NBS SPECIAL PUBLICATION 400-28

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Semiconductor Measurement Technology:

NBS/FDA Workshop

Reliability Technology for Cardiac Pacemakers

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards[1] was established by an act of Congress March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau consists of the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Institute for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of the Office of Measurement Services, the Office of Radiation Measurement and the following Center and divisions:

Applied Mathematics — Electricity — Mechanics — Heat — Optical Physics — Center for Radiation Research: Nuclear Sciences; Applied Radiation — Laboratory Astrophysics[2] — Cryogenics[2] — Electromagnetics[2] — Time and Frequency[2].

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement, standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government agencies; and develops, produces, and distributes standard reference materials. The Institute consists of the Office of Standard Reference Materials, the Office of Air and Water Measurement, and the following divisions:

Analytical Chemistry — Polymers — Metallurgy — Inorganic Materials — Reactor Radiation — Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations leading to the development of technological standards (including mandatory safety standards), codes and methods of test; and provides technical advice and services to Government agencies upon request. The Institute consists of the following divisions and Centers:

Standards Application and Analysis — Electronic Technology — Center for Consumer Product Technology: Product Systems Analysis; Product Engineering — Center for Building Technology: Structures, Materials, and Life Safety; Building Environment; Technical Evaluation and Application — Center for Fire Research: Fire Science; Fire Safety Engineering.

THE INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in improving cost effectiveness in the conduct of their programs through the selection, acquisition, and effective utilization of automatic data processing equipment; and serves as the principal focus within the executive branch for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Institute consists of the following divisions:

Computer Services — Systems and Software — Computer Systems Engineering — Information Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal Government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System; provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

Office of Standard Reference Data — Office of Information Activities — Office of Technical Publications — Library — Office of International Relations — Office of International Standards.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.

[2] Located at Boulder, Colorado 80302.

Semiconductor Measurement Technology:

NBS/FDA Workshop
Reliability Technology for Cardiac Pacemakers

Harry A. Schafft, Editor

Electronic Technology Division
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

This activity was supported by

The Food and Drug Administration
Bureau of Medical Devices & Diagnostic Products
Silver Spring, Maryland 20910
and
The National Bureau of Standards
Washington, D.C. 20234

U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, *Secretary*

Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

Issued June 1976

Library of Congress Catalog Card Number: 76-600030

National Bureau of Standards Special Publication 400-28
Nat. Bur. Stand. (U.S.), Spec. Publ. 400-28, 49 pages (June 1976)
CODEN: XNBSAV

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1976

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.10:400-28). Price $1.25 (Add 25 percent additional for other than U.S. mailing).

PREFACE

The workshop on reliability technology for cardiac pacemakers was conducted as part of the Semiconductor Technology Program in the Electronic Technology Division of the National Bureau of Standards (NBS) with the partial financial support of the Bureau of Medical Devices and Diagnostic Products of the Food and Drug Administration.

The Semiconductor Technology Program serves to focus NBS efforts to enhance the performance, interchangeability, and reliability of discrete semiconductor devices and integrated circuits through improvements in measurement technology for use in specifying materials in national and international commerce and for use by industry in controlling device fabrication processes. Its major thrusts are the development of carefully evaluated and well documented test procedures and associated technology and the dissemination of such information to the electronics community. Application of the output by industry will contribute to higher yields, lower cost, and higher reliability of semiconductor devices. The output provides a common basis for the purchase specifications of government agencies which will lead to greater economy in government procurement. In addition, improved measurement technology will provide a basis for controlled improvements in fabrication processes and in essential device characteristics.

The Program receives direct financial support principally from three major sponsors: The Defense Advanced Research Projects Agency (ARPA), the Defense Nuclear Agency (DNA), and the National Bureau of Standards. The ARPA-supported portion of the Program, Advancement of Reliability, Processing, and Automation for Integrated Circuits with the National Bureau of Standards (ARPA/IC/NBS), addresses critical Defense Department problems in the yield, reliability, and availability of integrated circuits. The DNA-supported portion of the Program emphasizes aspects of the work which relate to radiation response of electron devices for use in military systems. There is considerable overlap between the interests of DNA and ARPA. Measurement oriented activity appropriate to the mission of NBS is a critical element in the achievement of the objectives of both other agencies.

Essential assistance to the Program is also received from the semiconductor industry through cooperative experiments and technical exchanges. NBS interacts with industrial users and suppliers of semiconductor devices through participation in standardizing organizations; through direct consultations with device and material suppliers, government agencies, and other users; and through symposia and workshops. In addition, progress reports are regularly prepared for issuance in the NBS Special Publication 400 sub-series. More detailed reports such as state-of-the-art reviews, literature compilations, and summaries of technical efforts conducted within the Program are issued as these activities are completed. Reports of this type which are published by NBS also appear in the Special Publication 400 sub-series. Announcements of availability of all publications in this sub-series are sent by the Government Printing Office to those who have requested this service. A request form for this purpose may be found at the end of this report.

Semiconductor Measurement Technology
NBS/FDA Workshop
Reliability Technology for Cardiac Pacemakers

Harry A. Schafft, Editor

Table of Contents

Page

Semiconductor Measurement Technology:

NBS/FDA Workshop

Reliability Technology for Cardiac Pacemakers

by

Harry A. Schafft, Editor

Brief summaries are presented of 20 invited talks on the following topics: procurement and assurance of reliable, long lived semiconductor electronic parts; leak testing of device packages and pacemaker systems; activities of standardization organizations; and availability and use of resources for information and expertise. The purpose of the workshop was to address technical questions relevant to the enhancement and assurance of cardiac pacemaker reliability, and to bring together representatives from the pacemaker, military, aerospace, and other communities to discuss areas of mutual concern. The technical sessions highlighted the problems of pacemaker manufacturers associated with obtaining high reliability electronic components - problems shared with the most demanding users in the military and space communities. It was also noted that no government agency has the authority or responsibility for the development of methods to permit assured procurement of high quality electronic components for critical applications by organizations in the civilian sector. These organizations must rely on spin-off from military and space programs even when parts of this civilian sector have reliability requirements which are more severe than all but the most stringent military and space requirements. Included in appendices are measurement technology areas of concern identified by the pacemaker community; information about utilizing reliability data banks and facilities for searching literature and data; and organizations offering services in the microelectronics field.

