185F3	yes	Annual
FS040237	Eppley precision spectral pyranometer	PSP	24184F3	yes	Annual
FS043935	Eppley precision spectral pyranometer	PSP	25768F3	yes	Annual
FS048166	Kipp & Zonen pyranometer	CM 6B	61245	yes	Annual
FS048371	Kipp & Zonen pyranometer	CM 6B	71649	yes	Annual
FS048373	Kipp & Zonen pyranometer	CM 6B	71650	yes	Annual
FS048372	Kipp & Zonen pyranometer	CM 6B	71651	yes	Annual
FS048167	Kipp & Zonen pyranometer	CM 6B	61239	yes	Annual
FS068946	Flow meter turbine EG&G flow technology	FT4-8AENW-LEG-2	84010787	yes	with each test
FS068947	Flow meter turbine EG&G flow technology	FT4-8AENW-LEG-2	84010785	yes	with each test
FS068948	Flow meter turbine EG&G flow technology	FT4-8AENW-LEG-2	84010786	yes	with each test
FS068949	Flow meter turbine EG&G flow technology	FT4-8AENW-LEG-2	84010788	yes	with each test
FS068950	Flow meter turbine EG&G flow technology	FT4-8AENW-LEG-2	8607566	yes	with each test
FS068951	Flow meter turbine EG&G flow technology	FT4-8AENW-LEG-2	8607568	yes	with each test
FS068952	Flow meter turbine EG&G flow technology	FT4-8AENW-LEG-2	8607567	yes	with each test
FS033843	Flow meter, turbine F-16		1601931	yes	with each test
FS033843	Flow meter, turbine F-16		1601932	yes	with each test
FS043976	Flow meter FT 4–8 Carbide Jounal		8406179	yes	with each test
FS043977	Flow meter FT 4–8 Carbide Jounal		8406180	yes	with each test
FS043978	Flow meter FT 4–8 Carbide Jounal		8406181	yes	with each test
FS043979	Flow meter FT 4–8 Carbide Jounal		8406182	yes	with each test
FS043980	Flow meter FT 4–8 Carbide Jounal		8406183	yes	with each test

The form below is used to document and record equipment discrepancies.

Equipment Identifier	_ Date	/	/
Check all that apply.			
<ul> <li>Overload</li> <li>Mishandling</li> <li>Suspect Results</li> <li>Defective</li> <li>Outside specified limits</li> <li>Maintenance</li> <li>Damage</li> <li>Malfunction</li> <li>Modification</li> <li>Repair</li> </ul>			
Complete description of event, including observer's name, test and section b of observation and the test set-up, range and connections.	eing perfo	rmed at	the time
Observer:			
Test and section: Date of event/ Date of correction/			

## 5.6 Measurement Traceability

#### 5.6.1 General

All laboratory test equipment at the Florida Solar Energy Center used to test solar equipment is maintained in current calibration. The Test Instrument Manual includes information specific to the requirements for maintaining calibration, inventory, and operation of the laboratory test equipment. Information in the manual includes equipment manufacturers' manuals, calibration records, and location. Where applicable the specific uses of the equipment is identified and explained.

The Test Instrument Manual also defines calibration frequency requirements, traceability requirements, calibration sources, and documentation locations. Detailed calibration procedures and measurement accuracy are included in the equipment manuals and other manufacturer provided documents.

### 5.6.2 Equipment

All measurement equipment used for thermal performance/durability tests shall be maintained in calibration as recommended by the equipment manufacturer to maintain accuracy or as required by ASHRAE 93 or 96. In case of conflict between the two recommendations on frequency of calibration, the shorter time period shall be used. In no condition shall the calibration period be greater than one year. All equipment which requires calibration are listed. Equipment by type is listed below.

#### Measurement

#### Equinment

mousul chicht	-quipment
Solar Radiation	Pyranometers and Pyrheliometers
Flow Rates	Turbine Flow Meters, Scale, Timers
Temperatures and Resistance	Thermometers and Electronic Bridges
Analog to Digital Computer	Data Logger
Calibration Voltage Source	Voltage Standard
Temperature Calibration	Glass Thermometers

#### 5.6.3 Measurement Traceability and Calibration

The Quality Manager maintains the Test Instrument Manuals for the laboratory. This includes calibration history, calibration schedule, procedures for handling and preparation of items for calibration, calibration providers. All measuring and testing equipment having an effect on the validity of tests is calibrated before being put into service. The overall program of calibration, verification, and validation of measurement and test equipment is designed and operated to ensure that measurements made by FSEC are either traceable to national standards of measurement or recognized natural physical constants, or as otherwise noted.

Solar radiation measuring instrumentation employed in the FSEC program is traceable to the World Radiometric Reference (WRR) through an absolute, self-calibrating cavity pyrheliometer that regularly participates in International Pyrheliometric Comparisons.

Calibration certificates indicate the traceability to national standards of measurement, or to the WRR, or to natural constants and provide either the measurement results and associated uncertainty of measurement or a statement of compliance with an identified specification. Calibration records document the as-found values and FSEC's tolerance limits for each instrument or device requiring calibration.

Should traceability to national or international standards of measurement or other direct means of validation not be possible or practicable, FSEC provides other satisfactory evidence of verification of its measurement or test results, for example, by participation in a suitable program of interlaboratory comparisons or proficiency testing.

The Reference Sources of measurement maintained by FSEC are used for calibration only and for no other purpose. The use of these Reference Sources is described in the individual calibration procedures for each laboratory. An independent third body that provides certified traceability to a national or international standard of measurement calibrates the Reference Sources annually.

The Quality Manager is responsible for maintaining a comprehensive calibration-scheduling program and is responsible for alerting staff of all calibration due dates. Historical records are kept of all instruments used for testing and calibration of testing equipment from the time of purchase until the property is disposed of. This period, for some items, may exceed five years.

The Test Engineer documents methods and procedures for all tests and test apparatus calibrations and related activities within his scope of activities, including sampling, handling, transport, storage, and preparation of items to be tested or calibrated, and estimation of uncertainty of measurement or analytical error in the calibration or test data. If possible, errors should be divided into bias (systematic) and precision (random) errorthat is, uncertainty analysis (for example, ANSI/ASME PTC 19.1–1985, Part 1, Measurement Uncertainty Instruments and Apparatus). These procedures shall be consistent with the uncertainty level required, and with any standard specifications relevant to the calibrations or tests concerned.

Where methods are not specified by the client or by the requirements of the quality control documentation, the laboratory shall select appropriate methods that have been published either as national or international standards (for example, ASTM, IEEE, ANSI, IEC and ISO, or UL), or by reputable technical organizations, or in relevant scientific texts or journals. Reference to, and deviations from, the methods and procedures shall be clearly documented and made available to the laboratory test operator and client.

Where it is necessary to employ methods that have not been established as consensus standards according to the preceding paragraph, these shall be subject to agreement with the client, be fully documented and validated, and be available for examination by the client and other authorized recipients of the relevant reports.

Where sampling is carried out as part of a test method, the laboratory shall use documented procedures and appropriate statistical techniques to select samples.

Calculations and data transfers shall be subject to appropriate independent checking as noted in the section of this document entitled "Audit and Review, and Verification Practices" (above).

When computers or automated equipment are used for the capture, processing, manipulation, recording, reporting, storage, or retrieval of test and calibration data, the laboratory shall ensure that

Computer software is documented and validated as adequate for use

Procedures are established and implemented for protecting the integrity of data; such procedures shall

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include, but not be limited to, integrity of data entry or capture, data storage, data transmission, and data processing

- Computer and automated equipment is maintained to ensure proper functioning and provided with environmental and operating conditions necessary to maintain the integrity of test and calibration data
- Appropriate procedures are documented and implemented to maintain security of data, including the prevention of unauthorized access to, and amendment of, computer records
- The documented procedures to meet the foregoing requirements conform to the guidelines stated in ASTM E 1579, or equivalent. The laboratory shall have an established program for the calibration and verification of its measuring and test equipment, including the use of necessary reference materials and reference standards and appropriate independent, between-calibration checks.

As relevant, any reference standards, including on-site primary, transfer, or working standards, and designated measuring and testing equipment, shall be subjected to in-service checks between calibrations and verifications.

Reference materials shall be traceable to national or international standards of measurement or to national or international certified standard reference materials, unless it can be demonstrated that neither is possible.

All procedures for in-house calibration shall be documented, including an estimation of uncertainty. These should include acceptance criteria and corrective action if equipment falls outside these criteria.

## 5.7 Sampling

FSEC strictly follows a published and distributed Random Selection Procedure in order to properly select a solar collector for test. It is contained in FSEC publication "Operation of a Collector Certification Program" FSEC-GP-6–80 section 3.1, when the certification process starts when an approved FSEC representative, either an FSEC employee or an impartial selecting official, shall select for test a production-unit solar collector at random from existing stock at the manufacturer's plant or distribution point. The manufacturer must present at least five units for the selecting official to choose from. After the selection is complete, an FSEC label is placed on the selected collector by the official. Random selection forms, completed by both the selecting official and the manufacturer's representative, are also required as part of this sampling process. The random selection form is three parts, there is an FSEC copy, a manufacturer's representative copy that stays with the representative and a laboratory copy to accompany the collector to our lab or another accredited lab.

A similar procedure shall be followed for selecting a photovoltaic system for system level testing. Additionally, photovoltaic module selection for module testing shall require the selection of typically nine to eleven modules or more for a complete test sequence.

# 5.8 Handling and Transportation of Test and Calibration Items

FSEC follows procedures and maintains appropriate facilities to protect and safeguard test items from deterioration, loss or damage during transportation, receipt, preparation, handling, storage, testing, retention, and final return, distribution or disposal. If specific instructions for a test item are provided by or requested of the manufacturer or their representative, they will be reviewed and followed. All special care instructions shall be included with the test item documentation package which follows the test item through the testing sequence(s). When specified environmental conditions are required, these conditions shall be maintained, monitored and recorded. These records shall also be included in the test item's documentation package. FSEC shall provide storage and security that protects the condition and integrity of the secured test items.

FSEC utilizes a positive, unique and permanent system for identifying test items. This system ensures that test items cannot be confused physically, or that records in the documentation package or the electronic computerized database cannot be confused. The unique identification alphanumeric characters assigned to the test

item or system during the random selection process or receiving inspection shall be retained throughout the life of the test item in the laboratory. This system also provides for subdivision of components from a photo-voltaic system during individual component characterization, testing and evaluation.

Upon receipt of a test item, any abnormalities or departures from normal or specified conditions shall be recorded in the documentation package. In the event of a problem, the laboratory shall consult the client for further instructions before proceeding and record the discussion and subsequent instructions and directions.

## 5.9 Assuring the Quality of Test and Calibration Results

FSEC ensures the quality of all of its test results by monitoring all of its test results. Despite the fact that all solar thermal and photovoltaic test data acquisition is computer automated, all test data are monitored in a graphic and/or tabular manner in real time at the test site. Monitoring is performed in this manner to verify that the environmental test conditions are within specifications during test data collection and to verify stability requirements. Additionally, final tabular test data is reviewed for upper and lower limits and stability.

FSEC participates in interlaboratory comparison programs of solar radiation instruments, solar collectors, photovoltaic modules and photovoltaic reference cells.

Sections of standardized tests are replicated according to international and national standards and procedures or FSEC policy. For example, test data is collected from solar thermal devices a minimum of four times at four different temperatures. This yields a minimum of sixteen data points that are used for calculations to curve fit the thermal performance curve family. Similarly for photovoltaic devices, a minimum of three I-V curves are collected for electrical performance and a minimum of three I-V curves are collected per temperature for temperature coefficient calculations.

Also, complete test sequences are occasionally repeated on retained solar collectors.

This practice provides a system level approach to determining short-term and long-term differences.

Additionally, test results are correlated against material and construction characteristics of a collector, module or system. Test results used include thermal performance curve fit, efficiency, incident angle modifier, time constant and short term durability for solar thermal devices and open-circuit voltage, short-circuit current, maximum power point, efficiency, and temperature coefficients for photovoltaic devices.

FSEC's test equipment hardware and software is safeguarded from unauthorized or undocumented changes.

FSEC uses an equipment sticker/seal system to label, code, identify and indicate the status of calibration on all of its vital test equipment.

All test data collection and test report software shall contain original and modification date records in either the header or footer of the program line listing. A running record of software correction factor changes shall be maintained in the line listing or the accompanying data read file. This provides an easy reference to see that the correctly updated test equipment hardware is used with the correctly updated software.

### 5.10 Reporting the Results

#### 5.10.1 General

#### Documentation Maintenance

The Quality Manager retains current and previous versions of all documents pertaining to quality assurance, calibrations, and test procedures. Changes to these documents will be made only with the approval of the Quality Manager. The Test Engineers and technicians shall be informed of all changes via Email. The Quality Manager and the Test Engineer shall review the documentation on at least a yearly basis. The documents are maintained on a database accessible through an Intranet web system that is available to all employees and is open for review to any auditors. Each time a document or a form is required it is accessed through the web system and thus the latest version is always available.

#### 5.10.2 Test reports and calibration certificates

#### 5.10.3 Test Reports

FSEC test reports for solar thermal devices and for photovoltaic modules and system shall include the following information as a minimum:

1) a title;

- 2) name and address of laboratory, and location where tests were carried out;
- 3) unique identification of the test report (such as serial number) on each page and a clear identification of the end of the test report;
- 4) name and address of the client placing the order;
- 5) description and unambiguous identification of the item(s) tested;
- 6) date of receipt of test item(s) and date(s) of performance of the test(s);
- 7) test results with units of measurement, or dimensionless ratio if a percentage;
- 8) reference to sampling procedures used by the laboratory;
- 9) the name(s), function(s) and signature(s) of person(s) authorizing the test report;
- 10) where relevant, a statement to the effect that the test results relate only to the items tested;
- 11) a consistently placed statement regarding any deviations, substitutions, deletions, additions, or modification to any part of the test sequence(s).

In addition, each test report shall bear the statement, "This test report shall NOT be reproduced except in full, without the written approval of FSEC."

#### Approval Signatories

The Quality Manager determines the individuals authorized to sign FSEC laboratory test reports and certifications. The criterion for selecting these individuals is also determined by the Quality Manager and is related to the type of test performed. All tests shall have a minimum of two signatures, the test engineer and Program Director.

#### 5.10.4 Calibration Certificates

Calibration certificates indicate the traceability to national standards of measurement, or to the WRR, or to natural constants and provide either the measurement results and associated uncertainty of measurement or a statement of compliance with an identified specification. Calibration records document the as-found values and FSEC's tolerance limits for each instrument or device requiring calibration.

Should traceability to national or international standards of measurement or other direct means of validation not be possible or practicable, the laboratory shall provide other satisfactory evidence of verification of its measurement or test results, for example, by participation in a suitable program of interlaboratory comparisons or proficiency testing.

The Reference Sources of measurement maintained by FSEC are used for calibration only and for no other purpose. The use of these Reference Sources is described in the individual calibration procedures for each laboratory. A independent third body that provides certified traceability to a national or international standard of measurement calibrates the Reference Sources annually.

The Quality Manager is responsible for maintaining a comprehensive calibration-scheduling program and is responsible for alerting staff of all calibration due dates. Historical records are kept of all instruments used for testing and calibration of testing equipment from the time of purchase until the property is disposed of. This period, for some items, may exceed five years.

### 5.10.5 Options and Interpretations

#### 5.10.6 Testing Results Obtained from Subcontractors

Whenever it is necessary to have tests or calibrations performed outside of FSEC, the Quality Manager shall verify by documentation review that the work performed by a subcontractor was performed at a facility that conforms to all applicable portions of ISO 17025 for the required test and/or calibration.

#### 5.10.7 Electronic Transmission of Results

In the case of transmission of test results via telephone, cellular phone, satellite, E-mail, fax, floppy diskette, CD-ROM or other electronic or electromagnetic means, the requirements of ISO 17025 shall be met.

#### 5.10.8 Format of Reports and Certificates

Standard and complete test report formats have been developed and used by FSEC to report test results of solar thermal devices and photovoltaic modules and systems. These formats meet and exceed the test report requirements of section 5.10.3.

### 5.10.9 Amendments to Test Reports

Material amendments to a test report after issue shall be made only in the form of a further document, or data transfer, which include the statement "A Supplement to Test Report, serial number...[or as otherwise identified]", or an equivalent form of wording. Such amendments shall meet all the requirements of ISO 17025.

When it is necessary to issue a complete new test report, it shall be uniquely identified and shall contain a reference to the original that it replaces.

## Annex A. Position Descriptions

Position Title: Position Description: Specific Duties:	<b>Quality Manager</b> This position is a senior level engineering position. Position responsibilities include implementing and maintaining the total Quality Plan, performing quality audits, technical evaluations of equipment, systems and procedures, specification develop- ment, evaluation of equipment test procedures, document tracing/storage and filing. Assist the Quality Technical Manager with implementing the Total quality Plan.
	Maintain the documents in the quality system including drafting, changing, and issuing up-to-date documents. These include all documents in the quality system, documents for performing testing, and calibration.
	Identify appropriate computer programs for use in FSEC's quality plan
Educational Requirement:	Respond to public's request for system test information. MS degree or BS degree and equivalent experience.
<b>Position Title:</b> Position Description:	Associate Engineer (TESTS) (Test Engineer) This position is a senior level engineering position. Position responsibilities include measuring the performance, within the specific technical specialty, of system designs, technical evaluations of equipment, systems and procedures, specification development, equipment testing, preparation of system designs for solar demonstration projects and preparation of solar documents for public distribution, analysis.
Specific Duties:	Conducting collector performance tests and preparation of test reports.
Educational Requirement:	Respond to public's request for solar energy information. MS degree or BS degree and equivalent experience.
Position Title:	Senior Engineering Technician/Designer
<b>Position Description:</b>	This position functions as an engineering technician for the
Specific Duties:	Testing and Operations Division. Fabricates, installs and calibrates a variety of electronic and mechanical instru- ments used in solar energy research and/or demonstration projects (for example, complex test stands, weather and solar radiation measuring stations).
	Repairs and replaces controls instrumentation, (for example, temperature and pressure transducers on test stands). Repairs a variety of complex electronic equipment (for example radiation measuring devices, data logger, weather station instrumentation). Repairs mechanical equipment (for example tracking motors on solar energy collector that stands).
	Provides the professional research staff specifications on less complex compo- nents of the data acquisition and analysis system. Collects and records test data. Replaces tapes used to collect test data. Performs engineering computations and provides summaries and/or reports to the professional research staff.
	Connects equipment and performs hydraulic pressure tests on collectors. Installs collectors on test stands, connects fittings and prepares for tests.
Educational Requirement:	Design electrical power connections to supply power to test and shop equip- ment. Layout and connects power and instrumentation feeder lines. High school graduation plus 1.5 years of related experience.

Position Title: Position Description: Specific Duties: Educational Requirement:	<b>Engineering Technician/Designer</b> This position functions as an engineering technician in the Testing and Operations Division. Responsibilities include planning and setting up tests, conducting tests of solar collectors and other solar devices, maintaining test schedules, processing data and calibrating equipment. Sets up tests for collectors, coordinates test operations, operates electronic meas- urement systems and computers to collect and record data. High school graduation plus 4 years experience in a research laboratory.
Position Title:	Research Engineering Support Specialist
Position Description:	This is work performing technical support in the erection, Description:
<b>Specific Duties:</b> (not all inclusive)	maintenance, and/or operation of sophisticated equipment for a research project. Installs, tests, and maintains equipment using knowledge not normally accessible to technicians.
	Performs major maintenance or schedules overhaul of specific equipment.
	Instructs others in use, operation, and preventative maintenance where applicable.
	Maintains operational logs and diaries.
Educational Requirements:	A high school diploma and three years of appropriate experience. Appropriate vocational/technical/manufacturers training may substitute for two years of the required experience.
<b>Position Title:</b> Position Description:	<b>Senior Research Engineering Support Specialist</b> This is work planning and coordinating the erection, maintenance, and/or operation of sophisticated equipment for a research project.
<b>Specific Duties:</b> (not all inclusive)	Coordinates the installation, testing, run-in, and scheduled maintenance program for specific equipment.
	Coordinates assigned projects and/or processes to provide cost effectiveness and return on investment.
	Designs and implements training programs for the use, operation, and preventa- tive maintenance where applicable.
	Evaluates and analyzes operational logs and diaries.
	Develops schedules and work plans for installing, testing, and maintenance activities.
Educational Requirements:	A high school diploma and four years of appropriate experience. Appropriate vocational/technical/manufacturers training may substitute for two years of the required experience
Position Title:	Engineer
Position Description:	This is work designing and implementing one or more aspects Description: of an engineering/architectural project or study.
Specific Duties:	Designs facilities, maintenance operations and control systems.
(not all inclusive)	Performs engineering/architectural studies and prepares efficiency and perform- ance reports.
	Researches topics and/or co-authors research papers for publication.
	Reviews design reports, plans, and specifications.

	Instructs others in the use and operation of research equipment.
	Coordinates the work of architects, engineers, and contractors on projects.
	Performs conceptual design of specialized research equipment.
<b>Education Requirements:</b>	A bachelor's degree in an appropriate area of specialization or a
	high school diploma and four years of appropriate experience.
	Appropriate college coursework or vocational/technical training may substitute at
	an equivalent rate for the required experience.

## Annex B. Resumes

Individual resumes are not included in this document, but are available to auditors.

## Annex C. Solar Collector Documentation Package

**Collector Receiving Form** 

Collector Test Log

**Collector Shipment Form** 

Certification Changes

#### **Collector Receiving Form**

Any collector damage noted?  NO YES Explain: Note any random selection stickers. Organization: FSEC SRCC Number of stickers: Location of stickers:	/ES frame, header and seals.
Model:Any container damage noted?	/ES frame, header and seals.
Any container damage noted?  NO YES Explain: Any brackets, literature, loose components, and so forth?  NO YES Explain: Any collector for shipping damage. Pay particular attention to glazing,  Any collector damage noted?  NO YES Explain: Note any random selection stickers. Organization:  FSEC SRCC Number of stickers: Location of stickers:	frame, header and seals.
Any container damage noted?  NO YES Explain: Any brackets, literature, loose components, and so forth?  NO YES Explain: Any collector for shipping damage. Pay particular attention to glazing,  Any collector damage noted?  NO YES Explain: Note any random selection stickers. Organization:  FSEC SRCC Number of stickers: Location of stickers:	frame, header and seals.
Any brackets, literature, loose components, and so forth? □ NO □ Y Explain:	frame, header and seals.
Explain:	frame, header and seals.
Explain:	frame, header and seals.
Inspect collector for shipping damage. Pay particular attention to glazing, Any collector damage noted?	
Any collector damage noted?  NO YES Explain: Note any random selection stickers. Organization: FSEC SRCC Number of stickers: Location of stickers:	
Note any random selection stickers. Organization:  FSEC  SRCC Number of stickers: Location of stickers:	
Organization:  FSEC  SRCC Number of stickers: Location of stickers:	
Organization:  FSEC  SRCC Number of stickers: Location of stickers:	
Number of stickers:	
-	
🗆 Put collector in pre-exposure storage.	
$\Box$ Give this form to the T&O department secretary.	
T&O Secretary	
□ Start collector file.	
Create collector record in Certify database.	
$\Box$ Request any needed documentation or fees from company.	
Test requested:	
Fees paid:	
T&O Director	
Test Authorized:	
(Director, T&O)	
□ Return to testing personnel.	