Key Words: Cardiac pacemaker; data banks; failure analysis; failure modes; hermeticity; hybrid devices; leak testing; measurement technology; microelectronics; MOS devices; process control; reliability; semiconductor devices; surgical implants.

1. INTRODUCTION

For the first time, experts from the cardiac pacemaker community were joined by experts from the high-reliability electronics and other technical communities in a workshop to address technological problems related to assuring the reliability of cardiac pacemakers. The workshop was held on July 28 and 29, 1975, at the National Bureau of Standards (NBS) in Gaithersburg, Maryland, and was jointly sponsored by NBS and the Food and Drug Administration (FDA) of the Department of Health, Education, and Welfare.

The workshop grew out of FDA's concern about the need to recall or to more frequently monitor about 23,000 pacemakers during the last three years, and about the number of deaths attributed to pacemaker failures which have resulted from a variety of component and material-related problems. Particular concern focused on the reliability of the semiconductor electronic components used in pacemakers, and the integrity, or hermeticity, of the pacemaker enclosure and of the component device packages.

In April of 1975 the Electronic Technology Division of NBS was asked by FDA to organize a workshop which would address problems relevant to cardiac pacemaker reliability. The intent of the workshop was to infuse needed technology from other technical communities, particularly the high reliability semiconductor electronics community. The Electronic Technology Division became involved for a number of reasons: because of its work in semiconductor device measurement technology, spanning well over a decade; its expertise in hermeticity testing; and its experience with evaluating and transferring technology, and with organizing workshops for information exchange in its area of responsibility.

Before designing the workshop it was necessary to have the pacemaker community identify areas that it wanted addressed. This input was obtained during a series of visits to a representative sample of the community by three NBS staff members: George G. Harman, Stanley Ruthberg, and Harry A. Schafft. The face-to-face interactions that these visits provided also facilitated a mutual assessment which, on the one hand, was valuable in evaluating the input from the pacemaker community and, on the other hand, allowed the intent of NBS in organizing the workshop to be gauged. These interactions proved to be an important factor in the development of an effective workshop. The inputs obtained were summarized in an introductory presentation at the workshop; the text of this presentation is included in Appendix B.

In addition to obtaining suggested topic areas, the visits also revealed that much of the technology and the procedures of the high reliability semiconductor device community had already been transferred. Engineers were encountered who had previously been associated with space and military programs and had brought with them valuable expertise in high reliability technology. Pacemaker manufacturers were found using, to varying extents, independent semiconductor-based organizations which are able to provide procurement and testing services for high reliability parts that individual pacemaker companies cannot easily provide for themselves because of their relatively small purchase volumes. Some manufacturers were also found with ties to semiconductor organizations that supply high reliability parts from controlled or captive assembly lines. In short, the pacemaker industry was seen as one very much concerned with and involved in high reliability technology and faced with problems similar, in many respects, to the high reliability space and military communities with which the NBS staff was already familiar.

Therefore, the workshop was designed not only to make available experts and sources of information for the pacemaker community to probe and explore at the meeting, but also to encourage meaningful technical exchanges and contacts which would continue beyond the term of the workshop. Realizing that the pacemaker and the semiconductor electronics communities have common interests, it was hoped that by a pooling of efforts better responses could be found to the complex problems which each has faced in the pursuit of increased reliability.

2. PURPOSE AND ORGANIZATION OF REPORT

The purpose of this report is to summarize briefly the presentations given at the workshop, and to record information provided by the speakers about service organizations, data banks, information sources, and resource areas that may be of value to the attendees and other interested parties.

Following a brief summary of the highlights of the workshop are four sections titled Electronic Reliability, Hermeticity, Resource Areas, and Standards Organizations, the names of the technical sessions of the workshop. In these four sections, brief reviews are provided of the presentations given in each of the respective sessions, in the order in which they were given. Each review is headed by a topic title followed by the speaker's name, affiliation, address, and telephone number, which are provided should the reader wish to contact the speaker for more details. The complete titles of the papers may be found in the program of the workshop, included as Appendix A. The results of the discussion periods are not provided except as they are included in the highlights section. Selected materials given by the speakers and other material that might be useful for reference are included as appendices.

The reviews of the presentations were prepared primarily from written materials provided by the speakers. Each speaker has read and approved the review of his or her presentation, and, where appropriate, the material in the appendices.

3. HIGHLIGHTS

The pacemaker community repeatedly emphasized that the reliability requirements for components to be used in pacemakers are more severe than all but the most stringent military and space requirements. These requirements take on added dimensions with the development and anticipated use of power sources with operating life of 5, 10, or more years.

Reliability requirements for pacemakers are difficult to fulfill because high quality components are not readily-available, off-the-shelf items. The low-volume purchases generally involved do not provide the economic leverage to encourage special efforts by vendors to supply them.

Basic to the problems of procuring high quality electronic parts and of assuring their reliability, which the pacemaker and other communities face, are deficiencies in the measurement technology needed to carry out these functions. There are no adequate standard or consensus process control and procurement procedures by which high reliability electronic components may be purchased; there are no clearly satisfactory means to test with confidence the reliability of parts purchased in small volume.

An example where the measurement technology is deficient is in testing the hermetic nature of electronic part and pacemaker packages. A major reason for a hermetic package is to exclude the presence of water vapor which, especially with minute ionic contaminants, can cause failure of the sealed electronic device. There are still serious uncertainties related to establishing maximum acceptable leak rates, to determining how much internal moisture can be tolerated, and to relating the ingress of moisture to that of the test gases used in the methods for measuring the leak rates of packages.

Even passing all leak tests is no insurance against failure because, firstly, package design and materials may be such that subsequent handling and testing will result in a package leak; and secondly, inadequate control of assembly procedures and materials can result in sealing-in the minute amounts of moisture that can cause failure.

A major government policy question was raised during a discussion period which serves to cap the concerns expressed about measurement technology and reliability. Following a presentation on a government program to develop highly reliable hybrid circuits for an application to nuclear weapons, it was observed that no government agency has the authority or responsibility for the development of methods to permit assured procurement of high quality electronic components for application to the solution of critical problems in the civilian sector. At the present time, developments in this area rely primarily on spin-off from military and space activity, which is decreasing, and on developments by an industry (the semiconductor device industry) principally oriented to the production of good quality parts in high volume with little incentive to supply high reliability parts in the low volumes required.

As an indication of the usefulness of the workshop as a vehicle for facilitating useful technical exchanges and contacts, attendees at the closing session recommended that additional meetings be held and that NBS should be the focal point for organizing such meetings. One recommendation was that NBS hold an annual three-day meeting devoted to specific problems of interest to the pacemaker community. Several industrial representatives volunteered to assist NBS in the development of a follow-up meeting. This interest was reiterated in a subsequent questionnaire sent to the workshop attendees to which over 90 percent of the attendees from the pacemaker community responded. As a result of this positive response, NBS plans to sponsor in 1976 another meeting for the pacemaker community.

4. ELECTRONIC RELIABILITY

4.1 Data Banks and Services

Harold Lauffenburger
Reliability Analysis Center
RADC/RBRAC
Griffiss Air Force Base, NY 13441
(315) 330-4151

The Government Industry Data Exchange Program (GIDEP) and the Reliability Analysis Center (RAC) are government funded data programs for acquisition, storage, retrieval, and dissemination of reliability test and experience information. Because both organizations are neither producers nor users of components or systems, the analyses and recommendations provided by GIDEP and RAC are free of proprietary and competitive biases. Because the services provided should be useful to those in the pacemaker community not already familiar with them, they are summarized in Appendix C.

The missions and services of these two programs are complementary and each is best employed as an adjunct to the user's in-house reliability engineering expertise and resources.

4.2 Electronics for DoD and NASA

Clyde Lane
Rome Air Development Center (RBRM)
Griffiss Air Force Base, NY 13441
(315) 330-3473

To obtain and assure reliable semiconductor products, the Department of Defense established a system which provides a variety of standardization and control documents, some of which are listed in table 1. The Rome Air Development Center provides staff and supports activities to operate the system and make it responsive to changes in technology and needs of the military. These activities include device design and process studies, quality and reliability assurance, failure analysis, field experience, data collection and analysis, participation on special committees and study groups, and reliability and maintainability support to electronic systems.

The system is built around three classes (A, B, and C) of device reliability obtained by requiring appropriate levels of rigor for screen tests to remove faulty parts, physical and electrical characterization, interchangeability guarantees, lot acceptance criteria, supplier and process controls, and Government surveillance. Class A is the highest reliability class and is the one that is appropriate for electronic parts in pacemakers as it is for most missile and space applications.

Military systems are the primary beneficiaries but the system is open for use by the civilian sector. In fact, civilian use is encouraged for the mutual benefit of both because the increased demand and purchase volume would result in increased availability and reduced cost of high reliability parts.

TABLE 1 — LIST OF SELECTED DOD/NASA STANDARDIZATION DOCUMENTS

MIL-STD-883A	Military Standard, Test Methods and Procedures for Microelectronics (15 November 1974) Scope: Provides uniform methods and procedures for testing microelectronic devices, including physical and electrical tests, and basic environmental tests relevant to military and space operations.
MIL-M-38510	Military Specification, General Specification for Microcircuits (20 November 1969) Scope: Establishes general requirements for monolithic, multichip, and hybrid microcircuits and for the quality and reliability assurance requirements which must be met in the procurement of microcircuits to be used in military equipment. [A companion document to MIL-STD-883A.]
MIL-STD-750B	Military Standard, Test Methods for Semiconductor Devices (27 February 1970) Scope: Provides uniform methods and procedures for testing discrete semiconductor devices, including physical and electrical tests, and basic environmental tests relevant to military and space operations.
MIL-S-19500E	Military Specification, General Specification for Semiconductor Devices (1 April 1968) Scope: Establishes general requirements for discrete semiconductor devices and for the quality and reliability assurance requirements which must be met in the procurement of discrete devices to be used in military equipment. [A companion document to MIL-STD-750B.]
NHB 5300.4(3C)	Line Certification Requirements for Microcircuits (May 1971) Scope: Establishes minimum requirements for initiating and maintaining the certification of a manufacturing line to fabricate and assemble high reliability microcircuits for Government use. Aspects covered include plant facilities, equipment, personnel training, process controls, and documentation.
MIL-HDBK-217B	Military Standardization Handbook, Reliability Prediction of Electronic Equipment (20 September 1974) Scope: Deals with reliability prediction of military electronic equipment, and provides a common basis for predicting reliability and comparing reliability predictions in military contract work and in proposals.
QPL-19500	Qualified Products List Scope: A list of discrete electronic devices that have been qualified under the requirements for the product as specified in the applicable specification.
QPL-38510	Qualified Products List Scope: A list of semiconductor microcircuits that have been qualified under the requirements for the product as specified in the applicable specification.

4.3 Hybrid Device Processing

Robert A. Lowry, Jr.
Micro-Rel, Inc.
1005 S. Park Lane
Tempe, AZ 85281
(602) 968-6411

Process control is the key to achieving high reliability in hybrid devices.

It begins with vendors of piece parts and materials who:

- exercise adequate control over their products, and
- understand explicitly what is expected by the hybrid manufacturer.

It continues at the hybrid facility with:

- second sources for all major piece-part suppliers,
- incoming inspection for lot-to-lot uniformity,
- functional line testing,
- inspection of each device lot after each major assembly operation,
- careful qualification of each process change,
- use of clear, well-defined process specifications, including methods for rework, and
- a document control system which maintains all process specifications and their changes, and maintains traceability of all pertinent parts and materials.

Not to be overlooked in process control is the importance of employee motivation to reduce the chance for human error. Motivation can be engendered by informing all concerned about successes as well as problems, and by developing an appreciation for the importance of the end use to which the devices they produce will be applied.