#### **Collector Test Log**

Dogo	1	~	£	-1	
Pane				- 1	

SUMMARY PAGE
FILE NUMBER:
MANUFACTURER:
CONTACT PERSON:
PHONE NUMBER:
MODEL NUMBER:
SERIAL NUMBER:
RECEIVED DATE:
GROSS FRONTAL AREA:
TRANSPARENT FRONTAL AREA:
ASHRAE TEST FLOW RATE, WATER
GLAZED: (transparent area (ft <sup>2</sup> ) * 0.0294 =gpm
UNGLAZED: (transparent area (ft <sup>2</sup> ) * 0.1030 =gpm
MANUFACTURER'S RECOMMENDED FLOW RATE:gpm
Flow calibration constant:
Nominal rpm:
MAXIMUM OPERATING PRESSURE:
DATE EXPOSURE STARTED:

SKETCH OF COLLECTOR SHOWING TEST ORIENTATION

Revised 12/15/99

A. COLLECTOR IDENTIFICATION Manufacturer and Address:	A. COLLECTOR IDENTIFICATION Manufacturer and Address: Collector Model Number: B. COLLECTOR CONSTRUCTION (FSEC Measurements) Overall dimensions (in ft. to 3 decimal places) Length:
Manufacturer and Address:	Manufacturer and Address:
B. COLLECTOR CONSTRUCTION (FSEC Measurements) Overall dimensions (in ft. to 3 decimal places) Length:	<b>B. COLLECTOR CONSTRUCTION</b> (FSEC Measurements) <i>Overall dimensions</i> (in ft. to 3 decimal places) Length:
B. COLLECTOR CONSTRUCTION (FSEC Measurements) Overall dimensions (in ft. to 3 decimal places) Length:	<b>B. COLLECTOR CONSTRUCTION</b> (FSEC Measurements) <i>Overall dimensions</i> (in ft. to 3 decimal places) Length:
(FSEC Measurements)         Overall dimensions (in ft. to 3 decimal places)         Length:	(FSEC Measurements) Overall dimensions (in ft. to 3 decimal places) Length:
Overall dimensions (in ft. to 3 decimal places)         Length:	Overall dimensions (in ft. to 3 decimal places) Length:
Length:   Width:   Depth:   Cover material(s):   Transparent frontal dimensions (in ft. to 3 decimal places)   (For estimated measurements, make best guess here. Record actual measurements when the collector is disassembled in section O.)   Length (Est."):   Width:	Length:
Length:   Width:   Depth:   Cover material(s):   Transparent frontal dimensions (in ft. to 3 decimal places)   (For estimated measurements, make best guess here. Record actual measurements when the collector is disassembled in section O.)   Length (Est."):   Width:	Length:
Depth:	
Depth:	Width:
Cover material(s):	Depth:
Transparent frontal dimensions (in ft. to 3 decimal places)   (For estimated measurements, make best guess here. Record actual measurements when the collector is disassembled in section O.)   Length (Est."):	Overall front area: (length x width) = Cover material(s):
Length (Est."):	<i>Transparent frontal dimensions</i> (in ft. to 3 decimal places) (For estimated measurements, make best guess here. Record actual measurements when the collector is
Width:   Area:   Est. Thickness:   Est. Thickness:   Cover plate length:   Surface characteristics:   Surface characteristics:   Est. Seal:   Absorber (in ft. to 3 decimal places) Assumed Material(s): Est. Length: Est. Vidth: Est. Plate thickness (x.xxx inches): Flow pattern: Surface of tubes: St. On-center spacing of tubes (x.xxx inches): Est. Tube diameter (in inches to 3 decimal places): Concenter spacing of tubes to 3 decimal places): Concenter spacing of tubes of 3 decimal places): Concenter spacing of tubes of 3 decimal places): Concenter space of tu	
Area:	
Est. Thickness:	Width:
Est. Cover plate length:	Area:
Cover plate width:	
Surface characteristics:	
Est. Seal:	
Absorber (in ft. to 3 decimal places)         Assumed Material(s):         Est. Length:         Est. Width:         Est. Plate thickness (x.xxx inches):         Flow pattern:         Number of tubes:         Est. On-center spacing of tubes (x.xxx inches):         Est. Tube diameter (in inches to 3 decimal places):         O         Header diameter (in inches to 3 decimal places):         O         Assumed Plate to tube bonding method:         Assumed Tube to header bonding method:         Assumed Coating:	Surface characteristics:
Assumed Material(s):	ESt. Seal:
Assumed Material(s):	Absorber (in ft. to 3 decimal places)
Est. Length:	
Est. Width:	
Est. Plate thickness (x.xxx inches):	•
Flow pattern:	
Number of tubes:	
Est. On-center spacing of tubes (x.xxx inches):O Est. Tube diameter (in inches to 3 decimal places):O Header diameter (in inches to 3 decimal places):O Assumed Plate to tube bonding method:Assumed Tube to header bonding method:Assumed Tube to header bonding method:Assumed Coating:Assumed Coating:A	Number of tubes:
Est. Tube diameter (in inches to 3 decimal places):O Header diameter (in inches to 3 decimal places):O Assumed Plate to tube bonding method:Assumed Tube to header bonding method:Assumed Tube to header bonding method:Assumed Coating:Assumed Coating:Ass	Est. On-center spacing of tubes (x.xxx inches):
Assumed Plate to tube bonding method:	Est. Tube diameter (in inches to 3 decimal places):
Assumed Plate to tube bonding method:	Header diameter (in inches to 3 decimal places):O
Assumed Tube to header bonding method:Assumed Coating:	Assumed Plate to tube bonding method:
	Assumed Tube to header bonding method:
Est. Air spacing, glazing to absorber:	
	Est. Air spacing, glazing to absorber:

Collector Test Log		Page 3 of 12
	FSEC#	
Enclosure		
Material (sides):		
Material (back):		
Surface finish:		
Fasteners:		
Holes & cutouts:		
Insulation (measure in inches to 3 decimal places)		
Assumed Side material:		
Est. Side thickness:		
Assumed Back material(s):		
Est. Back thickness(es):		
Assumed Caulking, sealant, and/or gasket type(s):		
Dry collector weight (in lbs. to 1 decimal place):		
Manufacturer's data? 🗆 Yes 🔅 No		
Full Collector weight, filled (in lbs. to 1 decimal place):		
Weight, fittings (in lbs. to 1 decimal place):		
Weight, water (in lbs. to 1 decimal place):		
(full collector)–(dry collector)–(fittings)		
Water temp.:		
Water density @ water temp (lb/gal):		
Water volume (in gal {water weight}/{water density} to 1 decimal place):		
Collector fluid capacity (in gal. to 1 decimal place):		
Manufacturer's data?  I fes I no		
C. PRE-EXPOSURE INSPECTION		
Manufacturer:		
File No.		
Initials:		
Initial5		
Collector Case, Enclosure, & Fasteners		
A. Cracking:		
B. Warping: Yes No		
C. Corrosion: $\Box$ Yes $\Box$ No		
D. Other:		
· · · · · ·		
Mounting Means (Mounting brackets, flanges, and so forth)		
A. Loss of Integrity:  Yes No		
B.Other:		
	Re	vised 12/15/99

Collector Test Log			FSEC# _	Page 4 of 1
Seals and Gaskets				
A. Cracking:	🗆 Yes	🗆 No		
B. Loss of Elasticity:	$\Box$ Yes	$\square$ No		
C. Loss of Adhesion:	$\Box$ Yes	□ No		
D. Other:				
Cover(s)/or Reflector(s)				
A. Cracking:	🗌 Yes	🗌 No		
B. Crazing:	🗌 Yes	🗌 No		
C. Buckling:	🗆 Yes	🗆 No		
D. Warping:	🗆 Yes	🗆 No		
E. Delamination:	🗆 Yes	🗆 No		
F. Other:				
Absorber Coating				
A. Crazing:	🗆 Yes	🗌 No		
B. Cracking:	🗆 Yes	🗌 No		
C. Blistering:	🗆 Yes	🗌 No		
D. Other:				
Absorber Inlet & Outlet	Tubes			
A. Deformation:	🗆 Yes	🗆 No		
B. Corrosion:	🗆 Yes	🗆 No		
C. Leakage:	🗆 Yes	🗆 No		
D. Other:				
Absorber Flow Tubes				
A. Deformation:	🗆 Yes	🗆 No		
B. Corrosion:	🗆 Yes	🗌 No		
C. Leakage:	🗆 Yes	🗌 No		
D. Loss of Bonding:	🗌 Yes	🗌 No		
E. Other:				
Absorber Headers				
A. Deformation:	🗆 Yes	🗆 No		
B. Corrosion:	🗆 Yes	🗆 No		
C. Leakage: D. Other:	□ Yes	□ No		
Absorber Mountings				
A. Loss of Integrity:	🗆 Yes	🗆 No		
B. Other:				
			R	evised 12/15/9

Collector Test Log	Page 5 of 12
	FSEC#
Insulation	
A. Water Retention: $\Box$ Yes $\Box$ No	
B. Swelling: $\Box$ Yes $\Box$ No	
C. Outgassing:	
D. Other:	
Random Selection Labels      Random selection labels issued by:      □ FSEC      □ SRCC      There were labels affixed to collector.      Label locations were:	
<b>D. PRE-EXPOSURE HYDROSTATIC PRESSURE TEST</b> (160 psig for collectors street pressure (80 psig) to 107 psig; 1.5 x recomm	nended pressure for collectors
above 107 psig and below 80 psig, down to 25 psig)	
Make	
Model	
Recommended Maximum Operating Pressure	psig
Required Fluid is Water	
Requirements	
Actual	
Start	
End	
Test Pressure	psig
Test Duration	min
Observation: (discernable loss of pressure? $\Box$ Yes $\Box$ No	
TEST CONDUCTOR(S):	
DATE:	
E. EXPOSURE TEST INSPECTIONS (Carefully examine enclosure, glazing, absorber plate, absorptive coating, in: inlet & outlet ports. Detail any observable changes including exact location. DATE	
	Revised 12/15/99
	INC VISCU 12/10/00

Collecto	r Test Log					Page 6 of 1
					FSEC#	
hour prior	n 3 different days to test, and withi a normal rain sh	in last 10 days of n two hours of sola ower.)	ar noon. Spray f	or 5 minutes. V	Vet surface	that would be
Spray Temp		nents: 24 ºC±5 ºC				
MINIMUM	Spray Flow Rate	: .03 gal/min $ft^2$ =				GPN
Spray Test 1st	Inlet Date	Start Temp	Avg. Insol. Time	All Above (W/m²)	850?	Discernable Change? □ Yes □ No
2nd 3rd						□ Yes □ No □ Yes □ No
	IAL SHOCK/CO					
	v	s of exposure, at lea	ast 950 W/m_ ir	n plane of the c	ollector for	one hour prior
	l within two hour	,				
						ft
*						
Inlet						
	°F					
		per ft <sup>2</sup> of area				
Test Durati	on 5 minutes	<b>I</b>				
Observatio	ns (discernable cl	nange?) 🗌 Yes 🗌	] No			
Insolation l	Level ( 950 w/m_	for one hour? $\Box$	Yes 🗌 No			
Average Ins	solation Level one	e hour prior to test				
Avg. Ambie	ent Temp					
	? 🗆 Yes 🗆 No					
Test Condu	ictor(s):					
IL DEMO		OCUDE				
	VAL FROM EXP					
Date Kerrio Timo Domo	veu nom Exposu	re:				
Commonte	veu. : (any degradation	n?)				
Comments	. (any degradation					
						Revised 12/15/9

Collector Test Log	9			FSEC#	Page 7 of 12
I. POST-EXPOSURE	INSPECTI	ON			
Manufacturer:				 	
File No				 	
Post-exposure Date: _				 	
Initials:				 	
Collector Case, Enclosur	e. & Fasten	ers			
	☐ Yes	□ No			
B. Warping:	□ Yes	□ No			
C. Corrosion:		□ No			
D. Other:				 	
Mounting Means (Moun	ting brack	ats flanges	and so forth)		
A. Loss of Integrity:					
B.Other:					
Seals and Gaskets					
A. Cracking:	🗆 Yes	🗆 No			
J	🗆 Yes	🗌 No			
C. Loss of Adhesion:	🗆 Yes	🗆 No			
D. Other:				 	
Cover(s)/or Reflector(s)					
A. Cracking:	🗆 Yes	🗆 No			
B. Crazing:	🗆 Yes	🗆 No			
C. Buckling:	🗆 Yes	🗆 No			
D. Warping:	🗆 Yes	🗆 No			
E. Delamination:	🗆 Yes	🗆 No			
F. Other:				 	
Absorber Coating					
A. Crazing:	🗆 Yes	🗆 No			
B. Cracking:	□ Yes	□ No			
C. Blistering:	□ Yes	□ No			
D. Other:				 	
Absorber Inlet & Outlet	Tubes				
A. Deformation:	$\square$ Yes	🗆 No			
B. Corrosion:	$\Box$ Yes	$\square$ No			
C. Leakage:	$\Box$ Yes	□ No			
D. Other:					
				P	10/17/0
				Re	vised 12/15/9

Collector Test Log	g			FS	EC#	Page 8 of 12
Absorber Flow Tubes						
A. Deformation:	🗆 Yes	🗆 No				
B. Corrosion:	$\Box$ Yes	□ No				
C. Leakage:	$\Box$ Yes	□ No				
D. Loss of Bonding:	$\Box$ Yes	□ No				
E. Other:						
Absorber Headers						
A. Deformation:	🗆 Yes	🗆 No				
B. Corrosion:	🗆 Yes	🗆 No				
C. Leakage:	🗆 Yes	🗆 No				
D. Other:						
Absorber Mountings						
A. Loss of Integrity:	🗆 Yes	🗌 No				
B. Other:						
Insulation						
A. Water Retention:	🗆 Yes	🗆 No				
B. Swelling:	$\Box$ Yes	🗌 No				
C. Outgassing:	$\Box$ Yes	🗌 No				
D. Other:						
J. POST-EXPOSURE	LEAKAGE	TEST				
(Same requirements as	above)					
Required Fluid is Water						
Requirements						
Actual						
Start						
End Test Pressure						ncid
						psig psig
Test Duration						
Observation: (discerna	ble loss of	pressure?)	□ Yes □ No			min
TEST CONDUCTOR(S	5):					
DATE:						
					-	1 1 1 1 1
					Rev	ised 12/15/99

#### **Collector Test Log**

FSEC# \_\_\_\_\_

#### **K. DIFFERENTIAL PRESSURE TEST**

Date:
Start Time:
Inlet Temp(s)
Required
Actual
Ambient Temp(s)
Min.(1/2xASHRAE):
Back Pressure(psig)
Intermediate Flow:
Test Conductor(s)
ASHRAE Flow Rate:
File Name(s)
Intermediate Flow:
("FSEC#DPx")
Max.(2xASHRAE):

#### L. FLOW CALIBRATION TEST

Date
Start Time
Inlet Temp. [ºF]
delta pressure ("H <sub>2</sub> O")
Calibration constant
Back Pressure (board)[psi]
Back Pressure (MTP)[psi]
Flow Rate (board rotometer)[gpm]
Flow Rate (MtP flow meter) [gpm]
File Name(s)
Conductor(s)
("FSEC#CAL")

Revised 12/15/99

Collector Test Log		Page 10 of 12
		FSEC#
M. TIME CONSTANT 1	EST	
(Prefer inlet temp within	± one °C of ambient temperature. F	low rate should be the same as for perform-
ance test. Solar should be	-	
Date		
Flow Rate		
Start Time		
Primary Solar		w/m
Ambient Temp		0(
Secondary Solar		w/m
Inlet Temp		0(
Wind Speed		m/:
Time Constant		mir
N. PERFORMANCE TE		
Flow Calibration Constan	t:	
Date Mounted on MTP:	<u></u>	
Date Performance Test Sta	rrted:	
(First date MTP is "rolled		
Date Performance Test Fi	nished:	
File No		
	d for inspection?  Yes No	
Collector Case, Enclosure,	2 Fastanars	
A. Cracking:	$\square$ Yes $\square$ No	
B. Warping:		
C. Corrosion:	$\Box$ Yes $\Box$ No	
D. Other:		
·····		
Mounting Means (Mountir	g brackets, flanges, and so forth)	
A. Loss of Integrity:	🗆 Yes 🛛 No	
B. Other:		
Seals and Gaskets		
A. Cracking:	□ Yes □ No	
B. Loss of Elasticity:	□ Yes □ No	
C. Loss of Adhesion:	□ Yes □ No	
D. Other:		
		Revised 12/15/99

Collector Test Log	9		FSEC# _	Page 11 of
Cover(s)/or Reflector(s)				
A. Cracking:	🗆 Yes	🗆 No		
B. Crazing:	□ Yes	□ No		
C. Buckling:	☐ Yes	□ No		
D. Warping:	□ Yes	□ No		
E. Delamination.	□ Yes	□ No		
F. Other:			 	
Absorber Coating				
A. Crazing:	🗆 Yes	🗆 No		
B. Cracking:	🗆 Yes	🗆 No		
C. Blistering:	🗌 Yes	□ No		
D. Other:			 	
Absorber Inlet & Outlet	Tubes			
A. Deformation:	🗆 Yes	🗆 No		
B. Corrosion:	🗆 Yes	🗆 No		
C. Leakage:		🗆 No		
D. Other:			 	
Absorber Flow Tubes				
A. Deformation:	🗆 Yes	🗆 No		
B. Corrosion:	🗆 Yes	🗆 No		
C. Leakage:	🗌 Yes	□ No		
D. Loss of Bonding:	□ Yes	□ No		
E. Other:			 	
Absorber Headers				
A. Deformation:	🗆 Yes	🗆 No		
B. Corrosion:	□ Yes	□ No		
C. Leakage:				
D. Other:			 	
Absorber Mountings				
A. Loss of Integrity:	🗆 Yes	🗆 No		
B. Other:			 	
Insulation				
A. Water Retention:	🗆 Yes	🗆 No		
B. Swelling	🗆 Yes	🗆 No		
C. Outgassing:		🗆 No		
D. Other:			 	
			R	evised 12/15

Collector Test Log	Page 12 of 12
	FSEC#
Transparent frontal dimensions (in ft. to 3 decimal places)	
Glazing thickness (in inches to 3 decimal places):	
Cover plate length:	
Cover plate width:	
Seal:	
Absorber (in ft. to 3 decimal places)	
Material(s):	
Length:	
Width:	
Plate thickness (x.xxx inches):	
On-center spacing of tubes (x.xxx inches):	
Tube diameter (in inches to 3 decimal places):	
Plate to tube bonding method:	
Tube to header bonding method:	
0	
Coating:Air spacing, glazing to absorber:	
Air spacing, glazing to absorber:	
Insulation (measure in inches to 3 decimal places)	
Side material:	
Side thickness:	
Back material(s):	
Back thickness(es):	
Caulking, sealant, and/or gasket type(s):	
MANUFACTURER:	
FSEC#	
P. LOG RECORD	
	rowhere For example if more then one
Include on this sheet any explanatory comments not included els set of data is available what selection criteria is used, or if exposu	
*	are was interrupted.
Date	
Initials	
Comments	
	Revised 12/15/9

### **Collector Shipment Form**

Collector ManufAddress	
Address	
FSEC #	
Collector Verified	(Initials)
Collector Packaged	(Initials)
0	(Initial w/date)
Collector Shipped	(Initial w/date)
Instructions:	
<ol> <li>Find collector and identify FSEC #.</li> <li>Verify you have correct collector with one other person. (SB, John H., Jim H)</li> </ol>	
3. Pack collector. Write identification number and collector manufacturer on the outside	de of the box
4. Give secretary the collector manufacturer's name & number for mailing labels. (Recl	
versus name before typing label)	ICCR I DEC #
5. Place labels on collector box (verifying previously written name & FSEC # on box).	
6. Have secretary call freight company to pick up.	
7. Return form to originator after pick up.	
8. File form in collector file.	
CERTIFICATION CHANGES	
1. Run [TESTING] ASHPCH and [TESTING] PREQRT on	(original file)
2. Verify that these match the published data.	
3. Run [TESTING] CHANGE:	
Old file number (above)	
New FSEC number	
New model number1. Name change:	
New manufacturer	
2. Size change:	
New gross area	ft²
New transparent area	
3. Transmissivity Change:	
Old transmissivity	
New transmissivity	
4. Run [TESTING] ASHPCH and [TESTING] PREQRT on	MFD
5. Verify that patch list of MFD has correct:	
make, model, areas	
6. Verify that the NBS equations are the same.	
7. File all outputs in the new file.	
	Revised 12/15/99

#### **Certification Changes**

- 1. Run [TESTING] ASHPCH and [TESTING] PREQRT on \_\_\_\_\_\_ (original file)
- 2. Verify that these match the published data.
- Run [TESTING] CHANGE: Old file number (above) New FSEC number \_\_\_\_\_\_\_\_\_\_ New model number \_\_\_\_\_\_\_\_\_\_
  1. Name change: New manufacturer
  2. Size change: New gross area \_\_\_\_\_\_\_\_ft<sup>2</sup> New transparent area \_\_\_\_\_\_\_ft<sup>2</sup>
  3.Transmissivity Change: Old transmissivity \_\_\_\_\_\_\_\_ New transmissivity \_\_\_\_\_\_\_
- 4. Run [TESTING] ASHPCH and [TESTING] PREQRT on \_\_\_\_\_.MFD
- 5. Verify that patch list of MFD has correct: make, model, areas
- 6. Verify that the NBS equations are the same.
- 7. File all outputs in the new file.

## Appendix 2: General Requirements for Accreditation of Laboratories (intended for use with ISO/IEC 17025)

## August 2000

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## Foreword

The AMERICAN ASSOCIATION FOR LABORATORY ACCREDITATION (A2LA) is a non-profit, non-governmental, public service, membership organization dedicated to operating a nationwide, broad spectrum laboratory accreditation system. Accreditation is defined as a formal recognition of competence that a laboratory can perform specific tests or calibrations. Accreditation is available to any type of testing or calibration laboratory, be it in the private sector (independent or in-house) or in the government sector.

A2LA was formed in 1978, as a practical and efficient organization to develop and manage a system to verify and recognize competent laboratories. Accreditation is available for virtually all types of tests, calibrations, measurements and observations that are reproducible and properly documented.

The accreditation of laboratories is offered in the field of calibration and the following fields of testing:

Acoustics and Vibration	Biological	Chemical	Construction Materials
Electrical	Environmental	Geotechnical	Mechanical
Nondestructive	Thermal		

Special programs are developed in response to user needs and may cut across more than one field of testing. If only a few tests from a second field are to be included and all testing is managed in one facility under one quality system, these tests may be added to the scope of accreditation in the primary field at no charge for a second field. If there are two managers of equivalent status responsible for the testing in each field, accreditation will be necessary in both fields.

Users of accredited laboratories are advised to obtain the *Scope(s)* of *Accreditation* from any accredited laboratory or from A2LA. The Scope(s) of Accreditation identifies the specific tests or types of tests or calibration capability for which the laboratory is accredited.

The general requirements (general criteria) for accreditation used by A2LA are from the international standard, ISO/IEC 17025–1999, "General requirements for the competence of testing and calibration laboratories." Additional *program requirements* (specific criteria) for specific fields (e.g. calibration, environmental testing) or specific programs which are necessary to meet particular user needs (e.g. Automotive EMC Laboratory Accreditation Program) complement these general requirements in particular areas.

In effect, A2LA accreditation attests that a laboratory has demonstrated that:

- a) it is competent to perform specific tests, types of tests, calibrations, or types of calibrations listed on its Scope(s) of Accreditation;
- b) its quality system addresses and conforms to all elements of ISO/IEC 17025–1999 (and, as a result ISO 9001–1994 or ISO 9002–1994), is documented per ISO/IEC 17025, and is fully operational;
- c) it conforms to any additional requirements of A2LA or specific fields or programs necessary to meet particular user needs.

It is A2LA policy not to accredit or renew accreditation of a laboratory that fails to meet the above criteria (see Part B, Conditions for Accreditation and Part C, Accreditation Process, sections on deficiencies, accreditation decisions and suspension or withdrawal of accreditation).

, President

## PART A. EXPLANATORY NOTES FOR THE GENERAL REQUIREMENTS FOR THE COMPETENCE OF TESTING AND CALIBRATION LABORATORIES (ISO/IEC 17025-1999)

#### Introduction by A2LA

All laboratories accredited by the American Association for Laboratory Accreditation (A2LA) are required to comply with ISO/IEC 17025-1999, "General requirements for the competence of testing and calibration laboratories", unless there is some unusual circumstance in the laboratory which might make compliance with a specific provision inappropriate. Laboratories will be assessed against the full text of the standard. **Laboratories must obtain a copy of ISO/IEC 17025. Part A of this document does not include all the requirements of the standard.** The **A2LA Explanatory Notes** that follow (sections in Italics) are interpretative guidance on particular requirements in the text. These explanatory notes are not to be interpreted as additional requirements, but rather as clarification and recommendations for implementation.

For laboratories engaged in specific fields such as environmental testing or calibration, these requirements may need amplification with specific criteria which include additional requirements. These specific program requirements are published by A2LA and provided to laboratories seeking accreditation in the associated fields.

ISO/IEC 17025 covers both calibration and testing laboratories, so the pairing of "calibration and test" is frequently repeated. In this context, test laboratories should ignore the word "calibration" (with the exception of sections 5.4.6.1 and 5.6.2.2) and calibration laboratories should ignore the word "test."

According to the standard's Introduction (paragraph 4), laboratories meeting the requirements of 17025 comply with ISO 9001 or ISO 9002, depending on the activities they undertake. As a result, additional evaluation against ISO 9001 or ISO 9002 should not be necessary for laboratories accredited to ISO 17025. It is also noted in the standard's introduction that certification (or registration) against ISO 9001 and ISO 9002 does not of itself demonstrate the competence of the laboratory to produce technically valid data and results.