The choice of technologies used in-house to manufacture hybrid devices must consider the availability of supporting equipment. Relatively new technology may not have equipment sufficiently refined to achieve the process control needed. Once the technology is selected, production people who have become skilled in the use of the equipment must be supported directly in the production area by key engineers with expertise in the technology.

Careful qualification of process changes is accomplished by producing devices under controlled conditions with the process change and by testing the devices as defined in various military standards. Such qualification can reveal potential problems not otherwise obvious.

The order of the assembly steps and the timing of inspections affects both reliability and cost of hybrid devices. Steps must be ordered so that they are sequentially compatible, and inspections should be performed when quality can still be upgraded, if necessary, by performing rework steps. For example, transistor bonding should follow capacitor attachment to avoid flux-induced surface contamination of the transistors; and inspection of the epoxy die bond should precede epoxy cure because the die can then still be easily removed and because the device is thereby saved from an extra high-temperature epoxy cure cycle with the attendant increased change of device degradation.

4.4 Small-Volume Parts Purchase

Robert Fischer[1]
Continental Testing Laboratories
Fern Park, FL 32731

Procuring and assuring highly reliable parts is more difficult when small purchase quantities are involved. For this reason, the pacemaker and other relatively small communities requiring high reliability parts should be alert to, and use as appropriate, the services that a variety of independent semiconductor-based organizations can provide.[2] Such organizations can provide procurement and test services that individual pacemaker companies may not economically be able to provide for themselves. Because they serve many companies, such organizations are able to deal directly with device manufacturers with greater success because the combined purchase volume is sufficient to merit the extra attention required of the vendor. Furthermore, such organizations can more efficiently provide test services and the broad expertise required to assure that the electronic parts purchased are of adequately high quality. Also, there are other semiconductor organizations which are able and willing to supply high quality parts from controlled or captive assembly lines, according to mutually agreed upon processes and procedures.[3]

---

[1]Now with Custom Devices, 4246 E. Wood Street, Phoenix, AZ 85040; Telephone: (602) 268-1371.

[2]A partial list of organizations offering services in the microelectronic field was distributed during the workshop and is reproduced in Appendix F. [Editor]

[3]Recommended reading is a report which reviews the merits and drawbacks of different types of product assurance methods and specification systems, and proposes an approach where devices are obtained from vendors in wafer form on the basis of stringent wafer acceptance tests and are subsequently processed on a controlled line under strict quality control conditions. [A. G. Stanley, Review of High-Reliability Procurement Practices in the Semiconductor Industry, Report No. ESD-TR-74-11, January 1974. Report available at a cost of $4.00 for hard copy and $2.25 for microfiche from the National Technical Information Service (NTIS), Springfield, VA 22151 by using the NTIS accession number AD 773 833.]

4.5 MOS Devices

John D. Heightley
Sandia Laboratories
Albuquerque, NM 87115
(505) 264-6303

In the test and procurement of high reliability MOS devices at Sandia, the principal reliability problems have been found to be oxide contamination and static discharge.

An efficient screen test to remove MOS devices with oxide contamination is to subject the devices to dc bias at high temperatures (125°C to 150°C) for 168 hours; if more than 1 1/2 percent of the devices fail the electrical tests that follow, the devices that pass are subjected to the high-temperature, bias stress for another 168 hours; if more than 1 1/2 percent of these devices fail the electrical tests, the entire lot is scrapped.

Great care must be exercised to avoid device damage due to static discharge during handling and testing.[1] Static discharge may not always cause a catastrophic failure but can cause subsequent degradation of the device characteristics.

The only way to eliminate dice and packaged parts that have processing- and assembly-induced faults is to exercise very close control over these operations. To obtain high-quality, high-reliability integrated circuits, the customer must have a knowledgeable resident inspector at the manufacturing facility to assure that the required specifications are being met and that adequate controls are being exercised. Demonstrated 10 million device-hour operation with zero failures has been achieved for MOS devices manufactured with carefully specified and controlled processes, and screened with high-temperature biased tests.

4.6 Hybrid Devices

Charles Tapp
Sandia Laboratories
Albuquerque, NM 87115
(505) 264-3751

Sandia's approach for achieving high reliability hybrid microcircuits can be reduced to three parts:

(1) the development of in-house expertise in the materials and processes utilized in the manufacture of hybrid microcircuits, with the

[1]A library of the various techniques that have been employed to prevent MOS device failure due to electrostatic discharge (ESD) has been compiled by the Reliability Analysis Center. For information and assistance on ESD protection, contact Lee Mirth, RAC Project Engineer, RADC(RBRAC), Bldg. 3, Griffiss AFB, NY 13441; Telephone: (315) 330-4151. [Editor]

decision to use a single hybrid technology compatible with beam leaded devices;

(2) the use of as simple a chemical and metallurgical system as possible to maximize the probability of thoroughly understanding all the possible reactions and interactions; and

(3) the development and maintenance of a close coordination with the single production source for the hybrid microcircuits.

Achievement of in-house expertise has involved an investment, since 1970, of approximately 20 workyears per year researching elements of this hybrid technology. The information gathered has been put into report form which is available to pacemaker manufacturers.[1,2] Also available is a list of specifications for the hybrid technology used in production.[3,4]

Before a newly developed technology is transferred to the production line, a special facility at the manufacturer's site is used to simulate the production environment. This is done to exercise the new technology and thereby search for possible problems that would not have been found in development, and to determine that the new technology is compatible with other processes and procedures already incorporated on the production line.

The metallurgical system chosen uses gold, thin-film technology. Thermocompression bonding of gold wire to gold metallization is the fundamental interconnection used. Some applications requiring very low inductance necessitates the use of a thoroughly investigated lead-indium solder. For some devices, particularly MOS devices which are available only with aluminum terminations, one-mil aluminum ultrasonic wire bonds are used.

Does this approach to high reliability work? The first two years of production experience have been very satisfactory. The yields have been consistently higher than the goals set. The hardware produced performs for an order of magnitude longer than is required and there have been no field failures.

---

[1]C. M. Tapp and R. K. Traeger, Bibliography, Sandia Laboratory Hybrid Microcircuit and Related Thin Film Technology (June 1974). [Available at a cost of $4.00 from the National Technical Information Service (NTIS), Springfield, VA 22151 by using the NTIS order number SAND74-0009.]

[2]C. M. Tapp and T. A. Wiley, A Review of Hybrid Microelectronics (June 1974). [Available at a cost of $4.50 from the National Technical Information Service (NTIS), Springfield, VA 22151 by using the NTIS order number SLA-73-1063.]

[3]C. M. Tapp and D. J. Sharp, A Compilation of Specifications Describing Hybrid Microcircuit Technology (June 1974). [Available at a cost of $7.75 from the National Technical Information Service (NTIS), Springfield, VA 22151 by using the NTIS order number SLA-74-0300.]

[4]A TV tape cassette reviewing the hybrid production facility at Sandia is available on request from C. M. Tapp, Department 2430, Sandia Laboratories, Albuquerque, NM 87115.

4.7 Standards for Hybrids

Daniel D. Zimmerman
Johns Hopkins University
Applied Physics Laboratory
Laurel, MD 20810
(301) 953-7100, x2609

A standards document for hybrid microcircuits has been developed by the Standards and Specifications Committee of the International Society for Hybrid Microcircuits (ISHM).[1]

This document, Hybrid Microelectronics Standard Specification Guidelines,[2] establishes uniform methods for the procurement and test of hybrid microcircuit assemblies. Such assemblies include thick and thin film hybrid microcircuits, microcircuit arrays, and the elements from which such microcircuits and arrays are formed, including active and passive chip parts. Multiple levels of general performance requirements are defined. This is done in recognition of the varying applications of hybrid microcircuits and of the need for corresponding provisions for product quality assurance and control. Where appropriate, reference is made to applicable documents available from sources other than ISHM.

As the document becomes more widely used, the comments received by ISHM on this work will be reviewed and analyzed for application in future revisions. Recognizing the need to extend the document, particularly in test methods, ISHM is coordinating with other standards organizations for the preparation and adoption of needed standard test methods where none now exist.

4.8 Analyses for High Reliability

John Devaney
Hi-Rel Laboratories
San Marino, CA 91108
(213) 357-6083

Destructive physical analysis is a relatively new approach to join failure analysis in improving reliability in microelectronics. Whereas failure analysis is used to determine why failure occurred, destructive physical analysis is used to detect potential weaknesses in devices of a given production lot which could lead to premature failure. It is an approach that is gaining rapid and widespread acceptance; for example, some current Air Force and NASA programs are requiring

---

[1]Mr. Zimmerman was chairman of the ISHM Standards and Specifications Committee responsible for the document. [Editor]

[2]The document identified as ISHM SPA 001 is available from ISHM, P. O. Box 3255, Montgomery, AL 36109 at a cost of $25.

it to be used. The analysis is performed on random samples from production lots shipped to the user. The devices in the sample are subjected to visual, microscopic, and scanning electron microscope (SEM) inspections, and to wire bond pull and die shear tests to look for the effects of processing anomalies, mishandling, etc.

It is important to use the results of these analyses to identify problem areas. It is perhaps equally important to assure that the information gained be used for constructive communications among analysis facility, user, and supplier. Otherwise, it is possible that the goal of increasing the availability of more consistently reliable products would be negated by the use of this information to find scapegoats.

5. HERMETICITY

5.1 Moisture in Microcircuits

Robert W. Thomas
Rome Air Development Center (RBRM)
Griffiss Air Force Base, NY 13441
(315) 330-4632

There are problems with assuring that the presence of water vapor is kept to a minimum in semiconductor device packages.

That the standard hermeticity tests are not infallible is illustrated by a recent problem encountered in a high-reliability system. Devices which had passed helium fine leak and bubble gross leak tests specified by MIL-STD-883A failed after 50 hours of operation due to moisture-induced gold migration short circuits. Analysis revealed that the thermal shock test, prescribed in the qualification procedure, had fractured the glass-to-metal seal in the lead frame of the packages. The fractures, which allowed water vapor into the package interiors during the subsequent water quench, went undetected by the hermeticity tests that followed.

The problem of hermeticity tests goes deeper. Devices used on the Apollo program had a leak rate[1] of $1.7 \cdot 10^{-8}$ atm cm^3/s when measured seven years ago. Recent measurements revealed a very low water vapor concentration, about 200 ppm,

[1]Leak rate is generally considered to be the quantity of gas (in pressure-volume units) flowing through a leak per unit time, where the pressure on the low-pressure side of the leak has a negligible effect on the flow rate. It is implicitly assumed that the gas is at room temperature, is air, and is at one atmosphere pressure on the high-pressure side of the leak. Leak rate is commonly given in units of atm cm^3/s (10 Pa m^3/s) which is equivalent to a mass flow rate of about 4×10^{-5} g mol/s. [Editor]

even though a leak rate of 10^{-8} atm cm^3/s would have allowed well over a 90 percent exchange of the environment in that time. Thus, fine leak test methods do not provide accurate information about the leak rate for water vapor.

Assuring a hermetic package is only part of the solution to achieving a dry environment for the device. The emission of surface adsorbed moisture is a major source of water vapor in the package. Component parts must be baked at a high temperature (∿250°C) for a long time (∿10 hr) and then be assembled in a dry atmosphere without exposure, even for a few seconds, to the atmosphere. Plastic and epoxy materials may continue to evolve moisture unless careful bake-out procedures are used. They are, therefore, not recommended for die attachment in high reliability applications unless careful evaluations are conducted. Because of the high moisture permeability of plastic and epoxy materials, they are not recommended for use as device sealing materials.

Water vapor measurement data accumulated over the last two years and threshold values for moisture related failures are listed in table 2. The threshold values for water vapor concentrations are intended as general guidelines recognizing that these values are dependent on the process and the presence of other contaminants, such as ionic chlorine, which may be required to activate failure mechanisms.