#### 4. Management requirements

#### 4.1 Organization

#### 4.1.1 Legal responsibility

**A2LA Explanatory Note:** The laboratory can be a public or private entity, an established business or corporation, or an identifiable division or in-house activity of a business or corporation, which meets the applicable legal requirements of the governmental jurisdiction in which it conducts business. Legal responsibility aids in addressing issues of liability/accountability, uniqueness, and independence of operation.

#### 4.1.5 b) Undue internal and external pressures

**A2LA Explanatory Note:** Both in-house as well as commercial laboratory personnel should be insulated from work-related undue pressures which would compromise the quality of work. The source of undue pressure may be internal (e.g., management pressure, deadlines) or external (e.g., customer complaints, priority requests). Management should decide which types of undue pressure the staff might encounter and implement clear policies and instructions for countering them. Precautions should be taken to ensure that there are no conflicts of interest between staff and clients. If relevant, the laboratory should have a written policy against acceptance of gifts and gratuities by employees from clients in order to avoid perception of conflict of interest. Also, a policy for handling internal complaints or concerns from

employees should be included. Communications (priority requests, complaints, status inquiries, etc.) could be directed through supervision or administrative personnel. Ethics programs, skip-level management interviews, arbitrator programs, etc., may also provide avenues of coordination that preclude adverse effects resulting from commercial pressures. All these efforts may be included in the quality manual or issued as policy statements to employees.

#### 4.1.5 d) Avoidance of involvement in any inappropriate activities

**A2LA Explanatory Note:** This clause refers to activities undertaken by the laboratory or its staff outside of normal operations that could cast doubt upon the laboratory's integrity.

#### 4.1.5 e) Organization and management structure

**A2LA Explanatory Note:** An organization chart or charts with the reporting relationship to any parent organization or ownership should normally be a sufficient presentation of the organization and management structure of the laboratory.

#### 4.1.5 j) Deputies

**A2LA Explanatory Note:** Arrangements for designating the person(s) acting in the absence of the technical and quality management should be documented to ensure continuity of operation in case of absence(s). If the integrity of the laboratory is jeopardized by lack of other key staff, deputies for those positions should also be provided. Designated deputies should have the required knowledge and expertise to assume the position, or the activities should be appropriately curtailed where knowledge and expertise do not exist with the deputy. A deputy A2LA Authorized Representative, knowledgeable about A2LA accreditation policies and procedures, should also be named.

#### 4.2 Quality system

#### 4.2.1 Quality system: documented, communicated

**A2LA Explanatory Note:** Laboratory activities may already be incorporated in a quality manual covering a parent organization's total range of operations. If so, it may be necessary to extract that information and expand on it to establish quality policy and objectives, and perhaps create a separate manual, specifically relating to the laboratory's functions.

The laboratory may communicate the system's documentation through the use of (1) a controlled distribution list of individuals having numbered copies of the quality documentation (or equivalent electronic means of distribution), and (2) a documented laboratory training program.

#### 4.2.2 Quality system policies and objectives; quality policy statement

**A2LA Explanatory Note:** At a minimum, the quality manual must include a reference to each quality system policy indicating where in the quality system documentation the full policy can be found.

#### 4.3 Document control No A2LA Explanatory Notes

#### 4.4 Review of requests, tenders and contracts

## 4.4.1 c) Procedures for review of requests, tenders and contracts: selection of appropriate test and/or calibration method

**A2LA Explanatory Note:** During contract review, calibration laboratories should specifically discuss their measurement uncertainty with their clients to ensure they can meet the clients' specifications.

#### 4.5 Subcontracting of tests and calibrations

**A2LA Explanatory Note for Section 4.5:** Section 4.1.5 of ISO/IEC Guide 58, "Calibration and testing laboratory accreditation systems — General requirements for operation and recognition," states: "4.1.5 The accreditation body shall confine its requirements, assessment and decision on accreditation to those matters specifically related to the scope of the accreditation being considered."

Therefore, this subcontracting requirement applies only for subcontracting of any part of the tests or calibrations included in a laboratory's Scope of Accreditation. A2LA will only include in a laboratory's Scope of Accreditation tests or calibrations that the laboratory has been assessed as being competent and capable to perform; a laboratory cannot be accredited for a test or calibration unless it has the equipment, method(s), and trained personnel required. Permanent subcontracting, as described in 4.5.1, refers to situations where an accredited laboratory subcontracts a portion of its workload for a particular test or part of a test included in its Scope of Accreditation on an ongoing basis.

Laboratories should document their policies and procedures for hiring subcontractors. Accredited laboratories using the services of a subcontracting laboratory are responsible for ensuring to their clients that the subcontracting laboratory ry has a satisfactory quality system and is competent to perform the required calibrations or tests. Reliance on A2LA-accredited status for the pertinent calibrations or tests is sufficient. When a subcontractor is not accredited by A2LA or another organization recognized as equivalent, the laboratory should record its assessment of that laboratory's capability to meet 17025 requirements on a requirement-by-requirement basis. Investigations of non-accredited subcontractor laboratories should be done using an audit process similar to its own internal audit system as required by Section 4.13. As an example, the laboratory should require the following subcontractor records to demonstrate compliance with ISO/IEC 17025 for the work in question prior to subcontracting:

- A copy of the subcontractor's quality manual that meet the requirements of ISO/IEC 17025,
- A copy of the subcontractor's procedure(s) for the work in question,
- A copy of training records for the personnel responsible for performing the subcontracted work, and
- An example test report or certificate for the testing intended to be subcontracted.

#### 4.6 Purchasing services and supplies

#### 4.6.4 Evaluation of suppliers of critical consumables, supplies and services

**A2LA Explanatory Note:** The laboratory should identify the inputs to its processes in terms of equipment, materials and services which affect the integrity of its calibrations and tests and develop appropriate specifications and quality control measures.

The A2LA Traceability Policy requires that calibration services be obtained from laboratories accredited to ISO/IEC 17025 by A2LA or another accrediting body recognized by A2LA through its mutual recognition arrangements, when such laboratories are available for the calibrations required. This ensures that traceability to the relevant national or international metrology standards as required by Section 5.6 is authenticated. Laboratories should evaluate the measurement uncertainties claimed by their calibration provider to ensure any applicable specifications or requirements are met.

Reference material suppliers should be accredited if possible, and all suppliers of other outside support services and products should have a registered quality system to one of the ISO 9000 standards.

### 4.7 Service to the client

#### No A2LA Explanatory Notes

#### 4.8 Complaints

Policy and procedure for resolution of complaints

**A2LA Explanatory Note:** Complaints received need not be in writing. Many complaints arrive via telephone or other oral means. A record should be made of the complaint at the time received. They should be assigned to someone for resolution. Guidance should be supplied in the quality manual as to when a conversation becomes recorded as a complaint. All complaints should be concluded and a file should include the substance of the complaint and its resolution. Complaints may be generated by external customers or from within the laboratory's organization. Section 4.8 refers to complaints about the laboratory's activities. Complaints referred to in this section should not be confused with

complaints against quality characteristics of the actual product or item being tested or calibrated.

4.9 Control of nonconforming testing and/or calibration work **No A2LA Explanatory Notes** 

- 4.10 Corrective action No A2LA Explanatory Notes
- 4.11 Preventive action No A2LA Explanatory Notes
- 4.12 Control of records

#### 4.12.1 General

#### 4.12.1.1 Procedures for quality and technical records

**A2LA Explanatory Note:** The Conditions for Accreditation (Part B of this document) require that the laboratory retain all quality records (as defined in ISO/IEC 17025, Clause 4.12.1.1) and technical records supporting reported results (as defined in ISO/IEC 17025, Clause 4.12.2.1, and Clauses 5.10.2 through 5.10.4) throughout the period between A2LA on-site assessments.

#### 4.13 Internal audits

**A2LA Explanatory Note for Section 4.13:** This section requires that the laboratory have its own internal audit system. Internal audits are those of the laboratory itself. The laboratory can procure the services of an outside audit professional, provided the scope of the audits and follow-up activities cover the full range of operations as required in 4.13.1. It is not sufficient to rely only on external (second- or third-party) audits. A2LA assessments may complement, but not substitute for, the laboratory's own audits. Internal audits should also include audits of data quality. Audits should determine:

- whether procedures described in the quality system are being followed;
- whether objectives (as defined by the quality system) are being achieved;
- whether designated duties are being carried out satisfactorily; and
- whether there are opportunities for improvements.

#### 4.14 Management reviews No A2LA Explanatory Notes

#### **5** Technical requirements

- 5.1 General No A2LA Explanatory Notes
- 5.2 Personnel

#### 5.2.1 Competent personnel

**A2LA Explanatory Note:** The appraisal of personnel is a major part of laboratory assessments. This criterion is evaluated based on the range, complexity and frequency of performance of calibrations or tests for which accreditation is sought. For many tests, "sufficient personnel" may mean more than one staff person is involved to assure technical

competency. For example, a supervisor exercising technical control may be relatively inexperienced with respect to one facet of the laboratory's work, but another person or persons working in close collaboration with the supervisor may compensate for this inexperience. The accreditation in such a case would be reviewed if there was a major change in either person's duties. The loss of key personnel may affect continuing accreditation. For example, A2LA assessors identify key (or indispensable) staff whose absence would reduce the laboratory's technical competence and may prompt a reassessment before it would be normally scheduled or removal of the affected tests from the Scope of Accreditation.

Technical personnel should have demonstrable knowledge and skills to perform calibrations or tests and compute results. They may be asked to demonstrate tests or specific techniques during an assessment. The qualifications and experience required for senior staff are reviewed during the assessment. Factors to be considered include:

- the number of calibrations or tests for which accreditation is sought;
- the technical complexity of the calibrations or tests;
- measurement uncertainty claimed;
- the frequency at which specific calibrations or tests are conducted, particularly those calibrations or tests that are judged to be highly experience dependent;
- the contact that the senior staff maintains with the development of methodology and adoption of new methodology within the laboratory.

In all cases senior staff need to demonstrate appropriate understanding of the calibration or test areas in which they exercise supervision.

In assessing qualifications, the balance between relevant academic qualifications and practical calibration or test experience is considered in the light of the range, complexity and accuracy required.

For a laboratory seeking accreditation for a wide range of complex calibrations or tests, senior staff would be expected to have attained a high level of education in the relevant discipline together with sufficient experience in the relevant calibrations or tests.

The senior staff engaged in a limited range of relatively simple calibrations or tests, while holding lesser qualifications, may demonstrate appropriate competence by having relevant calibration or test experience and demonstrable laboratory management expertise.

More detailed personnel requirements may be specified in program requirements documents (e.g., environmental field of testing).

#### 5.3 Accommodation and environmental conditions

#### 5.3.1 Appropriate facilities and environment

**A2LA Explanatory Note:** These requirements also apply to off-site calibration or testing facilities in that care should be taken to monitor, record, and compensate for these environmental conditions (see A2LA Requirements for Accreditation of Site Testing and Site Calibration Laboratories).

#### 5.4 Test and calibration methods and method validation

#### 5.4.4 Non-standard methods

**A2LA Explanatory Note:** A2LA considers accreditation of in-house methods where existing standard methods are not suitable. These methods should be fully documented as described in the Note following Section 5.4.4 and appropriately validated in accordance with Section 5.4.5. Documentation of the validation of the method as established by the laboratory is the primary basis for determining if the method can be included in the scope of accreditation.

#### 5.4.6.2 Uncertainty of measurement for testing laboratories

**A2LA Explanatory Note:** Testing laboratories should evaluate the need for estimating measurement uncertainty for each test method according to the following two scenarios:

1. Methods that require the estimation of uncertainty are those where:

- a) Measurement results are quantitative, or
- b) Decisions are based on quantitative results, or

c) There exist client, specification, method or regulatory requirements for estimating uncertainty.

2. Methods that do not require the estimation of uncertainty are those where:

- a) Results are qualitative or,
- b) The major sources of uncertainty have been addressed in the test method (see Note 2 above).

The evaluation of the need for estimating measurement uncertainty should at a minimum include an identification and assessment of the major or most significant sources of uncertainty.

Guidance documents enjoying worldwide acceptance are available to assist in the estimation of measurement uncertainty. A list of these documents is included in the Bibliography at the end of this Section.

#### 5.4.7.2 Computers and automated equipment

**A2LA Explanatory Note:** Computers are used in many different aspects of a modern laboratory's business. Some test equipment has a significant computer function as an integral part of its operation. In this case, the laboratory should have supporting evidence that the equipment is capable to perform within the required uncertainty of measurement.

The laboratory should be able to demonstrate that the data generated by the software are equivalent to manually generated data across the full range of the equipment including input and as applicable display and print out. Procedures should address the use of the software and operation of the computerized system, including authorized access to and authorized amendment of computer records. The system should be capable of storing and retrieving all entries of and amendments to the data (see Section 4.12).

Some laboratories create their own management information systems which integrate data from different instruments, collate it, check it against reference standards, and print it out. In this case, the laboratory should have a system in place to handle computer operations including:

- appropriate organization and management functions;
- knowledgeable personnel;
- an appropriate environment;
- necessary equipment;
- needed software.

The laboratory should also have procedures for:

- validating the software (see 5.4.7.2a);
- operating the equipment (including data entry and data interpretation);
- reporting results coming from the computer equipment.

These computerized procedures should be adequate to meet revisions of test methods or standards whenever they apply. Regular back-ups of programs and data should be performed (see clause 4.12.1.4).

#### 5.5 Equipment

#### 5.5.1 Sampling, measurement and test equipment

**A2LA Explanatory Note:** According to the Conditions for Accreditation (Part B of this document), all equipment needed to perform the calibrations or tests (including environmental monitoring if required) must be available during on-site assessment. The requirements of 17025 and A2LA Policies apply whether the equipment is owned, leased, rent-ed, or borrowed.

## 5.5.6 Procedures for safe handling, transport, storage, use and planned maintenance of measuring equipment

A2LA Explanatory Note: Maintenance procedures should state in detail:

- *how historical maintenance information is kept;*
- how an instrument that has been subjected to any influences that might cause doubt as to its integrity is handled;
- how out-of-service-equipment is identified and/or isolated to prevent its use;
- how effects of previous calibrations or tests are determined;
- how operational status is identified; and
- where equipment is held while out of service.

#### 5.6 Measurement traceability

#### 5.6.2.1.1 Traceability to the International System of Units (SI) (Système international d'unités).

**A2LA Explanatory Note:** See the A2LA Traceability Policy for additional requirements regarding calibration services and demonstration of traceability.

#### 5.7 Sampling No A2LA Explanatory Notes

#### 5.8 Handling of test and calibration items No A2LA Explanatory Notes

#### 5.9 Assuring the quality of test and calibration results

**A2LA Explanatory Note:** The laboratory should have a systematic quality control program for checking or monitoring the reliability or accuracy of its results for all methods and measurement processes. The particular quality-control schemes and statistical techniques vary greatly with the nature and volume of calibration or testing. Statistical qualitycontrol charts or equivalent tabulations for monitoring accuracy and precision performance should be maintained for quality-control test items such as reference test materials/standards and replicate tests from the same material source as is practicable. The use of reference materials/standards provides for the monitoring of accuracy performance. Replicate testing of duplicate test items and repeated measurements provides for the monitoring of precision performance.

The retention and re-test of test items may be specified in response to questionable results or complaints. Evaluation of interrelated characteristics of individual test items can aid in detecting errors. More detailed quality control requirements may be specified in program requirements documents (e.g., environmental field of testing). For additional requirements relating to proficiency testing, refer to A2LA Proficiency Testing Requirements for Accredited Testing and Calibration Laboratories.

#### 5.10 Reporting the results

**A2LA Explanatory Note:** A2LA accreditation entitles an accredited testing laboratory to place the A2LA logo on test reports. A2LA accredited calibration laboratories are required to include the logo on accredited reports or certificates. A2LA strongly encourages the use of the logo by a laboratory when its accredited status contributed to its obtaining the contract for the work. The calibrations or tests reported in this manner must be performed under the terms of its accreditation and be included in the laboratory's scope of accreditation. According to the A2LA Policy on Laboratory Reference to A2LA Accredited Status (Part C, Section X of this document), reports including the A2LA logo shall include the laboratory's accreditation certificate number. A statement similar to the following should also be included:

This laboratory is accredited by the American Association for Laboratory Accreditation (A2LA) and the results shown in this test report [or calibration certificate] have been determined in accordance with the laboratory's terms of accreditation unless stated otherwise in the report.

Reports carrying the A2LA logo that contain data from calibrations or tests for which a laboratory is not accredited or which have been undertaken by a subcontractor laboratory must state that these data are not covered by the laboratory's A2LA accreditation.

Accredited laboratories have the responsibility to ensure that their clients receiving reports carrying the A2LA logo are

aware that products, materials or other items of calibration or test are in no way approved or endorsed by A2LA. The A2LA logo may be used on reports which extend the results on a sample or samples to the properties or qualities of a lot or batch from which the sample was drawn provided that the accredited laboratory's scope of accreditation covers the sampling involved, samples concerned were taken by the staff of the accredited laboratory using an approved sampling procedure (unless provisions of a special program permit otherwise), and the report includes all information required by clause 5.10.3.2.

Refer to the sections X and XI in Part C of this document regarding laboratory reference to A2LA-accredited status and misuse of the A2LA logo for related guidance on advertising and referring to accredited status.

#### 5.10.2 e) Identification of the method used

A2LA Explanatory Note: The issue date of the test method should be included in the report.

#### 5.10.2 f) description, condition, and unambiguous identification of item(s) tested or calibrated;

**A2LA Explanatory Note:** Clause 5.8.3 only requires that abnormalities or departures from normal or specified conditions be recorded. A similar practice should be acceptable in reporting results, i.e. a general statement regarding the acceptable condition of the item should suffice, with more detail given when departures are encountered.

5.10.2 j) the name(s), function(s) and signature(s) or equivalent identification of person(s) authorizing the test report or calibration certificate;

**A2LA Explanatory Note:** The use of photographic, electronic and mechanical means of reproduction of signatures or names of signers may be acceptable, as long as the user can identify the person taking responsibility for the report and that automated signatures are safeguarded.

#### 5.10.5 Opinions and interpretations

**A2LA Explanatory Note:** In order for opinions to be included in a test report or calibration certificate endorsed with the A2LA logo, the basis for arriving at the opinion must be part of a method or procedure included in the laboratory's scope of accreditation. If the opinions are not based on a process described in an accredited method or procedure, any expression of opinion or statements in amplification of the results may be provided in a separate unendorsed document.

# Bibliography: Documents relating to measurement uncertainty

- [1] *Guide to the Expression of Uncertainty in Measurement,* issued by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, and OIML. Available through ANSI (212 642 4900).
- [2] EA-4/03, Expressions of the Uncertainty of Measurements in Calibration (*previously EAL-R2*). Available at www.european-accreditation.org (free).
- [3] EURACHEM/CITAC Guide: Quantifying Uncertainty in Analytical Measurement. Available from A2LA, or CITAC (Co-operation on International Traceability in Analytical Chemistry), www.vtt.fi/ket/citac (free).
- [4] NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," Taylor & Kuyatt. Ordering information available at www.nist.gov.
- [5] UKAS M3003, The Expression of Uncertainty and Confidence in Measurement. Available for order from United Kingdom Accreditation Service, 21-47 High Street, Feltham, Middlesex, TW13 4UN. Order form

available at www.ukas.com.

[6] UKAS NIS 80, Guide to the Expression of Uncertainty in Testing (General Principles and Guidance for Estimating and Reporting Uncertainties of Measurement in Testing). See [5].

# Part B. Conditions for Accreditation (based on ISO/IEC Guide 58)

To attain and maintain accreditation, an applicant must agree to:

- 1) Afford accommodation and cooperation as is necessary to enable A2LA to verify compliance with the requirements for accreditation including provision for examination of documentation and access to all calibration and testing areas, equipment, records and personnel for the purposes of assessment, surveillance, reassessment and resolution of complaints;
- 2) Comply at all times with the criteria, requirements (including participation in proficiency testing as required), and conditions for accreditation;
- 3) Maintain impartiality and integrity;
- 4) Retain all quality records (as defined in ISO/IEC 17025, Clause 4.12.1.1) and technical records supporting reported results (as defined in ISO/IEC 17025, Clause 4.12.2.1, and Clauses 5.10.2 through 5.10.4) throughout the period between A2LA on-site assessments;
- 5) Claim that it is accredited only in respect of services for which it has been granted accreditation and which are carried out in accordance with these conditions;
- 6) Pay such fees as shall be determined by A2LA;
- 7) Not use its accreditation in such a manner as to bring A2LA into disrepute and not make any statement relevant to its accreditation which A2LA may consider misleading or unauthorized;
- Upon suspension, withdrawal or expiration of its accreditation (however determined) discontinue its use of all advertising matter that contains reference thereto and return any certificates of accreditation to A2LA;
- 9) Not use its accreditation to imply product approval by A2LA;
- 10) Endeavor to ensure that no certificate or report, nor any part thereof, is used in a misleading manner;
- 11) In making reference to its accreditation status in communication media such as advertising, brochures or other documents, comply with the requirements of A2LA;
- 12) Inform A2LA headquarters without delay and in writing of changes in any aspect of the laboratory's status or operation that affects the laboratory's legal, commercial or organizational status; organization or management (e.g., managerial staff); policies or procedures, where appropriate; premises; personnel, equipment, facilities, working environment or other resources, where significant; authorized signatories; or such other matters that may affect the laboratory's capability, or scope of accredited activities, or compliance with the criteria, requirements and conditions for accreditation;
- 13) Carry out any adjustments to its procedures in response to due notice of any intended changes by A2LA to the criteria, requirements, or conditions for accreditation, in such time as in the opinion of A2LA is reasonable.

In order to apply, the applicant laboratory's AUTHORIZED REPRESENTATIVE, must agree to the above conditions for accreditation and must attest that all statements made on their application are correct to the best of their knowledge and belief. An accredited laboratory's AUTHORIZED REPRESENTATIVE is responsible for ensuring that all of the relevant conditions for accreditation are met.

# Part C. A2LA Accreditation Process

# I. Application

A laboratory applies for accreditation by obtaining the application package from A2LA headquarters and completing appropriate application sheets. All applicants must agree to a set of conditions for accreditation (see Part B of this document), pay the appropriate fees set by the A2LA Board of Directors, and provide detailed supporting information on:

- Scope of testing or calibration in terms of field(s) of testing or calibration, testing or calibration technologies, methods and relevant standards, and measurement uncertainty budgets if applicable (always required for calibration and dimensional inspection testing laboratories);
- Organization structure; and
- Proficiency testing.

Accreditation is available for testing laboratories (tests) and calibration laboratories (calibrations). For tests, the scope of accreditation is normally identified in terms of standard test methods prepared by national, international, and professional standards writing bodies. If a laboratory desires accreditation only for a superseded version of a standard test method, the date of the version used is identified in its scope of accreditation. When the date is not identified in their scope of accreditation, laboratories are expected to be competent in the use of the current version within one year of the date of publication of the standard test method. For calibrations, the scope of accreditation is described typically in terms of the measurement parameter, range of measurement and best attainable uncertainties. In some cases, a laboratory's capability will be described in terms of types of tests, testing technologies, or other descriptive text when it is not appropriate or practical to identify specific tests or calibrations.

Accreditation of non-standard tests and calibrations which the assessor is permitted to examine in detail may be granted, and shall be referenced in the scope by unambiguous identification. A2LA reserves the right to refuse to consider accreditation for proprietary tests or calibrations, without prejudice, if there is not sufficient accessibility to the method.

If a laboratory wishes accreditation for the use of its own methods, then it must provide the following information to the assessor(s) before assessment:

- Origin of method;
- Comparison with the standard methods they replace including any departures from the standard (if applicable);
- Reasons for and effects of departures;
- Validation data (per Section 5.4.5 of ISO/IEC 17025).

### II. On-Site Assessment

Once the application information is completed and the appropriate fees are paid, A2LA headquarters staff identifies and tentatively assigns one or more assessors to conduct an on-site assessment. Assessors are selected on the basis of their testing or calibration expertise so as to be better able to provide guidance to the laboratories. They do not represent their employers (if so affiliated) while conducting assessments for A2LA. The laboratory has the right to ask for another assessor if it objects to the original assignment. A2LA assessors are drawn from the ranks of the recently retired, consultants, industry, academia, government agencies, and from the laboratory community. Assessors work under contract to A2LA. Assessments may last from one to several days. More than one assessor may be required.

Assessors are given an assessor guide and checklists to follow in performing an assessment. These documents are intended to ensure that assessments are conducted as uniformly and completely as possible among the assessors and from laboratory to laboratory.

Before the assessment is conducted, the assessor team requests copies of the quality manual and related documentation (i.e., SOPs related to ISO/IEC 17025 requirements) in order to prepare for the assessment. The quality manual and related documentation must be reviewed by the assessor team before the on-site assessment can begin. This review is done ideally before the assessment is scheduled. Upon review of submitted documentation, the assessor(s) may ask the laboratory to implement corrective action to fill any documentation gaps required by ISO/IEC 17025 before scheduling the assessment. A pre-assessment visit may be requested by the laboratory as an option at this point to enhance the success of the full assessment.

Prior to scheduling the full assessment, the assessor reviews the draft scope(s) to determine the tests to possibly witness, and checks on the availability of the technical personnel who perform the tests. An assessment agenda is provided by the assessor. The full assessment generally involves:

- An entry briefing with laboratory management;
- Interviews with technical staff;
- Demonstration of selected tests or calibrations including, as applicable, tests or calibrations at representative field locations;
- Examination of equipment and calibration records;
- Audit of the quality system to verify that it is fully operational and that it conforms to all sections of ISO/IEC 17025, including documentation;
- A written report of assessor findings; and
- An exit briefing including the specific written identification of any deficiencies.

During the full assessment, the assessor has the authority to stop the process at any time and consult with A2LA staff and the laboratory's management to determine if the assessment should proceed. In cases where the number of significant nonconformances affects the ability to successfully complete a full assessment, the visit may be converted to a pre-assessment. The full assessment is then rescheduled when the laboratory and assessor feel it is appropriate to proceed.

The objective of an assessment is to establish whether or not a laboratory complies with the A2LA requirements for accreditation and can competently perform the types of tests or calibrations for which accreditation is sought. However, when accreditation is required to demonstrate compliance with additional criteria which may be imposed by other authorities, such as in the case of U.S. EPA, the A2LA assessment will include such additional criteria. Assessors may also provide advice, based on observations or in response to questions, in order to help the laboratory improve its performance.

### III. Deficiencies

During the assessment, assessors may observe deficiencies. A deficiency is any nonconformity to accreditation requirements including:

- a laboratory's inability to perform a test or type of test for which it seeks accreditation;
- a laboratory's quality system does not conform to a clause or section of ISO/IEC 17025, is not adequately documented, or is not completely operational; or
- laboratory does not conform to any additional requirements of A2LA or specific fields of testing or programs necessary to meet particular needs.

At the conclusion of an assessment, the assessor prepares a report of findings, identifying deficiencies which, in the assessor's judgment, the laboratory must resolve in order to be accredited. The assessor holds an exit briefing with top management of the laboratory, going over the findings and presenting the list of deficiencies (deficiency report). The authorized representative of the laboratory (or designee) is asked to sign the deficiency report to attest that the deficiency report has been reviewed with the assessor. The signature does not imply that the laboratory representative concurs that the individual item(s) constitute a deficiency. The laboratory is requested to respond within one month after the date of the exit briefing detailing either its corrective action or why it does not believe that a deficiency exists. The corrective action response must include a copy of any objective evidence (e.g., calibration certificates, lab procedures, paid invoices, packaging slips and training

records) to indicate that the corrective actions have been implemented/completed. It is possible that the assessor's review of the corrective action response may be needed to determine if the response is satisfactory. If this review is expected to take more than one hour's time, A2LA may invoice the laboratory for this time at the prevailing assessor rate. The assessor will discuss the possibility of this review with the laboratory during the exit briefing and obtain the laboratory's concurrence.

It is entirely possible that the laboratory will disagree with the findings that one or more items are deficiencies. In that case, the laboratory is requested to explain in its response why it disagrees with the assessor.

If the laboratory fails to respond in writing within four months after the date of the exit briefing, it may be treated as a new applicant subject to new fees and reassessment should it wish to pursue accreditation after that time.

A laboratory that fails to respond to all its deficiencies within six months of being assessed shall be subject to being reassessed at its expense. Even if the laboratory responds within six months, A2LA staff has the option to ask for reassessment of a laboratory before an initial accreditation vote is taken based on the number, extent and nature of the deficiencies. The Accreditation Council panel also has the option to require reassessment of a laboratory before an affirmative accreditation can be rendered.

### IV. Accreditation Anniversary Date

The anniversary date of a laboratory's accreditation is established 105 to 135 days after the last day of the final on-site assessment before an initial accreditation decision, regardless of the length of time required to correct deficiencies. This date normally remains the same throughout the laboratory's enrollment.

Any extensions to an accreditation beyond the anniversary date must be requested and justified in writing by the laboratory. A2LA does not automatically grant extensions of accreditation. Extensions beyond 90 days are not normally granted. When fundamental nonconformances are identified during an assessment, extensions of accreditation are not considered until the laboratory submits objective evidence demonstrating that the nonconformances have been addressed. Likewise, extensions are not granted when delays are due to the laboratory's failure to respond to requests within established deadlines. When a laboratory is granted an extension, a revised Scope of Accreditation is issued which reflects the extended anniversary date. Because the Scope of Accreditation is not normally reissued for an extension. Upon completion of the renewal process, both documents are reissued, reflecting the renewed anniversary date.

# V. Proficiency Testing

Compliance with the ISO/IEC 17025 criteria is essential, but may not be sufficient for effectively evaluating laboratory competence. Applicants may be required to participate in relevant and available proficiency testing programs sponsored by A2LA or other organizations administering acceptable proficiency testing programs.

Proficiency testing is a process for checking actual laboratory testing performance, usually by means of interlaboratory test data comparisons. For many test methods, results from proficiency testing are very good indicators of testing competence. Proficiency testing programs may take many forms and standards for satisfactory performance can vary depending on the field. For details on the requirements for proficiency testing, please refer to the A2LA Proficiency Testing Requirements for Accredited Testing and Calibration Laboratories.

### VI. Accreditation Decisions

Before an accreditation decision ballot is sent to Accreditation Council members, staff shall review the deficiency response, including objective evidence of completed corrective action, for adequacy and completeness. If staff has any doubt about the adequacy or completeness of any part of the deficiency response, the response is submitted to the assessor(s). Since all deficiencies must be resolved before accreditation can be granted, staff shall ask the laboratory for further written response in those cases where staff recognizes that an affirmative vote is not likely because of incomplete corrective action in response to deficiencies or obvious lack of supporting evidence that corrective action has been completely implemented.

Staff selects a "Panel of Three" from the Accreditation Council members for voting. The "Panel of Three" selection takes into account as much as possible each member's technical expertise with the laboratory testing or calibration to be evaluated. The laboratory is consulted about any potential conflicts of interest with the Accreditation Council membership prior to sending their package to the Accreditation Council. At least two affirmative ballots (with no unresolved negative ballots) of the three ballots distributed must be received before accreditation can be granted.

It is the primary responsibility of assessors to judge whether the observed evidence is serious enough to warrant a deficiency. However, the panel members that are asked to vote on an accreditation decision are required to make a judgment whether or not deficiencies still exist based on information contained in the ballot package. Accordingly, panel members can differ with assessor judgments, based upon their interpretation of the criteria for the specific case under question and the supporting evidence available whether a deficiency does or does not exist. Staff attempts to resolve these differences as they arise, but it remains for the panel to make the initial decision.

Staff shall notify the laboratory asking for further written response based on the specific justification for one or more negative votes received from the panel. If further written response still does not satisfy the negative voter(s), a reassessment may be proposed or required. If a reassessment is requested by more than one voter, the laboratory is asked to accept a reassessment. If the laboratory refuses the proposed reassessment, a nine-member Accreditation Council appeals panel is balloted (see sections on XII. Adverse Accreditation Decisions and XV. Appeals Procedures below). If two-thirds of those voting agree to a reassessment, accreditation is denied until a reassessment and satisfactory laboratory response(s) to all deficiencies are completed.

If accreditation is granted, the A2LA staff prepares and forwards a certificate and scope of accreditation to the laboratory for each enrolled field of testing (and special program if appropriate). The laboratory should keep its scope of accreditation available to show clients or potential clients the testing technologies and test methods for which it is accredited. A2LA staff also uses the scopes of accreditation to respond to inquiries and to prepare the A2LA Directory. In some cases, (e.g. calibration, environmental testing) where a large number of tests need to be identified, a supplemental scope is prepared by staff in cooperation with the laboratory.

## VII. Annual Review

Accreditation is granted for two years. However, after the first year of accreditation, each laboratory must pay annual fees and assessor fees and undergo a one-day surveillance visit by an assessor. This surveillance visit is performed to confirm that the laboratory's quality system and technical capabilities remain in compliance with the accreditation requirements. For subsequent annual reviews occurring after the renewal of accreditation (see Section VIII) each laboratory must pay annual fees and submit updating information on its organization, facilities, key personnel and results of any proficiency testing. Objective evidence of completion of the internal audit and management review is also required. If the renewal laboratory does not promptly provide complete annual review documentation, significant changes to the facility or organization have occurred, or proficiency testing results have been consistently poor, a one-day surveillance visit and payment of the associated assessor fees is required.

### VIII. Reassessment and Renewal of Accreditation

A2LA conducts a full on-site reassessment of all accredited laboratories at least every two years. Reassessments are also conducted when evaluations and submissions from the laboratory or its clients indicate significant technical changes in the capability of the laboratory have occurred. Each accredited laboratory is sent a renewal questionnaire, well in advance of the expiration date of its accreditation, to allow sufficient time to complete the renewal process. A successful on-site reassessment must be completed before accreditation is extended for another two years.

If deficiencies are noted during the renewal assessment, the laboratory is asked to write to A2LA within 30 days after the assessment stating the corrective action taken. All deficiencies must be resolved before accreditation is renewed for another two years.

The renewal decision process is similar to the initial decision process (see section VI. Accreditation Decisions), except as follows:

1) If there are no deficiencies, renewal is automatically processed without an Accreditation Council panel vote.

- 2) If there are only a few deficiencies of a minor nature (i.e., the non-compliances do not directly affect the integrity of calibration or test results) and there is sufficient objective evidence that the deficiencies have been resolved, the President may elect to renew accreditation without an Accreditation Council panel vote.
- 3) If there are major deficiencies (i.e., the non-compliances directly affect the integrity of calibration or test results), the staff advises the laboratory of the required time-frame (normally 30 days) in which to resolve all deficiencies or be subject to further actions leading to suspension or withdrawal of accreditation (see sections XII. Adverse Accreditation Decisions, XIII. Suspension of Accreditation, and XIV. Withdrawal of Accreditation). Several related minor deficiencies or repeat deficiencies from previous assessments may also be considered a major deficiency. In these cases, a ballot of the Accreditation Council panel is conducted using the same voting procedure as for initial accreditation decisions.

In cases where significant deficiencies are identified in a renewal assessment, the laboratory may be required to undergo a surveillance assessment in conjunction with the next annual review to verify continued implementation of corrective actions (see section VII above).

### IX. Adding to the Scope of Accreditation

A laboratory may request an expansion to its scope of accreditation at any time. Such a request must be submitted in writing to A2LA headquarters. Each request is handled on a case-by-case basis. Unless the previous assessor can verify the competence of the laboratory to perform the additional tests or calibrations, another onsite assessment is normally required. If the assessor can recommend a scope addition without an assessment, but this recommendation requires extensive review of supporting documentation requiring more than one hour's time, A2LA may invoice the laboratory for this review time at the prevailing assessor rate. If the additional tests or calibrations require a new technology, another assessment is definitely required. Similarly, if a laboratory relocates, a follow-up assessment is warranted.

### X. Laboratory Reference to A2LA Accredited Status

A2LA-accredited laboratories are strongly recommended to use the "A2LA-accredited" logo to demonstrate their third party recognition of technical competence. "A2LA-accredited" logo sheets are sent to all accredited laboratories, and an electronic version is available upon request.

However, since A2LA laboratory accreditations are issued in a number of fields of testing and calibration, it is the ethical responsibility of accredited laboratories to describe their accredited status in a manner that does not imply accreditation in areas that are outside their actual scope of accreditation or for other testing/calibration facilities not covered under the present accreditation. This may be accomplished through adherence to the following:

- 1) Where the A2LA name and/or logo is used on general literature such as letterhead and advertisements, it shall always be accompanied by at the word "accredited".
- 2) While there are no restrictions on the size and color of the "A2LA-accredited" logo reproduction, the logo must maintain its form.
- 3) The "A2LA-accredited" logo may be generated electronically provided that the prescribed formats and

forms are retained.

- 4) When promoting or providing proof of accreditation, accredited laboratories should use the scope(s) of accreditation, as this document details the specific tests or calibrations which are accredited. The certificate should be used for display purposes and may also accompany the scope.
- 5) When the "A2LA-accredited " logo is used to endorse test or calibration results, it shall always be accompanied by the A2LA accreditation number(s). The following conditions apply:
  - a) The "A2LA-accredited" logo may be displayed on all calibration certificates, test certificates, and test reports which contain **exclusively** results from calibrations and tests that have been carried out within the accredited scope of the laboratory concerned.
  - b) Non-accredited results may be reported on calibration certificates, test certificates, and test reports with the A2LA logo provided these results are unambiguously identified as non-accredited. This may be done by placing an asterisk after each such result, along with a footnote stating: "This is not covered by our current A2LA accreditation".
  - c) On reports where results are reported within the field where accreditation exists but in a technology that is not included in the scope, they must be so identified. (For example, if a laboratory is accredited in the Environmental Field for only wet chemistry and metals, any gas chromatographic data reported would need to be identified as non-accredited.)
  - d) As of May 1, 1999, the calibration certificates issued by A2LA-accredited laboratories shall reference, at a minimum the A2LA name (or logo) and the accreditation number when the calibrations contained in the report are covered under the A2LA-accreditation. Refer to the A2LA Traceability Policy.
- 6) When the A2LA name and/or logo is used on a business solicitation document such as a proposal or quotation form, the laboratory has the responsibility to distinguish between those proposed tests or calibrations that fall within the laboratory's scope of accreditation and those that do not. This is done by attaching a copy of its current A2LA Scope of Accreditation sheet and Supplement to the Scope, if appropriate, or by noting which tests or calibrations are non-accredited.
- 7) The "A2LA-accredited" logo and/or reference to the laboratory's accreditation may be made in advertisements provided the requirements of this document are strictly followed.
- 8) The "A2LA-accredited" logo shall not be displayed on business cards in a manner that might imply personnel certification. This may be accomplished by including the statement "A2LA Accredited Laboratory".
- 9) The "A2LA-accredited" logo shall not be displayed on a test item or product or used to imply product certification. If the "A2LA-accredited" logo is used in literature relating to a product, the logo must appear directly adjacent to the reference to the accredited calibration or testing laboratory and it must be clearly stated that inclusion of the logo does not imply certification/approval of the products calibrated or tested.
- 10) Upon suspension or termination of accreditation, a laboratory must immediately cease to issue calibration certificates, test reports, and test certificates displaying the logo and shall cease publishing documents containing the logo.
- 11) An accredited laboratory owns the right to release A2LA assessor reports and deficiency reports as long as the reports are reproduced in whole and not in part. A2LA holds this assessment information in confidence unless specifically requested in writing by the accredited laboratory to release this information to another party.

Note: Every circumstance where the principle of accurate representation applies cannot be anticipated and dealt with in this document. Therefore, it is the responsibility of the accredited laboratory not to misrepresent its accredited status under any circumstances. If there are questions, the laboratory should submit intended uses of the logo, draft advertisements, and/or any other accreditation claims to A2LA for advance review.

# XI. Misuse of the A2LA Accreditation Logo

A2LA provides guidance to laboratories attaining accreditation for proper control on the use of its accreditation logo.

Incorrect references to A2LA or misleading use of the accreditation logo found in advertisement, catalogs, etc. shall be dealt with by suitable actions which could include legal or corrective action or publication of the transgression.

In cases of misuse of the accreditation logo by laboratories, A2LA shall take appropriate corrective action, which may include suspension of accreditation.

# XII. Accreditation Status and Adverse Accreditation Decisions

There are various levels of status that may be assigned to laboratories that cannot uphold the requirements for initial or continued accreditation:

**Voluntary Withdrawal** – An applicant laboratory not yet accredited, or a renewal laboratory, can decide to terminate further accreditation action and voluntarily withdraw from the accreditation program. The laboratory contact must inform A2LA in writing of this request. A2LA does not publicize the fact that a new laboratory had applied and then withdrawn; a list of previously accredited laboratories that have withdrawn is published with each A2LA News.

**Delinquent** – A laboratory (newly enrolled or renewal) is classified as delinquent when it has not completed the necessary assessment actions within an acceptable time frame. A laboratory's delinquent status is not publicized. The laboratory must undergo a full reassessment, paying only the assessor fees and expenses, before any further accreditation actions can be taken. A new laboratory's anniversary date is based on the date of this full reassessment (see section IV above). A renewal laboratory's anniversary date remains unchanged.

If a significant portion of a renewal laboratory's two-year accreditation term has already elapsed during which time it was not accredited, the laboratory is strongly encouraged to reapply as a new laboratory, paying new laboratory fees in addition to the assessor fees and expenses. By doing so, it would be assigned a new anniversary date based on the date of the new assessment (see section IV above).

**Inactive** – A laboratory is designated as inactive when it has specifically requested in writing that its accreditation be allowed to temporarily expire due to unforeseen circumstances that prevent it from adhering to the A2LA Conditions for Accreditation. To regain their accredited status, the Inactive lab must notify A2LA in writing of this desire, agree to undergo a full reassessment, paying all renewal fees and reassessment costs.

The Inactive status can be given to a laboratory for no longer than one year, after which time the laboratory is removed from A2LA records and designated as withdrawn.

Any decision from an appeals vote which would deny or withdraw a laboratory's complete accreditation, must be agreed upon by a two-thirds vote of those voting from the nine-member appeals panels of the Accreditation Council.

Suspension of all or part of a laboratory's accreditation may be a decision made by either the President or Accreditation Council panel. Suspension actions by the President are generally taken based on failure to comply with the conditions for accreditation (e.g., failure to pay required fees, failure to participate in required proficiency testing, etc.).

In some fields of testing or special programs, failure to meet with the criteria for acceptable proficiency test results can result in automatic enforced withdrawal of accreditation for the test(s) under question. These are identified in the specific requirements for those fields or in the A2LA Proficiency Testing Requirements for Accredited Testing and Calibration Laboratories.

See the following sections on XIII. Suspension of Accreditation, XIV. Withdrawal of Accreditation and XV. Appeals Procedures for further details.

# XIII. Suspension of Accreditation

The accreditation applicable to a specific laboratory may be suspended upon adequate evidence of:

- I non-compliance with the requirements of a nature not requiring immediate withdrawal;
- Improper use of the accreditation logo (e.g., misleading prints or advertisements are not solved by suitable retractions and appropriate remedial measures by the laboratory); and
- other deviations from the requirements of the A2LA accreditation program (e.g., failure to pay the required fee or to submit annual review information within 60 calendar days after it is due).

When an accredited laboratory is suspended, A2LA shall confirm an official suspension in a certified letter, return receipt requested, (or equivalent means) to the laboratory's authorized representative, stating:

- the cause;
- the conditions under which the suspension will be lifted;
- I that the suspension will be publicized in the A2LA Newsletter and on the Worldwide Web;
- I that the suspension is for a temporary period to be determined by the time needed to take corrective action;
- that, within thirty (30) days of receipt of the notice, the laboratory may submit in person, or in writing, information in opposition to the suspension, including any additional information that raises a genuine dispute over material facts;
- that a further review will be conducted to consider such information and a further written notification will be sent to the laboratory by certified mail, return receipt requested, indicating whether the suspension has been terminated, modified, left in force or converted to a withdrawal of accreditation.

# XIV. Withdrawal of Accreditation

A2LA shall withdraw accreditation for any of the following causes:

- under the relevant provisions for suspension of accreditation;
- If surveillance indicates that deficiencies are of a serious nature as judged by the Accreditation Council panel;
- when complaints are received relating to one or more of the laboratory's test reports and investigation reveals serious deficiencies in the quality system and/or competence in conducting the specific tests;
- if the system rules are changed and the laboratory either will not or cannot ensure conformance to the new requirements;
- on any other grounds specifically provided for under these program requirements or formally agreed between A2LA and the laboratory;
- when such action is necessary to protect the reputation of A2LA; and
- at the formal request of the laboratory.
- When it is proposed to withdraw accreditation, A2LA shall issue a written notice by certified mail, return receipt requested:
- I that withdrawal is being considered;
- of the reasons for the proposed withdrawal sufficient to put the laboratory on notice of the cause;
- that within thirty (30) days of receipt of the notice, the laboratory may submit in person, or in writing, information in opposition to the withdrawal, including any additional information that raises a genuine dispute over material facts; and
- of the effect of proposed withdrawal, including removing the laboratory's name from the A2LA Directory and publicizing the action in the A2LA Newsletter and on the Worldwide Web.

A laboratory may appeal to A2LA against a decision to withdraw or not to award accreditation.

### XV. Appeals Procedure

There are two possible levels that an appeal can reach before being resolved:

1) Accreditation Council (nine-member appeals panel);

2) Board of Directors.

The A2LA staff shall advise the applicant in writing of its right to challenge an adverse accreditation decision by the President or Accreditation Council panel. The appeals policy, including an applicant's right to a hearing, are contained in the A2LA Bylaws.

An appeal shall be lodged no later than thirty (30) days after notification of the decision by forwarding a certified letter to A2LA for timely consideration by the appeals panel of the Accreditation Council.

The decision of the Accreditation Council's appeals group is communicated in writing to the appellant.

If the decision is not favorable to the appellant, the appellant may lodge a further appeal within thirty (30) days of notification by forwarding a certified letter to A2LA for timely consideration by the Board of Directors. This letter shall include appropriate substantiation for the appeal. This letter will be promptly transmitted to the members of the Board of Directors appeals group, the composition of which to be determined taking into account any conflict-of-interest considerations.

The decision of the Board of Directors shall be final and is communicated in writing to the appellant.

### XVI. Confidentiality Policy

All information provided by applicants in connection with a request for an application package, an application for accreditation, an assessment or proficiency test is confidential. Such information is examined by a small group of A2LA staff, assessors, and Accreditation Council and external bodies as needed for recognition of the program. All are made aware of its confidentiality. Such information shall not be released unless the applicant provides A2LA permission in writing to do so.

Documents necessary to convey information about accredited laboratories and their scopes of accreditation are not confidential.

In response to a question about whether or not a particular laboratory has applied for accreditation, A2LA simply responds by saying that the laboratory is not accredited. Staff should neither confirm nor deny whether a laboratory has ever applied for accreditation. If the laboratory itself is saying that it has applied for accreditation, it is the laboratory's responsibility to release the information regarding its applicant status. If the caller says that the laboratory claims it applied, staff shall take the name, address and phone number of the laboratory to check to see if the laboratory is misleading the client but staff still will not verify the laboratory's application. Should an applicant laboratory require that staff verify for a potential client that it has applied to A2LA, staff shall indicate that it has applied only if the applicant makes such a request to A2LA in writing or designates on the application for accreditation that A2LA is authorized to release information regarding the applicant's status.

If an inquiry is made about a laboratory whose accreditation has lapsed but is in the renewal process, staff can indicate that the laboratory is not now accredited but is in the process of renewal, if that is the case. If the renewal laboratory's accreditation has lapsed with no indication (return of renewal forms or payment) of pursuit of renewal, staff indicates simply that the laboratory is not accredited.

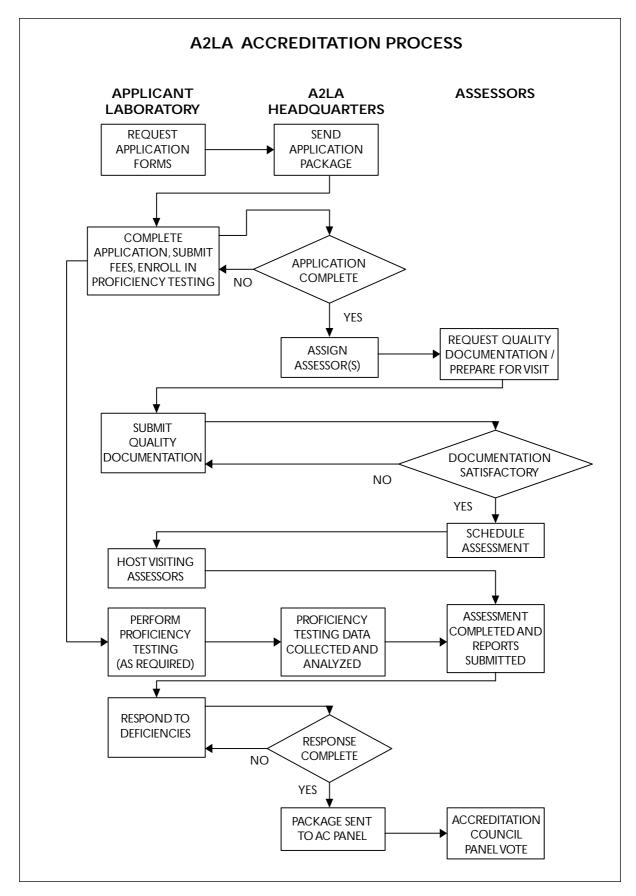
If A2LA finds that a laboratory is misrepresenting its applicant or accredited status, staff shall treat such information like a complaint by first informing the A2LA President. The President shall determine the appropriate action, which would usually involve contacting the laboratory directly about the alleged misrepresentation.