TABLE 2 — WATER VAPOR CONCENTRATIONS IN SEMICONDUCTOR DEVICE PACKAGES, AND MOISTURE-RELATED FAILURE — RADC ACCUMULATED DATA (1973-1975)

Typical Water Vapor Concentrations[1]

Package	Concentrations (ppm)
Ceramic (Cerpack)	500 to 1,000
Dual-Inline (DIPS)	5,000
TO-5	500
MIL-STD 38510 Parts	800
Hybrid	5,000 to 10,000

Device Failure and Water Vapor Concentrations[1]

Failure Mode	Water Vapor Concentration (ppm)	
	Demonstrated Failures	Failure-Free Upper Limit
Nichrome Disappearance	5,000 to 10,000	500
Aluminum Disappearance	50,000 to 250,000	1,000
Gold Migration	15,000 to 150,000	1,000
MOS Inversion	5,000 to 20,000	200

[1]Measured at package ambient of 100°C.

5.2 Effectiveness of Common Leak Detection Methods

Ralph McCullough
Texas Instruments, Inc.
Box 5012, Dallas, TX 75222
(214) 238-3931

When measuring for a leak rate of a given magnitude, all hermeticity test methods may allow some packages with such a leak to escape undetected (escape rate) and they may also reject some packages without such a leak (overkill rate). This may happen for a number of reasons: the pressures and pressurization times may not provide sufficient tracer gas or fluid in the package to permit detection over the entire leak rate range of interest; the leak channel may be plugged during pressurization or measurement; the package may have surface contamination which acts as a getter for the tracer gas; or a void may exist near the surface which makes it appear that the package has a leak when, in fact, it does not. The tendency for such misreadings to occur depends on the method used and the type and construction of the package tested. Hence, it is important to understand these considerations when using hermeticity test methods.

The effectiveness (in terms of escape and overkill rates) of five commonly used hermeticity test methods was studied under a contract to the Rome Air Development Center (RADC) and is described in a report.[1] The methods studied are the helium and radioactive tracer gas methods, which are used to test for fine leaks ($\lesssim 10^{-6}$ atm cm^3/s); and the bubble, pressure-bubble, and weight gain methods, which are used to test for gross leaks ($\gtrsim 10^{-5}$ atm cm^3/s). [Brief descriptions of the hermeticity test methods mentioned in this report are given in Appendix D - Editor.]

Selected for the study were 700 test packages with leak rates ranging from less than 10^{-8} atm cm^3/s to greater than 10^{-3} atm cm^3/s. Seven package types[2] were involved; package internal volume ranged from 0.006 to 1.07 cm^3.

Results of the study indicated that while the bubble method can detect leak rates less than 10^{-3} atm cm^3/s, the escape rate is so high as to raise questions about its use. Although the pressure-bubble method showed a lower escape rate than the bubble method, it had an overkill rate that was higher than the bubble method for a number of package types. Of the three gross-leak methods, the best test results were obtained with the weight gain method; it had the smallest escape and overkill rates. For example, all devices having leaks equal to and larger than 10^{-5} atm cm^3/s were detected, and except when

---

[1] R. McCullough, S. Banks, and J. Roberts, Investigation of Microcircuit Seal Testing, Report No. RADC-TR-75-89 (April 1975).

[2] TO-3 (metal; 1.07 cm^3), TO-84 (metal; 0.006 cm^3), TO-100 (metal; 0.086 cm^3), C-PAC (ceramic; 0.012 cm^3), C-DIP (ceramic, 0.014 cm^3), MOS DIP (metal/ceramic; 0.041 cm^3), and 1 x 1 Ceramic (ceramic; 0.45 cm^3).

used on a ceramic package with a volume of 0.5 cm^3, the weight gain method was relatively effective in the 10^{-6} atm cm^3/s range. When the weight gain was combined with one of the fine leak methods, the only packages which escaped detection had leak rates of less than 3×10^{6} atm cm^3/s.

5.3 Hermeticity Test Guidelines and Pacemakers

Stanley Ruthberg
Electronic Technology Division
National Bureau of Standards
Washington, DC 20234
(301) 921-3621

The selection of a definitive maximum leak rate pertinent for moisture ingress is still not possible, be it for the small electronic components or for the larger pacemaker packages. Specifications on leak rates are at best empirical because it is not yet possible to predict the rate at which moisture will enter a container characterized by a given leak rate.[1]

A number of hermeticity test methods[2] are evaluated in table 3. These methods are divided into two groups: one for gross leaks (with leak rates greater than about 10^{-6} atm cm^3/s) and one for fine leaks. To span the range of leak rates that are of interest to reliability engineers, at least one method from each group is needed because a no-leak indication by a fine leak method does not imply the nonexistence of a gross leak. While it is desirable first to eliminate packages with large leak rates, this is not done because the gross leak test methods commonly used involve contact with a fluid which can plug a small leak channel and prevent its detection with one of the fine leak test methods. To obviate this inefficient test sequence and to avoid possible contamination by small amounts of the test fluid that might penetrate the package, a differential pressure method[3] using a dry gas is suggested. While this method is not considered suitable for small semiconductor device packages, it would be feasible for packages with larger volumes.

The fine leak test methods commonly used for semiconductor devices, the back pressurization procedure of the helium leak detector method and the radioisotope method, are both indirect methods for measuring leak rates and require the application of gas flow models. Without reference to the appropriate gas flow model no relationship can be made between the measured and true leak rates.

---

[1]Work contracted by NBS is now addressing the relationship between leak rate and moisture penetration.

[2]Brief descriptions of the hermeticity test methods mentioned in this report are given in Appendix D. [Editor]

[3]W. M. Bullis, Ed., Semiconductor Measurement Technology: Combined Quarterly Report, October 1, 1973 to March 31, 1974, Section 11.5, NBS Spec. Publ. 400-4 (November 1974).

The difficulty associated with such modelling is that flow, be it molecular, laminar, or in between, depends on conditions of the test, the test gas used, and the characteristics of the leak. Extension of gas flow modelling to real packages with real leaks is needed before either method can be used with accuracy and confidence.

To avoid the problems attendant with using the indirect procedures for large device packages and pacemaker packages, these packages should be designed with a vent allowing access to the package interior. With this access, the direct flush procedure of the helium leak detector method may be used which can give a direct, quantitative measure of the leak rate.