# XVII. Conflict of Interest Policy

Since its inception, A2LA has had a policy that actual or apparent conflicts of interest must be avoided as mandated by normal business ethics. Consistent with the principles set forth in ISO/IEC Guide 58, "Calibration and Testing Laboratory Accreditation Systems — General Requirements for Operation and Recognition," A2LA believes that it is vital that its accreditation services be impartial and objective, uninfluenced by the private interests of individuals acting for A2LA. Accordingly, any person directly involved in actions relating to the A2LA accreditation process shall avoid direct participation in A2LA actions that may involve an actual or apparent conflict of interest.

The Chairman of the Board and the President shall, as promptly as possible, take all possible means to prevent or overcome any such actions that may conceivably be in violation of this policy.

Diagrams of the A2LA accreditation process and appeals process are provided on the next two pages.



#### **APPLICANT** ACCREDITATION A2LA **BOARD OF** LABORATORY **HEQDQUARTERS** COUNCIL (AC) DIRECTORS NEGATIVE **AFFIRMATIVE** REQUEST INITIAL **RESPOND TO** RESOLUTION DECISION NEGATIVE **OF NEGATIVE** VOTES VOTES(S) SUBMIT VOTE YES RESPONSES CHANGED TO AC MEMBER(S) TO POSITIVE WITH NEGATIVE VOTE(S) NO LAB NOTIFIED **OF RIGHT** TO APPEAL OFFICIAL SCOPE SUBMIT OF WRITTEN ACCREDITATION APPEAL ISSUED NO NEGATIVE AC NOTIFIED DECISION OF APPEAL UPHELD LAB NOTIFIED YES OF RIGHT TO APPEAL NO NEGATIVE **BOARD NOTIFIED** SUBMIT DECISION WRITTEN AND CASE FILES UPHELD FORWARDED APPEAL

YES

### A2LA APPEALS PROCESS DIAGRAM

LAB NOTIFIED OF FINAL DECISION

Cross References from ISO/IEC 17025-1999 to ISO/IEC Guide 25-1990			
Subject – from ISO/IEC 17025 contents	ISO/IEC 17025 Reference	ISO/IEC Guide 25-1990 Reference	Comments
Scope	1.1	1.1	
	1.2	None	
	1.3	None	
	1.4	1.3	
	1.5	7.6 Note	
		Introduction	17025 states a laboratory complies with the relevant standard (ISO 9001) or 9002); Guide 25 only stated that laboratory complied with the relevant sections.
Normative references	2	2	
Terms and definitions	3	3	
Management requirements			
Organization	4.1.1	4.1	
	4.1.2	4.1	
	4.1.3	4.1	
	4.1.4	None	
	4.1.5 a)	4.2 a)	
	4.1.5 b)	4.2 b)	
	4.1.5 c)	4.2 i)	
	4.1.5 d)	4.2 c)	
	4.1.5 e)	5.2 b); 5.2 c)	
	4.1.5 f)	4.2 d)	
	4.1.5 g)	4.2 e)	
	4.1.5 h)	4.2 f)	
	4.1.5 i)	4.2 g)	
Quality system	4.1.5 j) 4.2.1	4.2 h) 5.1	
Quality system	4.2.2	5.1; 5.2 a)	17025 requires a) through e) be in- cluded in the quality policy; Guide 25 only required them to be included in the quality documentation.
	4.2.2 a)	5.1	
	4.2.2 b)	5.2 a)	
	4.2.2 c)	5.2 a)	
	4.2.2 d)	5.1	
	4.2.2 e)	5.2	
	4.2.3	5.2 m)	Guide 25 did not require an outline
	4.2.4	5.2 e)	17005 1 1 1 10 1
Document control	4.3.1	5.2 d); 10.1	17025 includes more specific require- ments for document control; Guide 25 only required procedures.
	4.3.2.1 - 4.3.3.4	None	17005 1 1
Review of requests, tenders and contracts	4.4.1	5.2 i)	17025 includes more specific require- ments for contract review; Guide 25 only required arrangements.
	4.4.1 a) – 4.4.5	None	
Subcontracting of tests and calibrations	4.5.1	14.1	
	4.5.2	14.1	

Subject – from ISO/IEC 17025 contents	ISO/IEC 17025 Reference	ISO/IEC Guide 25-1990 Reference	Comments
	4.5.3	None	
	4.5.4	14.2	
Purchasing services and supplies	4.6.1	10.8; 15.1	
	4.6.2	15.2	
	4.6.3	None	
	4.6.4	15.3	
Service to the client	4.7	None	
Complaints	4.8	16.1	
Control of nonconforming work	4.9.1	5.2 o); 13.6	17025 lists specific requirements for the procedure; Guide 25 only covered item d)
	4.9.2	16.2	
Corrective action	4.10.1	5.2 o)	
	4.10.2	None	
	4.10.3	None	
	4.10.4	None	
	4.10.5	16.2	
Preventive action	4.11.1	None	
	4.11.2	None	
Control of records	4.12.1.1	None	Guide 25 did not require a procedure for control of records.
	4.12.1.2	12.2	
	4.12.1.3	12.2	
	4.12.1.4	10.7 c); e)	
	4.12.2.1	12.1	
	4.12.2.2	None	
	4.12.2.3	None	
Internal audits	4.13.1	5.3	
	4.13.2	5.3	
	4.13.3	5.5	
Management reviews	4.13.4 4.14.1	None 5.4	17025 lists 10 items to be covered in management review; Guide 25 did not include these items.
	4.14.2	5.5	
Technical Requirements			
General	5.1.1	None	
	5.1.2	None	
Personnel	5.2.1	6.1	
	5.2.2	6.2	17025 requires procedures for training; Guide 25 did not.
	5.2.3	None	
	5.2.4	5.2 e)	
	5.2.5	6.3	
Accommodation and environmental conditions	5.3.1	7.1; 7.2	
	5.3.2	7.3	
	5.3.3	7.4	
	5.3.4	7.5	
	5.3.5	7.6	

Subject – from ISO/IEC 17025 contents	ISO/IEC 17025 Reference	ISO/IEC Guide 25-1990 Reference	Comments
Test and calibration methods and method validation	5.4.1	10.1; 10.2; 10.5	
	5.4.2	10.3; 10.4; 10.5	
	5.4.3	None	
	5.4.4	10.4	
	5.4.5.1	None	
	5.4.5.2	10.4	
	5.4.5.3	None	
	5.4.6.1	None	
	5.4.6.2	None	
	5.4.6.3	None	
	5.4.7.1	10.6	
	5.4.7.2	10.7	
	5.4.7.2 a)	10.7 b)	
	5.4.7.2 b)	10.7 c)	
E	5.4.7.2 c)	10.7 d)	
Equipment	5.5.1 5.5.2	8.1 9.1	
	5.5.3	9.1	
	5.5.4	8.4 b)	
	5.5.5 a)	8.4 b) 8.4 a)	
	5.5.5 b)	8.4 b)	
	5.5.5 c)	None	
	5.5.5 d)	8.4 d)	
	5.5.5 e)	8.4 f)	
	5.5.5 f)	8.4 g)	Guide 25 did not require acceptance criteria to be documented.
	5.5.5 g)	8.4 h)	
	5.5.5 h)	8.4 i)	
	5.5.6	None	
	5.5.7	8.2	
	5.5.8	8.3	
	5.5.9	None	
	5.5.10	None	
	5.5.11	None	
<b>16</b>	5.5.12	None	
Measurement traceability	5.6.1 5.6.2.1.1	9.1 9.2	17025 requires traceability to the SI; Guide 25 required traceability to national standards.
	5.6.2.1.2	9.3	
	5.6.2.2.1	9.2	
	5.6.2.2.2	9.3	
	5.6.3.1	9.4; 9.5	17007
	5.6.3.2	9.6	17025 requires a procedure for inter- mediate checks; Guide 25 did not.
	5.6.3.4	None	
Sampling	5.7.1	10.5	
	5.7.2	None	
	5.7.3	None	

Subject – from ISO/IEC	ISO/IEC 17025	ISO/IEC Guide 25-1990	
17025 contents	Reference	Reference	Comments
Handling of test and	5.8.1	11.4	
calibration items			
	5.8.2	11.1	
	5.8.3	11.2	
	5.8.4	11.3	
Assuring the quality of test and calibration results	5.9	5.6; 5.6 a)	
	5.9 a)	5.6 c)	
	5.9 b)	5.6 b)	
	5.9 c)	5.6 d)	
	5.9 d)	5.6 e)	
	5.9 e)	5.6 f)	
Reporting the results	5.10.1	13.1	
	5.10.2 a)	13.2 a)	
	5.10.2 b)	13.2 b)	
	5.10.2 c)	13.2 c)	
	5.10.2 d)	13.2 d)	
	5.10.2 e)	13.2 h)	
	5.10.2 f)	13.2 e); 13.2 f)	
	5.10.2 g)	13.2 g)	
	5.10.2 h)	13.2 i)	
	5.10.2 i)	13.2 k)	
	5.10.2 j)	13.2 m)	
	5.10.2 k)	13.2 n)	
	5.10.3.1 a)	13.2 j)	
	5.10.3.1 b)	None	
	5.10.3.1 c)	13.2 l)	
	5.10.3.1 d)	None	
	5.10.3.1 e)	None	
	5.10.3.2 a)	None	
	5.10.3.2 b)	None	
	5.10.3.2 c)	None	
	5.10.3.2 d)	13.2 i)	
	5.10.3.2 e)	None	
	5.10.3.2 f)	None	
	5.10.4.1 a)	13.2 j)	
	5.10.4.1 b)	13.2 l)	
у	5.10.4.1 c)	None	
	5.10.4.2	None	
	5.10.4.3	None	
	5.10.4.4	None	
	5.10.5	None	
	5.10.6	13.3	
	5.10.7	13.7	
	5.10.8	13.4	
	5.10.9	13.5	

# Appendix 3. Photovoltaic Global Approval Program (PV GAP) Recommended Standards

Appendix 3A. PV RS-1 PV Stand-Alone System Design Qualifications and Type Approval

Appendix 3B. PV RS-2 Crystalline Silicon Terrestrial Photovoltaic (PV) Modules

Appendix 3C. PV RS-3 Thin-Film Terrestrial Photovoltaic (PV) Modules

# Appendix 3A. PV RS-1 PV Stand-Alone System Design Qualifications and Type Approval

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### Foreword

A large share of current applications of Photovoltaic (PV) solar energy applications regard stand-alone systems, where distance to or availability of a utility grid make this technology cost-effective and first choice.

In particular in rural areas of countries in development, a larger utility network for electricity supply cannot be economic, because low population density and low power demand per household would not justify the high investment costs of power distribution. There is a variety of applications, where Photovoltaic stand-alone systems provide since many years services such as lighting, refrigeration, communication, drinking water pumping and irrigation to name just a few. A number of studies have been performed in recent years which indicate that a large fraction of future photovoltaic applications may well be installed in those countries, with market volumes in the multi-gigawatt range.

In parallel there is a growing awareness of support organizations, government or nongovernment, profit or nonprofit, that provision of photovoltaic systems is an enabling support for these countries where most of the population lives today without electricity.

The success of photovoltaic systems calls for increased finance and a number of organizations provide already various financing schemes, which often include or require local manufacturing and installation.

It is obvious that photovoltaic technology must fulfill its promise, namely to guarantee basic electricity services for many years without maintenance and with reliable operation. If this promise fails, photovoltaics will remain in a niche market and be considered second-choice electricity useful only to generate demand for conventional electricity grids with probable high pollution.

The photovoltaic promise can be fulfilled if the system and its installation meet high standards in quality of manufacturing, performance and reliability.

The Photovoltaic Global Approval Programme (PV GAP), was founded in order to give support in establishing these duality goals, by guiding decisionmakers, manufacturers, financing organizations, installers and last not least the end user towards achieving an excellent electricity service which satisfies the needs for a long period of operation.

In following its objectives PV GAP has put in place working groups, which tackle the issues of Organization, Standards, Testing Labs on one hand and the compilation of a Handbook and the establishment of a particular Quality seal on the other.

This document shall serve as a starting point for discussion, both within the PV GAP Working Group on Standards as well as in the WG3 (PV Systems) of the Technical Committee 82 of the International Electrotechnical Commission. It is hoped that with this approach a contribution can be given to provide the poorest of this world's population access to a technology which may improve their conditions of life.

### Introduction

Photovoltaic Systems in the range smaller than 3 kW represent about two thirds of today's sales as they are usually applied in markets where other electricity sources would not be competitive.

These systems are worldwide installed and operational since years. They represent today the largest feedback concerning reliability, quality and service provided. It is well known that a certain fraction (estimated 30t) of these systems do not meet the high expectations users have put in from beginning. From a number of previous research and study projects, it is well documented what the reasons are and possible solutions to this problem have been outlined. However, with the knowledge available from these projects, a concerted effort is necessary now as all previous attempts were either below a critical mass or had not enough impact due to lack of agreed methods, standards and sufficient involvement from key players.

### Objectives

Therefore, for the approach of the Standards Group of PV GAP, the following objectives have been laid out:

To transform Photovoltaic systems and their components into standardized high-quality products for the

commercial market.

- To provide a single reference for system implementers, dealers and organizations in charge for selection, investment and follow-up of photovoltaic electricity programs.
- To increase significantly the share of Photovoltaic Systems in the decentralized electricity markets of the future.
- To implement a systems testing approach for a quality label of complete products ("Burn-in Tests")

# The PV GAP System Type Approval

The concept of PV GAP System Type Approval is based on identified bottlenecks in the quality of components on one hand, and system sizing and performance on the other.

This means in detail that:

- the high quality of components is a requirement for the quality level of the system, but not yet a sufficient condition
- all components have to match the same quality level
- all components have to match in sizing, ease of use and installation maintenance and cost in order to provide the service promised.

To implement these requirements as recommended standards for PV GAP approval, the following approach has been chosen:

- Submit all PV system components for type approval tests in order to certify a high reliability and quality level for each of the components.
- A complete system, assembled from prequalified components, is submitted to a simulated 10-day cycle test to verify its suitability for the services foreseen.

# Scope of the PV GAP System Type Approval

Photovoltaic stand-alone systems supply currently electricity for a vast variety of applications. It is almost impossible to provide quality standards for each of these systems. Therefore in this document an attempt is made to implement a concept that initially comprises only the most basic system providing illumination for small settlements (Solar Home System or SHS), but can be subsequently completed by other application specific component tests. The complete systems tests remains unchanged in its concept, but will be modified in its detail according to the services the system is foreseen to provide.

The photovoltaic stand-alone systems which are the topic in this standard, are generally consisting of:

- Photovoltaic Generator: module and connection box; mounting structure
- Balance of System Components: accumulator, charge-regulator, inverter, cables, wiring, switches, fuses, controllers
- Application Components: lamps, (pumps, radio transmitters, TV and radio sets, and so forth)

# Present Situation of PV Components Quality

#### Quality of Photovoltaic Modules

It is generally agreed, that in most applications the quality level of PV modules is sufficiently high. PV modules are tested since more than 15 years, according to test procedures Such as JPL Block V, JRC Ispra Spec. 502 and 503, and IEC 1215.

### Quality of Balance-of-System Components (Batteries, Charge Controllers, Inverters)

These Components are identified as the critical parts of todays PV installations with the highest failure rate. There have been numerous efforts to assess the performance, recommended practices and to apply qualification tests on these components. All of these efforts did not lead to a quality situation comparable to PV modules. To the opinion of the author at least one of the above listed success requirements was missing in the previous attempts to establish a quality label.

### Quality of Application Components

Applications typically use or adopt components not specifically designed for use of Photovoltaics. As these components are produced often for other large-scale markets, the quality testing occurred already through the market penetration. However, tests aiming to screen available components in terms of their performance and adaptability to particular issues of photovoltaic systems will be necessary.

### Limitations

PV GAP, as a promoter of internationally applicable quality standards, will be close affiliated with the IEC, as only this standards body represents a large number of National member committees. Therefore, in this document preference is given to refer to published IEC standards. However, where national standards or test practices of laboratories seem to match better the goals of PV GAP, they are referred to as well to foster discussion to improve and update existing standards.

In this present version only the Solar Home System for Lighting purposes is considered, in order to gain experience with the proposed concept and to allow for participation of a large number of manufacturers and test laboratories. This document shall be revised in regular intervals according to knowledge, experience and results.

### Contents and Structure of the Standards Documents

Title: Photovoltaic Stand-Alone Systems-Design Qualification and Type Approval Test Specifications

Part A:Test Procedures for Components Photovoltaic Modules Charge Controllers Accumulators Appliances Lamps

#### Part B:Test Procedures for System Approval Performance Test under Operating Conditions Verification of sizing Wiring Installation Performance Rating Indoor Method Outdoor Method

### Note:

Those parts of the proposed standard that are still missing are printed in italics.

# Contacts for Suggestions

This document will be periodically revised. Recipients of this document are invited to submit their comments to PV GAP Secretariat.

# **Recommended Test Specifications**

#### 1. Scope and Object

To lay down requirements for design qualification and type approval of stand-alone Photovoltaic (PV) Systems suitable for long-term operation in general open-air climates. The PV system under consideration in this standard is limited in size and function to stand-alone applications for single-family dwellings: Maximum array power at STC of less than 1000 W, basic electricity appliances such as lights, radio, TV, refrigerators and telecommunication systems.

### 2. Purpose

This document describes test procedures to determine the electrical and service characteristics of a Standalone PV system and its components, and to show as far as possible within reasonable constraints of cost and time that the system is capable to deliver its service during prolonged exposure in climates defined in the scope This document contains test procedures which are preliminary and will be revised before publication

This recommendation lays down the control tests and design specifications for the type approval of Solar Home Systems (SHS)

### 2.1. Objective

The general objective of these tests is to assess relative performances and to identify environmental factors and design features which could affect the attainment of a sufficiently long lifetime.

#### 3. Normative References

■ IEC publications quoted in this standard are: IEC 1277

#### 4. Sampling

Two complete systems for qualification testing (plus spares as desired) shall be taken at random from a production batch or batches. If the system components have not been certified by the according component type approvals, additional samples may be required as described in the relevant standards. The systems shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and have been subjected to the manufacturer's normal inspection, quality control and production acceptance procedures. The systems shall be complete in every detail and shall be accompanied by the manufacturer's handling, mounting and connection instructions, including safety instructions.

Where PV modules, Charge controllers, Accumulators and Lamps have been type-approved already, a copy of the relevant test certificate shall be included.

When the systems to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report (see Clause A8).

### 5. Marking

Each component of the system shall carry the following clear indelible markings:

- name, monogram or symbol of manufacturer;
- type or model number;
- serial number;
- polarity of terminals or leads (color coding is permissible);

The date and place of manufacture shall be marked on the component or be traceable from the serial number.

### 6. Testing

The system shall be divided into groups and subjected to the test sequences in Fig.1, carried out in the order laid down. Test procedures and severities, including initial and final measurements where necessary, are detailed in Part B.

- Visual Inspection
- Performance of modules at STC
- Installation
- PTOC Cycles:
  - High Irradiance, Low Temperature
  - High irradiance, High Temperature
  - Low Irradiance, Low Temperature
  - Low Irradiance, High Temperature
- Verification of Sizing
- Visual Inspection
- Performance of Modules at STC

### Table.1:Tests to Be Carried Out

In carrying out the tests, the tester shall strictly observe the manufacturer's handling, mounting and connection instructions.

### 6.1. Pass Criteria

A system design shall be judged to have passed the qualification tests, if each test sample meets all the following criteria:

a) PV modules, charge controller, Accumulator and Lamp bear a type approval certificate

b) No sample has exhibited any open-circuit, short circuit or ground fault during the tests.

- c) There is no visual evidence of a major defect, as defined in Clause 7.
- d) The insulation test requirements are met after the tests.

e) The performance requirements are met after the tests.

Should one system fail any test, another two systems meeting the requirements of Clause 4 shall be subjected to the whole of the relevant test sequence from the beginning. If one or both of these systems also fail, the design shall be deemed not to have met the qualification requirements. If, however, both systems pass the test sequence, the design shall be judged to have met the qualification requirements.

### 7. Major Defects

For the purposes of design qualification and type approval, the following are considered to be major defects:

- 1) broken or cracked PV module;
- 2) broken or cracked Accumulator
- 3) Loss of function of Charge Controller
- 4) Loss of function of Lamp
- 5) loss of mechanical integrity, to the extent that the installation and/or operation of the system would be impaired.

### 8. Reports

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A certified report of the qualification tests, with measured performance characteristics and details of any failures and retests, shall be prepared by the test agency. A copy of this report shall be kept by the manufacturer for reference purposes.

### 9. Modifications

Any change in the design, materials, components or processing of the system may require a repetition of some or all of the qualification tests to maintain type approval.

# Part A: Test Procedures for Components

# **Photovoltaic Modules**

### 1. Normative Reference

IEC 1215 Ed. 1.0	Crystalline silicon terrestrial photovoltaic (PV) modules-Design qualification and type
	approval
IEC 1646 Ed. 1.0	Thin-film terrestrial photovoltaic (PV) modules-Design qualification and type approval

### 2. Summary of Test Levels in IEC 1215

Test no./title	Test level
10. 1 Visual Inspection	See detailed inspection list in B1.2
10.2 Performance at STC	Cell temp. 25(C; Irradiance 1000 WM <sup>2</sup>
10.3 Insulation	1000 Vdc + twice the open-circuit voltage of the system at ] min.
	Insulation resistance not less than 50 Megohms at 50
10.4 Measurement of Temperature Coeff	
10.5 Measurement of NOCT	Total solar irradiance: 800 W.M <sup>2</sup>
	Ambient temperature: 20°C
	Wind Speed: I m-s-1
10.6 Performance at NOCT	Cell temp. NOCT. Irradiance: 800 W-m <sup>2</sup>
10.7 Performance at Low Irradiance	Cell temp. 25°C Irradiance: 200 w-m <sup>2</sup>
10.8 Outdoor Exposure	60 kWh.M <sup>2</sup> total solar irradiation
10.9 Hot Spot Endurance	Five one-hour exposures to 1,000 W-m <sup>2</sup> irradiance in worst-spot
	condition.
10.10 UV Exposure	15 kWh.M <sup>2</sup> UV irradiation
10.11 Then-nal Cycling	50 and 200 cycles from 40°C to +85°C.
10.12 Humidity Freeze	10 cycles from +850°C, 85% RH to-400°C
10.13 Damp Heat	1,000 hours at +850°C, 85% RH.
10.14 Robustness of Ten-ninations	As in IEC 68–2–2 1.
10.15 Twist	Deformation Angle: 1.21.
10.16 Mechanical Load	2 cycles of 2450 Pa unifon-n load, applied for I hour to fro back
	surfaces in turn.
10.17 Hail Resistance	25 mm diam. ice ball at 23.0 m-s-1, directed at I I impact 1

### 3. Energy Rating

See Draft IEC TC82/WG2 under consideration as international standard.

# Bibliography

1.IEC 1173 (1992-09)

Over voltage protection for photovoltaic (PV) power generating systems-Guide.

2.IEC 1194 (1992-12)

Characteristic parameters of stand-alone photovoltaic (PV) systems. Defines the major electrical, mechanical and environmental parameters for the description and performance analysis of stand-alone photovoltaic systems.

3.IEC 1215 Ed. 1.0

Crystalline silicon terrestrial photovoltaic (PV) modules-Design qualification and type approval.

4. IEC 1277 Ed. 1.0

Terrestrial photovoltaic (PV) power generating systems-General and guide.

5.IEC 1646 Ed. 1.0

Thin-film terrestrial photovoltaic (PV) modules-Design qualification and type approval.

6.IEC 1701 Ed. 1.0

Salt mist corrosion testing of photovoltaic (PV) modules

7.IEC 1702 Ed. 1.0

Rating of direct coupled photovoltaic (PV) pumping systems

8.IEC 1721 Ed. 1.0

Susceptibility of a photovoltaic (PV) module to accidental impact damage (resistance to impact test)

9.IEC 1727 Ed. 1.0

Photovoltaic (PV) systems-Characteristics of the utility interface

10. IEC 1829 (1995-03)

Crystalline silicon photovoltaic (PV) array-On-site measurement of I-V characteristics

11. IEC 891 Ed. 1.0

Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices

- 12. IEC 891-aml (1992-06)
  - Amendment No. 1

13. IEC 904–1 Ed. 1.0

Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics

14. IEC 904-2 Ed. 1.0

Photovoltaic devices. Part 2: Requirements for reference solar cells

15. IEC 904-3 Ed. 1.0

Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

16. IEC 904-5 Ed. 1.0

Photovoltaic devices. Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method

17. IEC 904-6 Ed. 1.0

Photovoltaic devices. Part 6: Requirements for reference solar modules

18. IEC 904-7 Ed. 1.0

Photovoltaic devices. Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device

19. IEC 904-8 Ed. 1.0

Photovoltaic devices. Part 8: Guidance for the measurement of spectral response of a photovoltaic (PV) device

20. IEC 904-9 (1995-09)

Photovoltaic devices. Part 9: Solar simulator performance requirements.

# Part A: Test Procedures for Components

# Charge Controllers

# 1. Purpose

To verify that Charge controllers for use in photovoltaic systems withstand prolonged operation and are functioning throughout the lifetime according to their foreseen purpose.

# 2. Scope

Charge Controllers for Lead-Acid Accumulators (vented and gas-tight). The tests described in this standard are limited to charge controllers which use the accumulator terminal voltage as criterion for operation.

# 3. Definitions (see IEC 1244)

Charge Controllers in PV stand-alone systems serve to match the supply of PV electricity as delivered by the PV modules to the specific characteristics of lead-acid accumulators by

- limiting excess gassing and water loss by reducing the charge current of the PV Modules such as that a certain Voltage (Vhcd: Voltage at High Charge Disconnect) is not exceeded.
- Imiting deep discharge of the accumulator in order to increase the cyclic lifetime. This is generally accomplished by automatic disconnect of the load circuit when the battery voltage decreases below a certain voltage (Ulcd; Voltage at low charge disconnect).

The specifications for charge-controllers list: lcmax Maximum Charge Current permissible ilmax Maximum load current permissible.

# 4. Tests

### 4.1 High Charge Disconnect Test Purpose

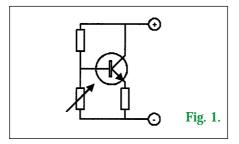
### 4.1.1 Purpose

To determine the High-charge disconnect and reconnect voltages of charge-controllers.

### 4.1.2 Apparatus

**4.1.2.1** Voltage / current source capable of delivering the maximum system voltage and charge current as specified by the manufacturer of the charge controller. Voltage and current shall be adjustable independently from each other.

**4.1.2.2** An accumulator of a voltage matching Uhcd of the charge controller specified and a capacity not smaller than lcmax [Al\* 4[h) or battery simulation circuit. (See Fig. 1.)



**4.1.2.3** Three-channel chart recorder, capable to measure the battery voltage to an accuracy of 0.2% and to measure the array and load current to an accuracy of it.

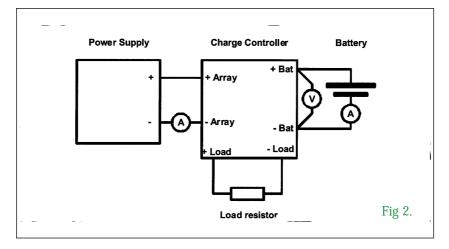
**4.1.2.3** A Resistor of the Size  $2^*$  Uhcd / Iagmax, tolerance  $20^*$ i capable of withstanding power dissipation of  $0.5^*$  Uhcd \* Icmax.

### 4.1.3 Procedure

**4.1.3.1** Mount the charge controller as recommended by the resistor and measurement.

# Note:

In connecting the components, care must be taken that sequence of connecting and wire sizes are as recommended by the manufacturer. If no sequence if given, connect first the accumulator. manufacturer.



Connect the Power Supply, accumulator, instruments as depicted in Fig 2.

**4.1.3.2** Make sure that the temperature of the charge controller is maintained at the prescribed test level.

**4.1.3.3** Set the current of the power supply to Ichmax.

**4.1.3.4** Using the chart recorder, record Voltage and Current for a period sufficiently long to cover both phases of the controller's Charge-Limit operation (see Fig.3).

**4.1.3.5** From the Chart recorder plot, determine Uhcd (voltage at High Charge Disconnect), that is the voltage measured immediately after the battery charge current switched from positive to zero).

# Remark:

Some charge-controllers are operating such that no measurement of Uhcr is possible. In this case Uhcd is the maximum voltage measured during a 12 hour period.

**4.1.3.6** From the Chart recorder plot, determine Uhcr (Voltage at High Charge Reconnect), that is the voltage measured just after the battery charge current switched from positive to negative).

Repeat step 3 and 4 for a total of 5 cycles.

**4.1.3.7** Calculate the average over all 5 measured values of Uhcd and the average over all 5 measured values of Uhcr. These are the final values of Uhcd and Uhcr.

# 4.2 Determination of Low Charge Disconnect and Reconnect Voltages

**4.2.1** Purpose: To determine the Low-charge disconnect and reconnect voltages of charge-controllers.

#### 4.2.2 Apparatus

# Note:

In connecting the components, care must be taken that sequence of connecting and wire sizes are as recommended by the manufacturer. if no sequence if given, connect first the accumulator. **4.2.2.1** A voltage / current source capable of delivering the maximum system voltage and charge current as specified by the manufacturer of the charge controller. Voltage and current shall be adjustable separately.

**4.2.2.2** An accumulator of a voltage matching Uhcd of the charge controller as specified and a capacity not smaller than lcmax [Al\* 4[h] or a battery simulation circuit. (See Fig. 1.)

**4.2.2.3** A three-channel chart recorder, capable to measure the battery voltage to an accuracy of 0.2t and to measure the array and load current to an accuracy of it.

**4.2.3.4** A Resistor of the Size 0.5 \* Uhcd Iagmax, tolerance 20%. capable of withstanding power dissipation of 2 \* TJhcd \* Iagma

4.2.3 Procedure

**4.2.3.1** Mount the Charge controller as recommended by the manufacturer. Connect the Power Supply, accumulator, resistor and measurement instruments as depicted in **Fig 2**.

**4.2.3.2** Make sure that the temperature of the charge controller is maintained at the prescribed test level.

**4.2.3.3** Set the current of the power supply to Ichmax.

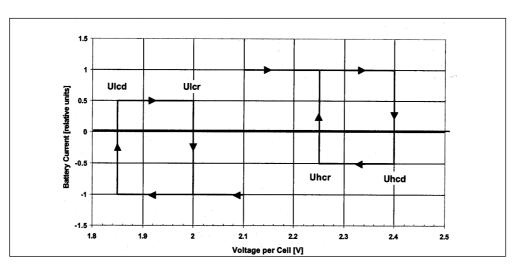
**4.2.3.4** Using the chart recorder, record Voltage and Current for a period sufficiently long to cover both phases of the controller's Charge-Limit operation (see Fig.3).

**4.2.3.5** From the Chart recorder plot, determine Ulcd (Voltage at Low Charge Disconnect), that is the voltage measured immediately after the Battery charge current switched from negative to positive).

**4.2.3.6** From the Chart recorder plot, determine Uhcr (Voltage at High Charge Reconnect), that is the voltage measured just after the battery charge current switched from positive to zero).

4.2.3.7 Repeat step 3 and 4 for a total of 5 cycles.

**4.2.3.8** Calculate the average over all 5 measured values of Ulcd and the average over all 5 measured values of Ulcr. These averages are the final values of Ulcd and Ulcr.





### 5. Measurement of Temperature Coefficients

6. Robustness of Terminations test As of IEC 121S, test 10.14

### 7. Determination of Stand-By Consumption

### 8. Insulation Test

### 9. Thermal Cycling

# Bibliography

### Charge Controllers

- 1. IEC 439-1 (1992-12)
- Low-voltage switchgear and controlgear assemblies. Part 1: Type-tested and partially type-tested assemblies.
- 2. IEC 439-1-ami (1995-11) Amendment No. I
- 3. IEC 439-1-am2 (1996-12) Amendment No. 2
- 4. IEC 439–2 (1987–11) Low-voltage switchgear and controlgear assemblies. Part 2: Particular requirements for busbar trunking systems (busways).
- 5. IEC 439-2-aml (1991-09) Amendment No. 1
- 6. IEC 439-3 (1990-12)

Low-voltage switchgear and controlgear assemblies. Part 3: Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use Distribution boards.

7. IEC 439-3-aml (1993-10) Amendment No. I

```
8. IEC 439-4 (1990-12)
```

Low-voltage switchgear and controlgear assemblies. Part 4: Particular requirements for assemblies for construction sites (ACS).

9. IEC 439-4-aml (1995-12) Amendment No. 1

status of a basic safety publication in acco

10. IEC 439-5 (1996-03)

Low-voltage switchgear and controlgear assemblies. Part 5: Particular requirements for assemblies intended to be installed outdoors in public places. Cable distribution cabinets (CDCS) for power distribution in networks. 11. IEC 529 (1989–11)

Degrees of protection provided by enclosures (IP Code). Applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 kV. Has the

# DC Safety

1. IEC 1204 (1993–02)

Low-voltage power supply devices, DC output. Performance characteristics and safety requirements.

# Part A. Test Procedures for Components

# Accumulators

Photovoltaic Stand-Alone Systems-Design Qualification and Type Approval Recommended Test Specifications

# Part A. Test Procedures for Components

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# Accumulators

Remark: Reference shall be made to Committee Draft IEC TC21/ 417/CD after decision about comments as listed in Compilation of comments 21 (Paris/Secretariat) 13, 20 March 1997

Contents of IEC TC21/417/CD

The contents and some details of this document are as indicated below:

Section 1: General

- 1. Scope
- 2. Object
- 3. Normative References
- 4. Terminology
- 5. Conditions of Use

Section 2: Functional Characteristics

- 6. Capacity
- 7. Cycle Endurance
- 8. Overcharge Protection
- 9. Charge Retention
- 10. Charge efficiency
- 11. Overdischarge Protection
- 12. Mechanical Endurance
- Section 3: General Test Conditions
  - 13. Accuracy of Measuring Instruments
  - 14. Preparation and Maintenance of Test Samples
- Section 4: Test Methods
  - 15. Capacity Test
  - 16. Cyclic Endurance Test
  - 17. Mechanical Endurance Test
- Section 5: Recommended Use of Tests
  - 18. Type test
  - 19. Acceptance Tests
  - 20. Safety
  - 21. Documentation

# Remark:

The Committee Draft describes a Cycle Endurance Test, comprising 50 shallow cycles at low State of Charge (Phase A), and low shallow cycles at high state of charge (Phase B). Both Phases A and B are repeated subsequently together with a capacity test, until the actual capacity is less than the rated capacity. See Figs. 1 and 2.

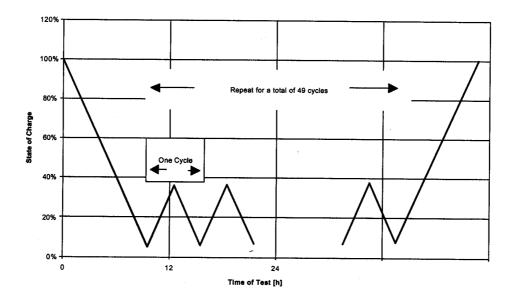
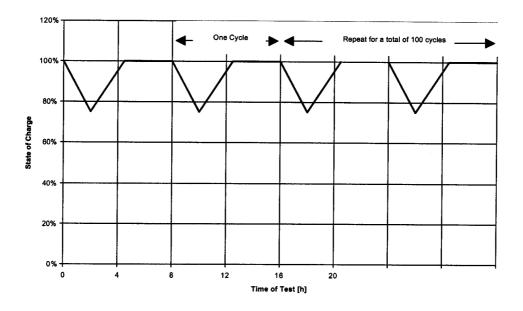


Fig. 2 IEC TC21/417/CD, Cyclic Endurance Test, Phase A



### Fig. 2 IEC TC21/417/CD, Cyclic Endurance Test, Phase B

Other standards to consider are: IEEE/ANSI 937 CAN/CSA F382-M89 NF C58–510 (see following pages below) Contents of French Standard NF C 58–510, January 1992 Title\* Lead-acid secondary batteries for storing photovoltaic generated electrical energy

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# Part A: Test Procedures for Components

### Fluorescent Lamps

For the time being, no recommended test specifications for lamps are ready to be included.

# Part B: Test Procedures for System Approval

### Installation

Performance Rating (indoor Method)

### 1. Purpose

To verify that a photovoltaic system can be assembled and put into operation to standard codes of practice and, by measuring its performance, to verify that it is capable to deliver the services of its intended use.

### 2. Scope

The PV system under consideration in this standard is limited in size and function to stand-alone applications for single-family dwellings: maximum array power at STC of less than 1000 W, basic electricity appliances such as lights, radio, TV, refrigerators and telecommunication systems.

### 3. Installation

- 3.1 Verify that the system is complete in all its components.
- **3.2** Mount the array using the structures and fixtures as foreseen by the manufacturer.
- **3.3** Mount charge-controller and battery as foreseen by the manufacturer. If the charge controller includes a circuit which takes into account the temperature of the battery, mount also the recommended or delivered temperature sensor. If the sensor is incorporated in the packaging of the charge-controller, mount the entire charge-controller as close as possible to the battery.
- **3.4** Install the load(s) following the manufacturers' instructions.
- **3.5** Wire the whole system, using the delivered cables and fixtures. Check that all polarities are clearly indicated.
- **3.6** From the instruction manual, determine the maximum array current at STC (Istc) and the maximum load current when all loads are operated (Tl-max).

3.7 For the cables between charge-controller and array, resp. battery, calculate the maximum Voltage drop dUa for array current and dUl for load current by dUa=0.035\*1\*Istc\*/a dUl=0.035\*1\*Ilmax\*/a with 1=length of wire [m) (single run)

and a= cross-section of single conductor (mm2l

**3.8** Take note of any missing parts necessary for completion or operation of the system.

#### 4. Rating

**4.1.** Performance Rating (indoor Method)

#### 4.1.1. Purpose

To verify that the sizing of the components is matched, that is, energy as delivered by the array, battery capacity and required service time of the load are designed such as to provide reliable service in its intended application.

#### 4.1.2 Procedure

The test procedures consists in performing a number of PTOC cycles with different profiles (See Table I below).

The following PTOC cycle profiles are specified:

- Cycle A: High Irradiance, Low Array Temperature
- Cycle B: High Irradiance High Array Temperature
- Cycle C: Low Irradiance, Low Array Temperature
- Cycle D: Low Irradiance, High Array Temperature

**4.1.2.1.1** Install the system as described in clause I of the PTOC test, but without connecting any load.

**4.1.2.1.2** Repeat PTOC cycle A until the battery is fully charged. This is the case when from the recorded I-arr a high-charge disconnect can be determined. Continue this cycle until it finishes with its last interval.

	PTOC Cycle A: High Irradiance, low Array		PTOC Cyc Irradian	le B: High ce, High	PTOC Cycle C: Low Irradiance, Low Array		PTOC Cycle D: Low Irradiance, High	
	Tempe	•	Array Ter	nperature	Tempe	rature	Array Temperature	
Time [h]	Irradiance [W/m2]	Tarray	Irradiance [W/m2]	Tarray	Irradiance [W/m2]	Tarray	Irradiance [W/m2]	Tarray
1	259	18	259	38	39	21	39	31
2	500	26	500	46	75	22	75	32
3	707	34	707	54	106	24	106	34
4	866	41	866	61	130	25	130	35
5	966	46	966	66	145	25	145	35
6	1000	49	1000	69	150	26	150	36
7	966	49	966	69	145	26	145	36
- 8	866	46	866	66	130	25	130	35
9	707	41	707	61	106	25	106	35
10	500	35	500	55	75	24	75	34
11	259	28	259	48	39	23	39	33
Total Irradiation	7500		7500	-	1100		1100	
[Wh/sqm]	7596		7596		1139		1139	

#### Table 1: PTOC Cycle Profiles

**4.1.2.3.** Connect the load

**4.1.2.4.** Apply one Low Irradiance, High Array Temperature PTOCcycle D.

4.1.2.5. Apply one Low irradiance, Low Array Temperature PTOC cycle C.

**4.1.2.6.1** Repeat Steps 4 and 5 until the battery is fully discharged. This is the case when from the recorded I-load a lowcharge disconnect can be determined. Continue this cycle until it finishes with its last interval.

**4.1.2.7.** Apply one high irradiance, high array temperature PTOC cycle B.

4.1.2.8. Apply one high irradiance, low array temperature PTOC cycle A.

4.1.2.9. Repeat steps 7 and 8 until the battery is fully charged.

This is the case when from the recorded I-arr a high-charge disconnect can be determined. Continue this cycle until it finishes with its last interval.

**4.1.2.10.** Switch off the solar simulator.

4.1.2.11. By measuring Iarr, determine any current which discharges the battery through the module.

**4.1.2.12.** (Re)connect the load.

**4.1.2.13.** Record Iload until a low-charge disconnect can be determined.

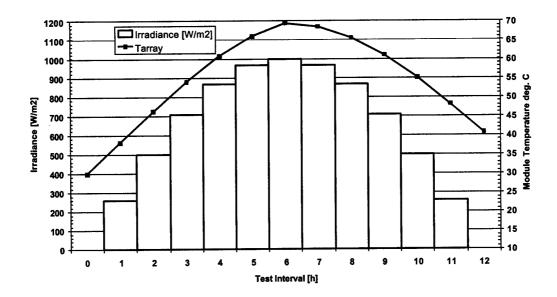


Figure: PTOC-Cycle A

**4.1.2.14.** Note the total time required for step 12, t-service.

**4.1.2.15.** Analyze the data by summing in turn all values of Iarr\*t and iload\*t determined in steps 3 to 9. These sums are called Ita-tot and Itl-tot.

**4.1.2.16.** Calculate Etot, which is the sum of irradiation values for each single cycle as indicated in the PTOC profiles.

4.1.2.17. Calculate the array-yield, Ita-tot/Etot [A/W/sqml.

4.1.2.18. Calculate the internal system efficiency, ltl-tot / Ita-tot

4.1.2.19. Calculate the external system efficiency, ltl-tot/Etot [A/W/sqm].

**4.1.2.20.** t-service, as determined in step 14, indicates the number of hours the system can provide its service without sunshine.

## Part B: Test Procedures for System Approval Performance Test under Operating Conditions (PTOC)

#### 1. Purpose

To determine the operating parameters of the PV system under conditions found during its intended use.

#### 2. Principle of Test

The photovoltaic system is assembled such as all components are connected as foreseen by the intended use. The array is subsequently exposed to 12 one-hour irradiation intervals, each with its specific irradiance and module temperature level, which vary from interval to interval according to the expected profile of outdoor conditions. The 12 irradiation intervals define one PTOC cycle.

#### 3. Equipment

Means to control the temperature of the photovoltaic array between 20 deg. C and 50 deg C during exposure to simulated light. Note: the test is best performed in a climatic chamber which either includes the solar simulator, or is equipped with a transparent wall to allow the beam of the solar simulator enter onto the array.

#### 4. Test Conditions

During one PTOC cycle the application load is maintained in operating conditions according to the expected use. In case of loads f or illumination purposes during night time, the load is disconnected during the PTOC cycle, and reconnected for a specified time with the array in dark.

#### 5. Test Procedure

**5.1.** Mount the photovoltaic array in the test plane of the solar simulator so that the normal of the array is parallel within  $\pm 5^{\circ}$ C to the center line of the beam. Install Battery, charge controller and load such as that the temperature of these devices can be maintained at  $30 \pm 3^{\circ}$ C. Connect all devices according to the manufacturers recommendations.

**5.2.** Set the irradiance at the test plane so that the reference device produces its calibrated short-circuit current at the desired level, as prescribed in the table of the irradiance / temperature profile to be measured.

**5.3.** Set the temperature of the array to the desired level, as prescribed in the relevant table of the irradiance / temperature profile to be measured.

5.4. By using the chart recorder, record the following electrical quantities:
Array Current Iarr
Battery Voltage: Ubat
Load Current: Iload

**5.5.** Maintain the conditions set in step 2 and 3 for one hour.

**5.6.** Repeat steps 2,3 and 4 for the remaining 11 values of the relevant irradiance temperature profile.

5.7. If necessary (see Test requirements). continue to record Iload for the specified time.

5.8. By analyzing Iarr as indicated by the chart-recorder, note any High-Charge disconnects and reconnects.

**5.9.** By analyzing the Iload as indicated by the chart-recorder, note any Low-Charge disconnects and reconnects.

5.10. By integration of all larr values over the measurement period, determine Iarr \* t [Ahl.

5.11. By integration of all iload values over the measurement period, determine Iload \* t [Ahl.

#### 6. Requirements

No evidence of short circuit, ground fault, disconnect or other electrical failures which impair the proper function of the system.

## Part B: Test Procedures for System Approval

## Verification of Sizing

System Sizing Draft for comments, IEC-TC82/WG3

#### 1. Purpose

To ensure that the solar home system is well balanced and sized to meet the demand, in order to achieve a reliable and safe system with a high price/performance ratio.

#### 2. Scope

Solar Home System for one household with lighting, radio and optional TV. The following components are subject to the sizing/design exercise in this standard: 9 the PV array consisting of PV modules 9 lead-acid battery 0 copper wires

3.	Def	init	ions

Wire Area [M2]
The twenty hour discharge capacity, being the capacity of a cell which can be discharged at a constant current 120 for twenty hours before a cutoff voltage of 1.80 V per cell is reached [M]
Month with the lowest mean daily irradiation
Daily Energy Use of All Loads [M/day]
Average Daily Energy Output of the Array [Wh/day]
Maximum Current in a Wire [A]l yearly average solar daily irradiation on array-surface Yearly Average Solar Daily Irradiation on the Array Surface [peak-hours/day]
Resistivity [Ohm*m]
Electrical Appliance or Light.
Length of a Wire [m]
Rated Power of One Load
Rated Power of the Array
Expected Daily Use of a Load [h/day)
Maximum Voltage Drop in a WireM

#### Sizing

The system sizing exercise consists of the following consecutive steps:

- estimation of the average daily load
- sizing of the PV array
- sizing of the batteries
- sizing of the wiring/connectors

## Average Daily Load

The average Daily Energy Use of a Load (Edaily energy use of a load) connected to the system can be derived using the following formula:

---

Edaily energy use of a load @ PloadxTdaily, one load

-

Use the following table to calculate the Daily Energy Use of All Loads:

Load	Power [W]	Daily Use [h/day]	Daily Energy Use [Wh/day]	
Light 1	P <sub>I,1</sub>	T <sub>I.1</sub>	$E_{l,1} = P_{l,1} \times T_{l,1}$	
Light 2	P <sub>1.2</sub>	T <sub>I.2</sub>	$E_{1,2} = P_{1,2} \times T_{1,2}$	
Light m	P <sub>l.m</sub>	T <sub>I,m</sub>	$E_{l,m} = P_{l,m} \times T_{l,m}$	
Appliance 1	P <sub>a.1</sub>	T <sub>a.1</sub>	E <sub>a.1</sub> = P <sub>a.1</sub> x T <sub>a.1</sub>	
Appliance 2	P <sub>a.2</sub>	T <sub>a,2</sub>	E <sub>a.2</sub> = P <sub>a.2</sub> x T <sub>a.2</sub>	
Appliance n	P <sub>a.n</sub>	T <sub>a.n</sub>	E <sub>a.n</sub> = P <sub>a.n</sub> x T <sub>a.n</sub>	
			Σ( E <sub>l,1</sub> ., E <sub>l,n</sub> +E <sub>a,1</sub> .,E <sub>a,n</sub> )	+

-

The Daily Energy Use of All Loads (Edaily energy use of all loads) can be calculated using the following formula:

Edaily energy use of all loads @ E( El,... El,n+Ea,l.. Ea,n)

The following table consists of the minimum daily service periods that have to be guaranteed by the system supplier for loads to be supplied with a PV system of more than 50 Wp:

Load	minimum daily service [h]
main lighting	3
secondary lighting	1
TV	1
radio/cassette player	2

System Energy Losses

Systems without an Inverter

If the system does not contain an inverter to power AC loads, the *Overall System Energy Loss* (Edaily system energy loss, without inverter) can be estimated at 20% of the *Daily Energy Use of All Loads:* 

Edaily system energy loss, without inverter @ 012 \* Edaily energy use of all loads Systems with an Inverter

In case an inverter is used to power AC appliances that consume more than 30% of the Daily Energy Use of All Loads, the Overall System Energy Losses can be estimated at 30% of the Daily Energy Use of All Loads.