TABLE 3 — EVALUATION OF SELECTED GROSS AND FINE LEAK RATE MEASUREMENT METHODS

Method	Range (atm cm^3/s)	Advantages	Disadvantages
BUBBLE	10^{-4} to 10^{-1}	• relative simplicity	• need for smooth package • need to observe entire package • high escape rate • test fluid may penetrate and eventually cause contamination failure in package with fine leak
WEIGHT-GAIN	$\sim 10^{-5}$ to 10^{-1}	• wide leak-rate range • quantitative measure of leak rate • low escape rate	• sensitive balance with large-mass capability needed • test fluid may penetrate and eventually cause contamination failure in package with fine leak
DIFFERENTIAL PRESSURE	$\sim 10^{-4}$ to 10^{-1}	• use of dry gas which will not plug fine-leak channels	• insufficient sensitivity for small-volume packages • sensitive to temperature-gradient effects
HELIUM LEAK DETECTOR Direct Mode (prefill and flush methods)	10^{-10} to 10^{-2}	• wide leak-rate range • direct leak-rate measurement • high sensitivity	• special seal environment required (for prefill method • leak-rate range decreased by long holding time (for prefill method) • vent in package required (for flush method)
Indirect Mode (back pressurization)	10^{-8} to 10^{-2}	• flexibility • inert gas used • wide leak-rate range	• requires gas flow model • requires long pressurization times
RADIOISOTOPE	$\sim 10^{-9}$ to 10^{-2}	In comparison with back pressurization procedure of helium method: • more direct • faster testing rate • package volume does not affect pressurization time or minimum measurable leak rate	• requires gas flow model • requires handling precautions because of radioactivity • measurement range relatively narrow for given test sequence. (To avoid unsafe radioactive levels, test is performed in stages starting with the gross end of the leak-rate range.) .

6. RESOURCE AREAS

6.1 Rome Air Development Center

Clyde Lane
Rome Air Development Center (RBRM)
Griffiss Air Force Base, NY 13441
(315) 330-3473

Activities underway at the Rome Air Development Center (RADC) in which RADC could serve as a resource for the pacemaker and other interested communities are listed below:

- microcircuit contamination control
- desorption isotherms for microelectronic surfaces
- reliability evaluation and electrical characterization of memories
- thermal resistance of microelectronic packages
- quality assurance procedures for complex microcircuits
- hybrid microcircuit prelidding burn-in
- evaluation of mechanical stress limit prediction procedures for large microcircuit packages
- failure-rate models for discrete semiconductors

6.2 Information Resources

Carolyn P. Brown
Library
National Bureau of Standards
Washington, DC 20234
(301) 921-3405

Library and other information sources that may be useful to the cardiac pacemaker community are summarized in Appendix E. The three information sources included in the summary are listed below.

1. Federally Sponsored Sources
    - Regional Medical Library Program
    - National Technical Information Service
    - Defense Documentation Center
2. Non-Profit Sources
    - Coordinator of Service to Business and Industry, Georgia Institute of Technology
    - Illinois Institute of Technology Research Institute
3. Commercial Sources
    - Lockheed Information Retrieval Service
    - System Development Corporation Search Service
    - Institute for Scientific Information

6.3 Semiconductor Technology Program at NBS

Alvin H. Sher
Electronic Technology Division
National Bureau of Standards
Washington, DC 20234
(301) 921-3132

The goals of the Semiconductor Technology Program are to provide Federal agencies, industry, and the general public with methods for assuring the reproducibility, serviceability, and reliability of solid state and other electronic components. The approach is one of developing and disseminating improvements in measurement technology that can be used in specifying materials and devices at the buyer-seller interface, and in controlling device fabrication processes by the industry. Work in the Program is supported jointly with other Government agencies, both civilian and military, that have mutual interests in measurement technology.

The task areas presently underway in the Program are:

- silicon characterization
- oxide characterization
- test patterns
- wafer test
- assembly and packaging
- thermal properties of devices
- photolithography

Of particular interest to the pacemaker community is work in test patterns and in assembly and packaging.

Test patterns are special structures included on silicon wafers used in integrated circuit production. They are powerful measurement tools that can monitor electrically various process parameters and provide a means by which both the manufacturer and user can be assured of manufacturing control. NBS work, headed by Dr. Martin G. Buehler, involves the development, analysis, and cataloging of recommended test structures, and the demonstration of their usefulness.

In the assembly and packaging area are activities in test methods to control and evaluate die attachment, interconnection bonding, and hermetic sealing. Stanley Ruthberg heads the NBS effort in hermeticity testing which was begun in response to industry needs determined through field visits and affirmed later in an NBS workshop on hermeticity. The workshop renewed industry interest in cooperative work on improved test methods now carried on in the ASTM Committee F-1 on Electronics by a section chaired by Ruthberg. NBS efforts in hermeticity are in evaluating and improving the precision, agreement, and applicability of currently employed methods, and in developing wider-range, noncontaminating methods.

The details of these and other activities in the Program are given in progress reports which have been published. Also, about one hundred publications on topics ranging from theoretical solutions of problems to "how-to" manuals for the optimum use of equipment have resulted from work under this Program; a list of these publications is available on request.

Another feature of the Program was the inauguration of a series of workshops on various measurement-related topics of concern to the electronics community. Subjects of the four workshops held to date are listed below with the dates; reports on each have been published.

1. Measurement Problems in Integrated Circuit Processing and Assembly - September 1973.
2. Hermeticity Testing for Integrated Circuits - March 1974.
3. Test Patterns for Integrated Circuits - September 1974.
4. Surface Analysis for Silicon Devices - April 1975.

Work of the Program is worthwhile only if its output is used voluntarily; NBS has no regulatory authority to enforce the use of any measurement technology it develops. The measurement tools developed must stand on their own merits in answering measurement needs in ways that are practical and economically feasible.

To assure use of the Program's outputs requires care in the selection of problems that are of critical importance and whose solutions will have broad and long-range impact. The selection is made with the aid of guidance obtained from extensive and direct contacts with appropriate parts of the semiconductor electronics and other communities.