Edaily system energy loss, whh inverter @ 01 3 \* Edaily energy use of all loads Daily System Energy Use

The Daily System Energy Use is the sum of the Daily Energy Use of All Loads and the Daily System Energy Loss.

Edaily system energy use-Edaily energy use of all loads + Edaily system energy loss

## Sizing the PV Array

When no tracking device is used, the following rules should be adhered to for the orientation and tilt angle of the array:

Orientation

On the Northern hemisphere, the array should face south.

On the Southern hemisphere, the array should face north.

Tilt angle

The PV array should be set at the following angle:

- For sites at latitudes between 15' S and 150 N: set tilt angle at IS' to ensure rainwater wash.
- For sites at latitudes between 15' and 30': set tilt angle at the latitude angle of the site, facing the equator.
- Sites at higher latitudes than 300, set tilt angle at the latitude angle of the site plus 15', to optimize for the winter months.

Average daily energy output

Household Energy Systems

For household energy systems the Average Daily Energy Output of the PV array can be calculated as follows:

- Derive Yearly Average Daily irradiation on Array Surface (inpeak-hours/day) from meteorological station near the site of intended use.
- Calculate the Average Daily Output of the Array, using the following formula:

Average, daily output array z Prated, array \* I Yearly average solar daily irradiation on array surface. The Average Daily Output of the Array has to be larger than the Daily System Energy Use.

### **Essential Energy Systems**

For essential energy systems (vaccination refrigerators or lighting in a clinic) the Average Daily Energy Output of the PV array can be calculated as follows:

- Derive Monthly Average Daily Irradiation on Array Surface in the Desio Month (in peak-hours/day) from meteorological station near the site of intended use.
- Calculate the Average Daily Output of the Array, using the following formula:

**Average, daily output array** = PrBted, array \* I **Yearly average solar daily** irradiation on **array surface** The Average Daily Output of the Array in the Design Month has to be larger than the Daily System Energy Use.

#### Sizing the Batteries

For 'solae batteries the battery size has to be: C20 > 715 \* Daily Energy Use of All Loads at 25°C.

(NB: This is the outcome of an extensive field test carried out by IIE in Mexico, in which 555 batteries were analyzed after up to 3 years of operation. This value corresponds to an autonomy of four days, in which the battery should not be discharged more than 50%, including a small correction factor for the discharge efficiency. The normal daily cycle does not go deeper than 10-15% of the nominal capacity with this size of battery.)

Sizing the wiring:

The wires should be made of copper.

The wires should be multist=ded.

## The Maximum Voltage Drop

For each wire, calculate the maximum current through the wire.

The maximum voltage drop along each wire can be calculated using the following formula:

Vdrop = (imax \* P \* Lwire )fawire

The resistivity (p) for soft copper is 1617\*1 0-9 Ohm\*m.

The voltage drop along each wire should not exceed 3% of the system voltage.

## Temperature Correction for Wire Sizes

[	Те	emperature Rat	ing of Conduc	luctor				
Ambient Temp. ºC	60°C	75⁰C	90°C	105°C				
<30	1.00	1.00	1.00	1.00				
3135	0.91	0.94	0.96	0.97				
3640	0.82	0.88	0.91	0.93				
4145	0.71	0.82	0.87	0.89				
4650	0.58	0.75	0.82	0.86				
5155	0.41	0.67	0.76	0.82				
5660		0.58	0.71	0.77				
6170		0.33	0.58	0.68				
7180			0.41	0.58				

Correction factors for temperature **shall be** applied using the tables below.

Table 1: Correction factors for conductor cross-section. For a given cross-section, divide by above factors to achieve cross-sections valid for the temperature rating. Round up to the next standard size. (Source: National Electric Code@ Table 6.9031(C))

## Maximum System Voltage

Determine the Maximum System Voltage of the system as follows:

- 1. From the manufacturer's data, take Open Circuit Voltage of a module at STC as defined in IEC 1215.
- 2. Multiply this voltage by the number of modules to be connected in series to form a complete system.
- 3. Select the lowest possible ambient temperature to be expected at the location where the system is to be installed. Consider lowest temperature during sunshine hours.
- 4. Multiply this value by a temperature correction factor as given in Table 2, selecting the roe of ambient temperature as determined by step 3.

Ambient Temp.	For ambient temperatures below 25, multiply the rated open-circuit voltage by the appropriate factor shown below				
2510	1.06				
90	1.10				
-110	1.13				
-1120	1.17				
-2140	1.25				

Table 2: Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules

(Source: National Electric Code@ Table 690-7)

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Amendment No. 2 IEC 439–2 (1987–11) Low-voltage switchgear and control gear assemblies. Part 2; Particular requirements for busbar trunking systems (busways).

- 4. IEC 439-2-ami (1991-09), Amendment No. 1.
- 5. IEC 439-3 (1990-12)

Low-voltage switchgear and control gear assemblies. Part 3: Particular requirements for low-voltage switchgear and control gear assemblies intended to be installed in places where unskilled persons have access for their use distribution boards.

- 6. IEC 439-3-aml (1993-10), Amendment No. 1.
- 7. IEC 439–4 (1990–12), Low-voltage switchgear and control gear assemblies. Part 4: Particular requirements for assemblies for construction sites (ACS).
- 8. IEC 439-4-aml (1995-12), Amendment No. 1.
- 9. IEC 439–5 (1996–03), Low-voltage switchgear and control gear assemblies. Part 5: Particular requirements for assemblies intended to be installed outdoors in public places-Cable distribution cabinets (CDCS) for power distribution in networks.
- 10. IEC 529 (1989–11). Degrees of protection provided by enclosures (IP Code). Applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 kV. Has the status of a basic safety publication in acco

#### DC Safety

1. IEC 1204 (1993–02) Low-voltage power supply devices, DC output-Performance characteristics and safety requirements.

#### Inverter

1. IEC 146-1-1 (1991-04)

General requirements and line commutated converters. Part 1–1: Specifications of basic requirements. 2. IEC 146–1–1-aml (1996–07), Amendment No. 1 to IEC 146–1–1.

- 3. IEC 146–1–2 (1991–04), General requirements and line commutated converters. Part 1–2: Application guide.
- 4. IEC 146–1–3 (1991–04). General requirements and line commutated converters. Part 1–3: Transformers and reactors.

#### Lamps

- 1. IEC 400 (1996–06) Lampholders for tubular fluorescent lamps and starterholders.
- 2. IEC 400-aml (1997-04), Amendment No. 1.
- 3. IEC 598-1 (1996-12), Luminaires. Part 1: General requirements and tests.

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- 4. IEC 598 2 1 (1979 01), Luminaires. Part 2: Particular requirements. Section One: Fixed general purpose luminaires.
- 5. IEC 598 2 1-aml (1987 01), Amendment No. 1.
- 6. IEC 598 2 23 (1996 04) Luminaires. Part 2: Particular requirements. Section 23: Extra low voltage lighting systems for filament lamps.
- 7. IEC 598 2 3 (1993 04)

Luminaires. Part 2: Particular requirements. Section 3: Luminaires for road and street lighting.

- 8. IEC 598 2 3-aml (1997 04), Amendment No. 1.
- 9. IEC 598 2 4 (1997 04)
- Luminaires. Part 2: Particular requirements. Section 4: Portable general purpose luminaires.
- 10. IEC 598 2 5 (1979 01)

Luminaires. Part 2: Particular requirements. Section Five: Floodlights.

- 11. IEC 598 2 5-aml (1987 01), Amendment No. 1.
- 12. IEC 598 2 5-am2 (1993 04), Amendment No. 2.
- 14. IEC 598 2 7 (1982 01)

Luminaires. Part 2: Particular requirements. Section Seven: Portable luminaires for garden use.

- 15. IEC 598 2 7-aml (1987 01), Amendment No. I.
- 16. IEC 598 2 7-am2 (1994 08), Amendment No. 2.
- 17. IEC 598 2 8 (1996 07)

Luminaires. Part 2: Particular requirements. Section 8: Handlamps.

18. IEC 81 (1984 01)

Tubular fluorescent lamps for general lighting service.

- 19. IEC 81-aml (1987 01), Amendment No. I.
- 20. IEC 81-am2 (1988 01), Amendment No. 2.
- 21. IEC 81-am3 (1992 07), Amendment No. 3.
- 22. IEC 81-am4 (1993 09), Amendment No. 4.
- 23. IEC 81-am5 (1994 12), Amendment No. 5.
- 24. IEC 810 (1993 10)

Lamps for road vehicles-Performance requirements.

- 25. IEC 810-aml (1994 07), Amendment No. 1
- 26. IEC 924 (1990 07)

D.C. supplied electronic ballasts for tubular fluorescent lamps. General and safety requirements.

- 27. IEC 924-aml (1993 03), Amendment No. 1.
- 28. IEC 925 (1989 06)
- D.C. supplied electronic ballasts for tubular fluorescent lamps-Performance requirements.
- 29. IEC 925-aml (1996 05), Amendment No.1.
- 30. IEC 95 1 Amd.1 Ed. 5.0, Amendment No. 1.
- 31. IEC 95 1 Amd.2 Ed. 5.0, Amendment No. 2.
- 32. IEC 1162 1 (1995 11)

Maritime navigation and radio communication equipment and systems-Digital interfaces. Part 1: Single talker and multiple listeners. Contains the requirements for data communication between maritime electronic instruments, navigation and radio communication.

#### Photovoltaic

1. IEC 1173 (1992 09)

Overvoltage protection for photovoltaic (PV) power generating systems-Guide.

2. IEC 1194 (1992 12)

Characteristic parameters of stand-alone photovoltaic (PV) systems. Defines the major electrical, mechani

cal and environmental parameters for the description and performance analysis of stand-alone photovoltaic systems. 3. IEC 1215 Ed. 1.0 Crystalline silicon terrestrial photovoltaic (PV) modules-Design qualification and type approval. 4. IEC 1277 Ed. 1.0 Terrestrial photovoltaic (PV) power generating systems. General and guide. 5. IEC 1646 Ed. 1.0 Thin-film terrestrial photovoltaic (PV) modules. Design qualification and type approval. 6. IEC 1701 Ed. 1.0 Salt mist corrosion testing of photovoltaic (PV) modules. 7. IEC 1702 Ed. 1.0 Rating of direct coupled photovoltaic (PV) pumping systems. 8. IEC 1721 Ed. 1.0 Susceptibility of a photovoltaic (PV) module to accidental impact damage (resistance to impact test). 9. IEC 1727 Ed. 1.0 Photovoltaic (PV) systems. Characteristics of the utility interface. 10. IEC 1829 (1995-03) Crystalline silicon photovoltaic (PV) array. On-site measurement of I-V characteristics. 11. IEC 891 Ed. 1.0 Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices. 12. IEC 891-aml (1992-06), Amendment No. 1 13. IEC 904-1 Ed. 1.0 Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics. 14. IEC 904-2 Ed. 1.0 Photovoltaic devices. Part 2: Requirements for reference solar cells. 15. IEC 904-3 Ed. 1.0 Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data. 16. IEC 904-5 Ed. 1.0 Photovoltaic devices. Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method. 17. IEC 904-6 Ed. 1.0 Photovoltaic devices. Part 6: Requirements for reference solar modules. 18. IEC 904-7 Ed. 1.0 Photovoltaic devices. Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device. 19. IEC 904-8 Ed. 1.0 Photovoltaic devices. Part 8: Guidance for the measurement of spectral response of a photovoltaic (PV) device. 20. IEC 904-9 (1995-09)

Photovoltaic devices. Part 9: Solar simulator performance requirements.

## Appendix 3B. PV RS-2 Crystalline Silicon Terrestrial Photovoltaic (PV) Modules

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## Foreword

- 1) PV GAP (Global Approval Program for Photovoltaics) is a worldwide organization for promoting satisfactory photovoltaic products and systems, and comprises several classes of membership as defined in its Statutes. One of the activities of PV GAP is to publish and maintain a Reference Manual, the preparation of which is entrusted to PV GAP members and coordinated by the Chairman of PV GAP; any member interested in a subject dealt with may participate in this work. PV GAP cooperates closely with the International Electrotechnical Commission (IEC) in respect of standardization (principally with IEC Technical Committee N° 82, Solar Photovoltaic Energy Systems) and certification (with the IEC Quality Assessment System for Electronic Components, IECQ).
- 2) In Part III of the Reference Manual, PV GAP lists certain standards that have been developed and recommended by experts from the PV industry and other organizations, to be used as interim, recommended standards until the corresponding IEC standards can be completed. The acceptance of these PV GAP "Recommended Standards" is voluntary. PV GAP only recommends these standards but disclaims any liability for their utilization.

It should also be noted that, as soon as a corresponding IEC standard is issued, the PV GAP "Recommended Standard" will be removed from Part III of the Reference Manual. A page will be inserted informing the reader about this and directing the reader to the location where the new IEC standard will be listed.

Members of the PV GAP Standardization Working Group are listed in Part III of the Reference Manual.

- 3) The present PV GAP Recommended Standard has been endorsed by the PV GAP Standardization Working Group, and approved by the PV GAP Executive Board.
- 4) General inquiries about PV GAP may be addressed to the publisher, which is the PV GAP Secretariat c/o IEC Central Office, 3 rue de Varembé, Box 31, CH 1211 Geneva 20, Switzerland, E-mail rk@iec.ch, TP +41 (22) 919 02 16, TF +41 (22) 919 03 01.

The publisher will be pleased to receive any comments from users of this PV GAP Recommended Standard. All comments will be acknowledged.

Whilst every effort has been made to ensure the accuracy of the contents of this PV GAP Recommended Standard, the publisher can accept no responsibility for any errors that may have occurred.

## Blank Detail Specification

# Qualification Approval under the IEC Quality Assessment System for Electronic Components (IECQ)

## 1. General

#### 1.1 Scope

This PV GAP Recommended Standard is a blank detail specification applicable to crystalline silicon terrestrial photovoltaic (PV) modules of assessed quality. PV modules according to this standard are provided for operation in Solar Home System applications. However, as PV modules, they are also suitable for other applications, as described in the manufacturer's data sheets.

This standard references IEC 61215 requirements and methods of test to be used in detail specifications derived from this specification, and lists the technical criteria that are necessary and sufficient to assess the quality of the PV modules in accordance with the IECQ Qualification Approval procedure described in QC 001002–3 clause 3.

#### 1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this PV GAP Recommended Standard.

IEC 61215: 1993, Crystalline silicon terrestrial photovoltaic (PV) modules—Design qualification and type approval

IEC 61345: 1998, UV test for photovoltaic (PV) modules

QC 001002–2: 1998, Rules of Procedure of the IEC Quality Assessment System for Electronic Components (IECQ)—Part 2, Documentation

QC 001002–3: 1998, Rules of Procedure of the IEC Quality Assessment System for Electronic Components (IECQ)—Part 3, Approval procedures

QC 001005, Register of Firms, Products and Services approved under the IECQ System, including ISO 9000

#### 1.3 Front page of detail specification

The layout of the front page of detail specific	cation shall be as follows	s (see key on following page):	
	(1)	PQCxxxAAxxxx	(2)
		Edition: 199x/200x	
		Page 1 of x	
Electronic components of assessed		0	(4)
(3)			
quality in accordance with:			
IEC 61215: 1993			
Detail specification for crystalline silicon ter	restrial PV modules of as	ssessed quality	
Туре:			(5)
Construction:			(6)
Outline drawing	(7)	Applications:	(8)
Dimensions in millimeters			
Electrical characteristics	(see 2.1 and 2.2)		(9)
Mechanical characteristics	(see 2.3)		(10)
Information about manufacturers who have	components approved a	ccording to this detail specification	n is
available in the current QC 001005.		-	

#### Key to Front Page

The numbers between brackets on the front page correspond to the following indications, which should be given.

#### Identification of the Detail Specification

- (1) The name of the National Standards Organization under whose authority the detail specification is published and, if applicable, the organization from whom the detail specification is available.
- (2) The IECQ logo and the number allotted to the completed detail specification by the National Standards Organization or the IECQ National Authorized Institution (PQCxxx is the IECQ provisional specification reference allocated earlier by the IECQ Secretariat to the blank detail specification. AA is the country identifier, for example, FR for France, DE for Germany, IN for India, US for USA).
- (3) The number and the year of availability of the IEC standard concerning test and measurement procedures for the PV modules and/or sectional specification; also national reference, if different.
- (4) If different from the IECQ number, the national number of the detail specification, date of issue and any further information required by the national system, together with any amendment numbers.

#### Identification of the PV Module

- (1) Type: for example, glass front, or nonglass
- (2) Construction: frame material, junction box, glass type, sealing and other typical construction details.
- (3) An outline drawing with main dimensions which are of importance for interchangeability. Alternatively, this drawing may be given in an appendix to the detail specification, but (7) should always contain an illustration of the general outer appearance of the PV module.
- (4) Typical field of applications.
- (5) Electrical characteristics.
- (6) Mechanical characteristics.

## 2. Characteristic Values of the PV Module

#### 2.1 Electrical Characteristics

Maximum power (P <sub>max</sub> )	W
Maximum power voltage (V <sub>pmax</sub> )	V
Maximum power current (I <sub>pmax</sub> )	А
Short-circuit current (I <sub>SC</sub> )	А
Open-circuit voltage (V <sub>OC</sub> )	V
Current-temperature coefficient	A/°C
Voltage-temperature coefficient	V/°C
Power-temperature coefficient	%/°C
Nominal operating cell temperature (NOCT)	°C
Maximum system operating voltage (V <sub>smax</sub> )	V
(see 10.3 of IEC 61215)	

NOTE: These data represent the performance of typical modules as measured at their output terminals, and do not include the effect of such additional equipment as diodes and cabling. The data are based on measurements made at standard test conditions (STC) which are:

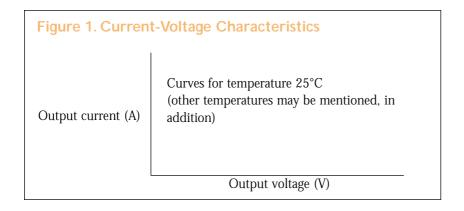
Illumination of 1kW/m<sup>2</sup> at air mass solar reference spectrum of AM 1,5 (except for the temperature coeffi-

Limits  $\pm 5\%$ 

cient characteristics, where IEC 60904-1, referenced in 10.4 of IEC 61215, states that irradiance shall be at least 800W/m2)

Cell temperature of 25°C or as otherwise specified (on curves).

#### 2.2 Current-Voltage Characteristics



#### 2.3 Mechanical Characteristics

Output cable, connector, or terminals Mass (kg)

#### 2.4 Additional Information (not for inspection purposes)

For example

-optional protective backplate,

-mounting hardware kits.

(7) Qualification Approval procedure

## 3. Qualification Approval Procedure

#### 3.1 General

The Qualification Approval procedure shall be in accordance with QC 001002–3, clause 3, with fixed sampling (3.1.4 a) of QC 001002–3).

NOTE 1 Qualification Approval is preceded by organization approval of the manufacturer (QC 001002–3, clause 2). Organization approval covers all of the quality system requirements, the quality system being described in a quality manual and complying with ISO 9001 or ISO 9002. Therefore details such as the address of the place of manufacture do not belong to the detail specification, which is a publicly available specification for anyone to use.

NOTE 2 Other types of IECQ product/process approval, namely Capability Approval, Technology Approval (including Manufacturing Line Approval) and Specialist Subcontractor Approval are more concerned with the process aspects. Therefore, in this blank detail specification for Qualification Approval, such aspects are not covered.

#### 3.2 Primary Stage of Manufacture

Formation of the contact metallization on the solar cell. The manufacturer of the solar cells, on whom the overall quality and reliability of the PV module is strongly dependent, shall have a quality system that meets the requirements of ISO 9002 or ISO 9001 or hold IECQ manufacturer's approval (see QC 001002–3 clause 2) for the manufacturing site.

#### 3.3 Subcontracting

Subcontracting of the primary and subsequent stages of manufacture is permitted, under the conditions laid down in QC 001002–3 clauses 2 and 3.

#### 3.4 Technical Requirements

Sampling, testing, pass criteria and classification of major visual defects shall be in accordance with IEC 61215.

NOTE This blank detail specification cannot add requirements that do not exist in IEC 61215. This is because IEC 61215 was prepared by an IEC technical committee (IEC TC 82) in which all IEC National Committees may participate.

Reporting, and issuing of the Qualification Approval certificate, shall be in accordance with QC 001002–3 clause 3.

#### 3.5 Increased Severity

Detail specifications derived from this blank detail specification may make the severities of test, the end-oftest requirements, or the sampling levels, more severe. These severities, or requirements, can never be made less stringent.

#### 3.6 Preparation of Detail Specifications

An individual manufacturer may prepare a detail specification from this blank detail specification and submit it to the responsible national organization for verification of compliance to the IECQ rules and the allocation of a number. After allocation of the number, the manufacturer may commence Qualification Approval testing under the surveillance of the IECQ National Supervising Inspectorate (NSI). After completion of the testing, the manufacturer or the responsible national organization shall publish the detail specification.

A group of manufacturers may act together to produce a common detail specification with one of them accepting the responsibility for the submission for verification and the allocation of a number, the procedure being the same as above.

The above actions may be in cooperation with one or more customers.

Detail specifications may also be prepared by a responsible national organization or by an IEC technical committee.

#### 3.7 Product Identification and Traceability

The minimum period referred to in 2.3.2 of QC 001002–3, italic subclause heading 4.8, for maintenance of records, shall be five years.

#### 4. Quality Conformance Inspection

Qualify conformance inspection comprises the tests stated in table 1:

-group A: lot-by-lot (100% inspection) tests;

-group C: periodic tests.

All tests of table 1 are mandatory. Where a subgroup contains cumulative tests, the order of the tests is mandatory. Specimens subjected to tests denoted as destructive (D) shall not be released for delivery.

Subclause number	Destructive o		Condi			Performance
Test of IEC 61215	nondestructiv	ve	of test			requirements
GROUP A INSPECTION (100%)						
<b>Subgroup A1</b> 10.1 Visual inspection	ND					As in 10.1 of IEC 61215
4 Marking			Check markin		resent	Clear and indelible.
—Dimensions (gauging)						See the outline drawing in item (7) of the cover page of this specifica- tion and any related tables.
Subgroup A2 10.2 Performance at STC	ND					See 2.1 and the manu- facturer's data sheet with the calibration ref-
10.3 Insulation test						erence As in 10.3 of IEC
GROUP B INSPECTION covering additional important characteristics none						61215
Subclause number and test (see Note 1)	Destructive or	Conditions	and crite	ple si accep erion Note	otance	Performance
of IEC 61215	nondestructive	of test	р	n	C	requirements
GROUP C INSPECTION (periodic)			9.4	1	0	an daar in an daat
<b>Subgroup C1</b> 10.4 Measurement of temperature coefficients	ND		24	1	0	or change in product See 2.1
10.5 Measurement of NOCT	ND					See 2.1
10.6 Performance at NOCT	ND					See 2.1, first five items
10.7 Performance at low irradiance	ND					See manufacturer's data sheet

### Table 1. Test Schedule for Quality Conformance Inspection

Subclause number and test (see Note 1)	Destructive or	Conditions	Sample size and acceptance criterion (see Note 1)			Performance	
of IEC 61215	nondestructive	of test	p n		c	requirements	
10.8 Outdoor exposure test	D	After, repeat tests 10.1, 10.02, 10.3 of IEC 61215	-				
10.9 Hot-spot endurance	D						
GROUP C INSPECTION (periodic)							
Subgroup C2 10.10 UV test	D	IEC 61345	12	2	0	See clause 7 of IEC 61345.	
10.11 Thermal cycling		50 cycles After, repeat tests 10.1 10.1, 10.2, 10.3 IEC 61215				See 10.1, 10.2, 10.3 of IEC 61215	
10.12 Humidity freeze						See 10.1, 10.2, 10.3 of IEC 61215	
10.14 Robustness of terminations				1	0	See 10.14.5 of IEC 61215	
10.15 Twist				1	0	See 10.15.4 of IEC 61215	
Subgroup C3	D		12	2	0		
10.11 Thermal cycling		200 cycles				See 10.11.5 of IEC 61215	
10.13 Damp heat		1 000h				See 10.13.4	
10.16 Mechanical load				1	0	See 10.16.4	
10.17 Hail				1	0	See 10.17.5	
NOTE 1—In this table:							
p = periodicity (in mon n = sample size <u>c = acceptance criterion</u>		of nonconforming	g items	;)			

## 5. Modifications Likely to Affect Qualification Approval

For the modifications listed below, the Qualification Approval tests in IEC 61215, shall be repeated as indicated:

#### a) Modification to cell technology

For modifications such as

-metallization materials and/or process,

—antireflective coating,

-diffusion process,

-order of cell process, and

-change of manufacturing site of the solar cells

repeat

-thermal cycling, 200 cycles (10.11),

-humidity freeze (10.12),

-damp heat (10.13),

—outdoor exposure (10.8), and

—hot spot endurance (10.9).

#### b) Modification to encapsulation system

For modifications such as

-different materials,

-different additives,

-different primer or method of priming, and

—modification of encapsulation process (that is, different time, temperature, pressure, and so forth) repeat

-thermal cycling, 200 cycles (10.11),

-UV (10.10, IEC 61345)/ thermal cycling, 50 cycles (10.11) / humidity freeze (10.12) sequence,

-insulation test (10.3), and

-outdoor exposure (10.8).

#### c) Modification to superstrate

For modifications such as

-different material,

-different thickness,

-different additives, and

—different preparation process,

repeat

----UV (10.10, IEC 61345) / thermal cycling, 50 cycles (10.11) / humidity freeze (10.12) sequence,

-twist test (10.15),

-mechanical load test (10.16),

-insulation test (10.3),

-hail test (10.17), and

-damp heat (10.13) (if nonglass)

#### d) Modification to backsheet/substrate

For modifications such as

—different thickness,

-different additives, and

-different preparation process,

repeat

-UV (10.10, IEC 61345) / thermal cycling, 50 cycles (10.11) / humidity freeze (10.12) sequence,

-robustness of terminations (10.14), and

-damp heat (10.13) (if nonglass),

If there is a change from superstrate to substrate design or from substrate to superstrate design, the entire qualification test sequence in IEC 61215 shall be conducted.

#### e) Modification to frame and/or mounting structure

For modifications such as

-cross section of frame

-different framing material, and

-elimination of frame altogether,

repeat

-mechanical load test (10.16),

-outdoor exposure (10.18),

- ---UV (10.10, IEC 61345) / thermal cycling, 50 cycles (10.11) / humidity freeze (10.12) sequence, if plastic material is used, and
- -hail test (10.17), unless tempered glass is used as superstrate.

#### f) Modification to junction box/electrical termination

For modifications such as

- -different material,
- -different design, and
- -different method of attachment

repeat

-robustness of terminations (10.14),

-thermal cycling, 200 cycles (10.11), and

-insulation test (10.3).

#### g) Lower or higher efficiency cells in identical package and identical cell process

Repeat

-hot-spot endurance (10.9),

-thermal cycle, 200 cycles (10.11), and

-damp heat (10.13).

## 6. Modifications That Do Not Require Retesting

Provided that all structural components, materials used and processes (including cell process) remain the same, the following modifications shall not require retesting:

-fewer cells in module;

--smaller cells in module, as long as each cell has the same number of interconnects and equivalent numbers of solder bonds per unit area.

## 7. Marking

Marking of the PV module shall be in accordance with clause 4 of IEC 61215. The detail specification may also require that, in addition, the following be marked:

-maximum power (W);

-maximum power current (A);

—open-circuit voltage (V);

-short-circuit current (A);

—NOCT (°C).

Marking of the package may also be required, for example

-manufacturer's name, logo or trade mark;

-model/type number;

-serial number.

## 8. Documentation

For each delivery a manufacturer's or distributor's Declaration of Conformity according to QC 010002–2 shall be included. The name and the site of the manufacturer of the solar cells shall be stated on the Declaration of Conformity.

#### 9. Appendixes

Appendixes may be included, if necessary, to show more details on PV module dimensions, mounting, terminal dimensions, and so forth.

## Appendix 3C. PV RS-3 Thin-Film Terrestrial Photovoltaic (PV) Modules

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## Blank Detail Specification

# Qualification Approval under the IEC Quality Assessment System for Electronic Components (IECQ)

### 1. General

#### 1.1 Scope

This PV GAP Recommended Standard is a blank detail specification applicable to thin-film terrestrial photo-voltaic (PV) modules of assessed quality.

This standard references IEC 61646 requirements and methods of test to be used in detail specifications derived from this specification, and lists the technical criteria that are necessary and sufficient to assess the quality of the PV modules.

#### 1.2 Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this PV GAP Recommended Standard.

IEC 61646: 1996, Thin-film terrestrial photovoltaic (PV) modules-Design qualification and type approval

IEC 61345: 1998, UV test for photovoltaic (PV) modules

QC 001002–2: 1998, Rules of Procedure of the IEC Quality Assessment System for Electronic Components (IECQ)—Part 2, Documentation

QC 001002–3: 1998, Rules of Procedure of the IEC Quality Assessment System for Electronic Components (IECQ)—Part 3, Approval procedures

#### 1.3 Informative Reference

QC 001005, Register of Firms, Products and Services approved under the IECQ System, including ISO 9000

#### 1.4 Front Page of Detail Specification The levent of the front page of detail specification shall be as follows (see key on following page):

The layout of the front page of detail specifi	ication shall be as follow	s (see key on following page):	
	(1)	PQC13 AAxxxx	(2)
		Edition: 199x/200x	
		Page 1 of x	
Electronic components of assessed	(3)	0	(4)
quality in accordance with:			( )
1			
IEC 61646: 1996			
Detail specification for thin-film terrestrial H	PV modules of assessed o	Juality	
Туре:			(5)
Construction:			(6)
Outline drawing	(7)	Applications:	(8)
Dimensions in millimeters			
Typical electrical characteristics	(See 2.1 and 2.2)		(9)
Mechanical characteristics	(See 2.3)		(10)
Information about manufacturers who have	· ,	according to this detail specification	
mormation about manufacturers who have	components approved e	seconding to this detail specification	

available in the current QC 001005.

#### Key to front page:

The numbers between brackets on the front page correspond to the following indications, which should be given.

#### Identification of the Detail Specification

- (1) The name of the National Standards Organization under whose authority the detail specification is published and, if applicable, the organization from whom the detail specification is available.
- (2) The IECQ logo and the number allotted to the completed detail specification by the National Standards Organization or the IECQ National Authorized Institution (PQC13 is the IECQ provisional specification reference allocated by the IECQ Secretariat to the blank detail specification. AA is the country identifier, for example, FR for France, DE for Germany, IN for India, US for USA).
- (3) The number and the year of availability of the IEC standard concerning test and measurement procedures for the PV modules and/or sectional specification; also national reference, if different.
- (4) If different from the IECQ number, the national number of the detail specification, date of issue and any further information required by the national system, together with any amendment numbers.

#### Identification of the PV Module

- (5) Type: for example, glass front, or nonglass
- (6) Construction: frame material, junction box, glass type, sealing and other typical construction details.
- (7) An outline drawing with main dimensions which are of importance for interchangeability. Alternatively, this drawing may be given in an appendix to the detail specification, but (7) should always contain an illustration of the general outer appearance of the PV module.
- (8) Typical field of applications.
- (9) Electrical characteristics and configuration.
- (10) Mechanical characteristics.

### 2. Characteristic Values of the PV Module

#### 2.1 Stabilized Electrical Characteristics

W
V
А
А
V
A/°C
V/°C
%/°C
°C
V

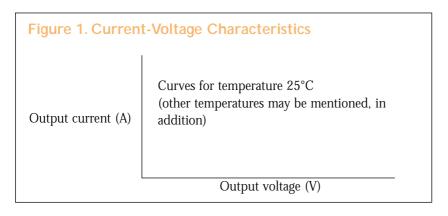
Note: These data represent the performance of typical modules as measured at their output terminals after they have stabilized from light induced degradation, and do not include the effect of such additional equipment as diodes and cabling. The data are based on measurements made at standard test conditions (STC) which are:

Illumination of 1kW/m<sup>2</sup> at air mass solar reference spectrum of AM 1,5

Cell temperature of 25°C or as otherwise specified (on curves).

Limits  $\pm 5\%$ 

#### 2.2 Current-Voltage Characteristics



#### 2.3 Mechanical Characteristics

Output cable, connector, or terminals Mass (kg)

#### 2.4 Additional Information (not for inspection purposes)

For example

-optional protective backplate,

-mounting hardware kits,

-bypass diodes.

## 3. Qualification Approval Procedure

#### 3.1 General

The Qualification Approval procedure shall be in accordance with QC 001002–3, clause 3, with fixed sampling (3.1.4a) of QC 001002–3).

*Note 1:* Qualification Approval is preceded by organization approval of the manufacturer (QC 001002–3, clause 2). Organization approval covers all of the quality system requirements, the quality system being described in a quality manual and complying with ISO 9001 or ISO 9002. Therefore details such as the address of the place of manufacture do not belong to the detail specification, which is a publicly available specification for anyone to use.

*Note 2:* Other types of IECQ product/process approval, namely Capability Approval, Technology Approval (including Manufacturing Line Approval) and Specialist Subcontractor Approval are more concerned with the process aspects. Therefore, in this blank detail specification for Qualification Approval, such aspects are not covered.

#### 3.2 Primary Stage of Manufacture

Formation of the thin-film layers. The manufacturer of the thin-film layers, on whom the overall quality and reliability of the PV module is strongly dependent, shall have a quality assurance system that meets the requirements of ISO 9001 or ISO 9002 or hold IECQ manufacturer's approval (see QC 001002–3 clause 2) for the manufacturing site.

#### 3.3 Subcontracting

Subcontracting of the primary and subsequent stages of manufacture is permitted, under the conditions laid down in QC 001002–3 clauses 2 and 3.

#### 3.4 Technical Requirements

Sampling, testing, pass criteria and classification of major visual defects shall be in accordance with IEC 61646.

Reporting, and issuing of the Qualification Approval certificate, shall be in accordance with QC 001002–3 clause 3.

#### 3.5 Increased Severity

Detail specifications derived from this blank detail specification may make the severities of test, the end-oftest requirements, or the sampling levels, more severe. These severities, or requirements, can never be made less stringent.

#### 3.6 Preparation of Detail Specifications

An individual manufacturer may prepare a detail specification from this blank detail specification and submit it to the responsible national organization for verification of compliance to the IECQ rules and the allocation of a number. After allocation of the number, the manufacturer may commence Qualification Approval testing under the surveillance of the IECQ National Supervising Inspectorate (NSI). After completion of the testing, the manufacturer or the responsible national organization shall publish the detail specification.

A group of manufacturers may act together to produce a common detail specification with one of them accepting the responsibility for the submission for verification and the allocation of a number, the procedure being the same as above.

The above actions may be in cooperation with one or more customers.

Detail specifications may also be prepared by a responsible national organization or by an IEC technical committee.

#### 4. Quality Conformance Inspection

Qualify conformance inspection comprises the tests stated in table 1:

-group A: lot-by-lot (100% inspection) tests;

-group C: periodic tests.

All tests of table 1 are mandatory. Where a subgroup contains cumulative tests, the order of the tests is mandatory. Specimens subjected to tests denoted as destructive (D) shall not be released for delivery.

			1			
Subclause number	Destructive o		Condi			Performance
Test of IEC 61646	nondestructiv	ve	of test			requirements
<b>GROUP A INSPECTION</b>						
(100%)						
Subgroup A1	ND					
10.1 Visual inspection						As in 10.1
4 Marking			Check			Clear and indelible.
—Dimensions			markin	g is pi	esem	
(gauging)						See the outline drawing
(gauging)						in item (7) of the cover
						page of this specifica-
						tion and any related
						tables.
Subgroup A2	ND					
10.2 Performance at STC						See the manufacturer's
						data sheet with the cali-
						bration reference
10.3 Insulation test						As in 10.3 of IEC
CROUP R INCREGENON						61646
GROUP B INSPECTION	1					
(100%), covering addition						
<b>important characteristics</b> none						
			C			
				ple si accep		
Subclause number				accep erion	lance	
and test (see Note 1)	Destructive or	Conditions		Note	1)	Performance
of IEC 61646	nondestructive	of test	р	n	ć	requirements
GROUP C			•			•
INSPECTION						
(periodic)						
Subgroup C1			24	1	0	or change in product
10.20 Wet leakage current	ND					
10.18 Light-soaking	ND					As in 10.20 of
						IEC 61646
10.4 Measurement of	ND					As in clause 6
temperature coefficients						of IEC 61646
10.5 Measurement	ND					See 2.1
of NOCT						
10.6 Performance	ND					See 2.1, first five
at NOCT	ND	After				items
10.7 Performance at	ND	After, repeat	)			See manufacturer's data sheet
low irradiance		tests 10.1, 10.2 10.3	5			uata sneet
10.8 Outdoor exposure	ND	10.3				
10.0 Outdoor exposure						

### Table 1. Test Schedule for Quality Conformance Inspection

Subclause number and test (see Note 1)	Destructive or	Conditions	Sample size and acceptance criterion (see Note 1)			Performance
of IEC 61646	nondestructive	of test	р	n	С	requirements
10.9 Hot-spot endurance	D					
10.20 Wet leakage current	D					As in 10.20 of IEC 61646
10.18 Light-soaking	ND			As i	n clause	6 of IEC 61646
GROUP C INSPECTION (periodic)						
Subgroup C2	D		12	2	0	As in 10.20 of IEC 61646
10.20 Wet leakage current						As in 10.20 of IEC 61646
10.18 Light-soaking						
10.10 UV test		IEC 61345				See clause 7 of IEC 61345.
10.19 Annealing						As in 10.19 of IEC 61646
10.11 Thermal cycling		50 cycles After, repeat tests 10.1, 10.1, 10.2, 10.3 IEC 61215				See 10.1, 10.2, 10.3 of IEC 61646
10.12 Humidity freeze						See 10.1, 10.2, 10.3 of IEC 61646
10.14 Robustness of terminations				1	0	See 10.14.5 of IEC 61646
10.15 Twist				1	0	See 10.15.4
10.20 Wet leakage current				2	0	of IEC 61646 As in 10.20
10.18 Light-soaking				2	0	of IEC 61646 As in clause 6 of IEC 61646
Subgroup C3	D		12	2	0	
10.20 Wet leakage current						As in 10.20
10.10 A						of IEC 61646
10.19 Annealing						As in 10.19 of IEC 61646
10.11 Thermal cycling		200 cycles				See 10.11.5
ioni incinar cycling		200 070100				of IEC 61646
10.20 Wet leakage current						As in 10.20
10.18 Light-soaking						of IEC 61646

Subclause number and test (see Note 1)	Destructive or Conditions		Sample size and acceptance criterion (see Note 1)			Performance
of IEC 61646	nondestructive	of test	р	n	С	requirements
Subgroup C4	D		12	2	0	
10.18 Wet leakage current						As in 10.18
-						of IEC 61646
10.19 Annealing						As in 10.19
0						of IEC 61646
10.13 Damp heat		1 000h				See 10.13.4
10.16 Mechanical load				1	0	See 10.16.4
10.17 Hail				1	0	See 10.17.5
10.20 Wet leakage current				2	0	As in 10.20
0						of IEC 61646
10.18 Light-soaking				2	0	As in clause 6
0						of IEC 61646

NOTE 1—In this table:

p = periodicity (in months)

n = sample size

c = acceptance criterion (permitted number or nonconforming items)

## 5. Modifications Likely to Affect Qualification Approval

For the modifications listed below, the Qualification Approval tests in IEC 61646 shall be repeated as indicated:

#### a) Modification to thin-film layers

For modifications such as

- -metallization materials and/or process,
- --semiconductor layer doping levels (major changes)
- --semiconductor layer thicknesses (major changes)
- -semiconductor layer materials
- -change of manufacturing site of the thin-film layers

repeat

- -thermal cycling, 200 cycles (10.11),
- -humidity freeze (10.12),
- -damp heat (10.13),
- -outdoor exposure (10.8), and
- —hot spot endurance (10.9).
- -Light-soaking (10.18)

#### b) Modification to encapsulation system

For modifications such as

-different materials,

-different additives,

-different primer or method of priming, and

—modification of encapsulation process (that is, different time, temperature, pressure, and so forth) repeat

-thermal cycling, 200 cycles (10.11),

----UV (10.10, IEC 61345) / thermal cycling, 50 cycles (10.11) / humidity freeze sequence (10.12),

—insulation test (10.3), and

-outdoor exposure (10.8).

—wet leakage current test (10.20)

#### c) Modification to superstrate

#### For modifications such as

-different material,

-different thickness,

-different additives, and

-different preparation process,

repeat

----UV (10.10, IEC 61345) / thermal cycling, 50 cycles (10.11) / humidity freeze (10.12) sequence,

-twist test (10.15),

-mechanical load test (10.16),

-insulation test (10.3),

-hail test (10.17), and

-damp heat (10.13) (if nonglass)

-wet leakage current test (10.20)

#### d) Modification to backsheet/substrate

For modifications such as

-different thickness,

-different additives, and

-different preparation process,

repeat

----UV (10.10, IEC 61345) / thermal cycling, 50 cycles (10.11) / humidity freeze (10.12) sequence,

-robustness of terminations (10.14),

-damp heat (10.13) (if nonglass).

-wet leakage current test (10.20)

If there is a change from superstrate to substrate design or from substrate to superstrate design, the entire qualification test sequence in IEC 61646 shall be conducted.

#### e) Modification to frame and/or mounting structure

For modifications such as

-cross section of frame

-different framing material, and

-elimination of frame altogether,

repeat

-mechanical load test (10.16),

-outdoor exposure (10.18) if plastic material is used,

---UV (10.10, IEC 61345) / thermal cycling (10.11), 50 cycles / humidity freeze (10.12) sequence, if plastic material is used, and

-hail test (10.17), unless tempered glass is used as superstrate.

#### f) Modification to junction box/electrical termination

For modifications such as

-different material,

-different design, and

-different method of attachment

repeat

-robustness of terminations (10.14),

-thermal cycling, 200 cycles (10.11), and

—insulation test (10.3).

-wet leakage current test (10.20)

#### g) Lower or higher efficiency cells in identical package and identical cell process

Repeat

—hot-spot endurance (10.9),

-thermal cycle, 200 cycles (10.11), and

-damp heat (10.13).

### 6. Modifications That Do Not Require Retesting

Provided that all structural components, materials used and processes (including cell process) remain the same, the following modifications shall not require retesting:

-fewer cells in module;

—smaller cells in module, as long as each cell has the same number or area of interconnects and equivalent numbers of solder bonds per unit area.

#### 7. Marking

Marking of the PV module shall be in accordance with clause 4 of IEC 61646. The detail specification may also require that, in addition, the following be marked:

-maximum power (W);

—maximum power current (A);

-open-circuit voltage (V);

—short-circuit current (A);

—NOCT (°C).

Marking of the package may also be required, for example

-manufacturer's name, logo or trade mark;

-model/type number;

—serial number.

#### 8. Documentation

For each delivery a manufacturer's or distributor's Declaration of Conformity according to QC 010002–2 shall be included. The name and the site of the manufacturer of the solar cells shall be stated on the Declaration of Conformity.

#### 9. Appendixes

Appendixes may be included, if necessary, to show more details on PV module dimensions, mounting, terminal dimensions, and so forth.

## Appendix 4. IEC Published Photovoltaic (PV) Standards

In the previous appendix, three important PV standards were recommended by the PV Global Accreditation Program (PV GAP). Additionally, at present a number of internationally accepted standards exist for testing photovoltaic modules and systems. Most of these standards have been drafted by Technical Committee 82 (TC 82) of the International Electrotechnical Commission (IEC), and have been approved and published by the IEC. Each of 25 published IEC photovoltaic standards are listed and included in this appendix. Also, the work is in progress for drafting another 15 PV standards by TC 82 of IEC on photovoltaic modules (6), systems (4), PV batteries (1), balance of system components (3), and certification (1).

### **PV Module Standards**

- 1. IEC 61836: 1997, Solar Photovoltaic Energy Systems—Terms and Symbols.
- 2. IEC 60891: 1987, Procedures for Temperature and Irradiance Corrections to Measured I-V Characteristics of Crystalline Silicon Photovoltaic (PV) Devices. Amendment No 1 (1992).
- 3. IEC 60904-1: 1987, Photovoltaic Devices. Part 1: Measurements of PV Current-Voltage Characteristics.
- 4. IEC 60904-2: 1989, Photovoltaic Devices. Part 2: Requirements for Reference Solar Cells.
- 5. IEC 60904-3: 1989, Photovoltaic Devices. Part 3: Measurement Principles for Terrestrial Photovoltaic (PV) Solar Devices With Reference Spectral Irradiance Data.
- 6. IEC 60904-5: 1993, Photovoltaic Devices. Part 5: Determination of the Equivalent Cell Temperature (ECT) of Photovoltaic (PV) Devices by the Open-Circuit Voltage Method.
- 7. IEC 60904-6: 1994, Photovoltaic Devices. Part 6: Requirements for Reference of Solar Modules.
- 8. IEC 60904-7: 1995, Photovoltaic Devices. Part 7: Computation of Spectral Mismatch Error Introduced in the Testing of Photovoltaic Device.
- 9. IEC 60904-8: 1995, Photovoltaic Devices. Part 8: Guidance for Spectral Measurement of Spectral Response of a Photovoltaic (PV) Device. Second Edition (1998).
- 10. IEC 60904-9: 1995, Photovoltaic Devices. Part 9: Solar Simulator Performance Requirements.
- 11. IEC 60904-10: 1998, Photovoltaic Devices. Part 10: Linearity Measurement Methods.
- 12. IEC 61215: 1993, Crystalline Silicon Terrestrial PV Modules—Design Qualification and Type Approval.
- 13. IEC 61345: 1998, UV Test for Photovoltaic (PV) Modules.
- 14. IEC 61646: 1996, Thin Film Silicon Terrestrial PV Modules-Design Qualification and Type Approval.
- 15. IEC 61701: 1995, Salt Mist Corrosion Testing of Photovoltaic (PV) Modules.
- 16. IEC 61721: 995, Susceptibility of a Module to Accidental Impact Damage (Resistance of Impact Test).

## **PV System Standards**

- 17. IEC 6661724: 1998 Photovoltaic System Performance Monitoring—Guidelines for Measurements, data exchange and Analysis.
- 22. IEC 61725: 1997 Analytical Expression for Daily Solar Profiles.
- 23. IEC 61727: 1995 Photovoltaic (PV) Systems—Characteristics of the Utility Interface.
- 24. IEC 61829: 1995 Crystalline Silicon Photovoltaic (PV) Array—On-site Measurement of I-V Characteristics.
- 25. IEC 1277: 1995, Terrestrial Photovoltaic (PV) Power Generating Systems—General and Guide.

# Acronyms and Abbreviations

AGM	Absorbed glass mat
ANW	Approved new work
ASTM	American Society for Testing and Materials
BOS	Balance of system
CDIS	Committee Draft International Standard
etdc	Electronic Test and Development Centre
FSEC	Florida Solar Energy Center
GEF	Global Environment Facility
HVD	High-voltage disconnect
IEC	International Electrotechnical Commission
IECQ	International Electromechanical Commission Quality Assessment System for Electronic Components
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Standardization Organization
ITU	International Telecommunications Union
LAP	Laboratory accreditation program
LVD	Low-voltage disconnect
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory of the United States
NVLAP	National Voluntary Laboratory Accreditation Program
NSI	National Supervising Inspectorate
PNW	Proposed new work
PV	Photovoltaic
PV GAP	Global Approval Program for Photovoltaics
PWM	Pulse width modulated
QuaP-PV	Quality Program for Photovoltaics
	(The full name of the program is Mitigating Global Climate Change through the Development of a
	Quality Process Infrastructure for Renewable Energy.)
SHS	Solar home system
SCC	Standard Coordinating Committee
ТС	Technical committee
UL	Underwriters Laboratories
UNDP	United Nations Development Programme
WTO	World Trade Organization

## Units of Measure

- °C = degrees Celsius
- Hz = hertz, cycles per second
- kHz = kilohertz
- kW = kilowatt
- lumen = L = the luminous flux emitted in a unit solid angle by a point source of 1 candle intensity
  - m = meter
  - mm = millimeter

#### newton (N) = the force that produces an acceleration of 1 meter per second per second on a mass of 1 kilogram

- Pa = pascal = newtons per square meter
- kWp = peak kilowatt
  - V = volt = the difference of electric potential between two points of a conductor carrying a constant current of 1 ampere across an electric resistance of 1 ohm
  - W = watt = 1 joule per second and equal to the power in a circuit in which a current of 1 ampere flows across a potential

difference of 1 volt

## References

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