After a selection is made, progress of work through the research and development stages is reported in publications, at meetings of standards committees, and through other channels to prospective users of the Program's output. Feedback received from these contacts provide guidance in redirecting the work, if necessary, to respond to changing measurement needs and priorities.

If the result of the work is a new or improved measurement method, it is documented and tested in-house first and then in interlaboratory tests through standards groups in cooperation with industry. Ultimately the output is incorporated into a standard test method or published to provide ready reference material, or both. Staff members encourage the implementation of the methods developed through visits and, in some cases, through direct training activities on production lines, as well as through talks, publications, and videotaped presentations.

6.4 Metallurgy at NBS

William Ruff
Metallurgy Division
National Bureau of Standards
Washington, DC 20234
(301) 921-2991

There are two metallurgical studies underway in the NBS Metallurgy Division pertinent to the cardiac pacemaker community. Inquiries for details of these and other studies are invited. One study involves crevice corrosion of metals used in biological implants and the identification of harmful corrosion products. The other study is of the effect of various solutions on titanium alloys in connection with the formation of protective oxide films, the effects of sterilization and surface preparations on this film, and the influence of mechanical wear on the film and its subsequent exposure to saline solutions. Electron microscope and diffraction methods have been employed to characterize such films in these studies.

6.5 Measurements for EMI

John W. Adams
Electromagnetics Division
National Bureau of Standards
Boulder, CO 80302
(303) 499-1000, x3741

There are several difficult measurement problems that must be addressed before effective procedures can be suggested to protect pacemakers against electromagnetic interference (EMI). More study is needed in the measurement of electric and magnetic fields to which the implanted pacemaker is exposed before any standard procedure can be prepared to determine the susceptibility of pacemakers to EMI. Many variables are involved in such measurements, for example, frequency, orientation, polarization, and modulation of the electromagnetic fields. The size, shape, conductivity, permittivity, and orientation of the body to the electromagnetic field are also variables because they affect the coupling of the electromagnetic energy into the body. Furthermore, the conductivity and permittivity is a function of the body tissue. Realistic, upper bounds may be established which can greatly reduce the number of variables that need to be involved and some data to do this are available.[1]

Another measurement problem that needs to be considered is how to simulate the electromagnetic fields and the bodies enclosing the pacemaker. There are

---

[1]C. C. Johnson and A. W. Guy, Nonionizing Electromagnetic Wave Effects in Biological Materials and Systems, Proc. IEEE 60, 692-718 (1972).

procedures for generating test fields over a limited set of conditions, for example, at a few discrete frequencies, or even over a limited bandwidth. But, does such limited testing provide adequate assurance or simply a false sense of security?

Two recently developed devices should be considered for EMI measurements: (1) isotropic broadband probes,[1] useful in determining the maximum value of electric or magnetic fields regardless of frequency or direction of the source; and (2) TEM cells[2] for generating electromagnetic fields. More development of the second is still needed, however, to overcome their present limitations.

7. STANDARDS ORGANIZATIONS

7.1 Association for the Advancement of Medical Instrumentation (AAMI)

Guy S. Hammer, II
AAMI, Suite 602
1901 N. Ft. Myer Drive
Arlington, VA 22209
(703) 525-4890

The Association for the Advancement of Medical Instrumentation (AAMI) is concerned with all medical instruments, devices, and systems, and their applications in the areas of medical research, diagnosis, therapy, and administration. Formed in 1965 to promote the interests and serve the needs of the medical instrumentation field, membership now includes some 3,000 individuals, 200 corporations, and 100 institutional members. One of AAMI's primary coordination efforts is the development and promulgation of medical device standards. Among present efforts relative to cardiac pacemakers are the preparation of a pacemaker standard on labeling and performance requirements and terminology for cardiac pacemakers under contract from FDA, and the administration of the Secretariat of Subcommittee 2 (Cardiovascular), under the ISO Technical Committee 150 on Implants for Surgery, which is also preparing a pacemaker standard.

---

[1] F. M. Greene, Development of Electric and Magnetic Near-Field Probe, NBS Tech. Note 658 (January 1975).

[2] M. L. Crawford, Generation of Standard EM Fields Using TEM Transmission Cells, IEEE Trans. Electromagnetic Compatability EMC-16, 189-195 (November 1974).

7.2 American Society for Testing and Materials (ASTM)

7.2.1 ASTM Committee F-4 on Surgical Implants

Emanuel Horowitz
Institute for Materials Research
National Bureau of Standards
Washington, DC 20234
(301) 921-2878

ASTM Committee F-4 was founded in 1962 to serve as a forum for discussion of problems of surgical implants and for development of consensus standards for use by manufacturers, surgeons, scientists, engineers, and representatives of the public interest.

The formation of this committee was inspired by orthopedic surgeons and early activities concerned mainly metallurgical orthopedic implants. Interests and activities have expanded to include other surgical disciplines such as cardiovascular implants and implants for neurosurgery. In recent years, the scope of the committee's materials work has been enlarged to include polymers, ceramics, and composites; and consideration is being given to an activity devoted to design data, criteria, and guidelines. The entire committee and its subcommittees and task groups meet twice yearly and have produced 36 surgical implant standards.

7.2.2 ASTM Committee F-1 on Electronics

Robert I. Scace
Electronic Technology Division
National Bureau of Standards
Washington, DC 20234
(301) 921-3625

ASTM Committee F-1 on Electronics develops test methods, specifications, recommended practices, and nomenclature for electron devices, with emphasis on the areas of materials, manufacturing process control, and test equipment. Committee F-1 is one of the few standards organizations that require an interlaboratory evaluation of a method before it can be issued as a completed standard. This concept was introduced to prevent the issuance of standard methods that work only in committee.

The subcommittees of Committee F-1 are listed in table 4. Those that should be of greatest potential interest to pacemaker manufacturers are the Hybrid Microelectronics and Assembly Subcommittees which are each divided into three sections as listed. Documents issued by Committee F-1 that may be of interest are listed in table 5. Committee F-1 encourages the participation of the pacemaker community in the activities of the Committee that are of interest to them.

TABLE 4 — SUBCOMMITTEES OF ASTM COMMITTEE F-1 ON ELECTRONICS

Lasers	Hybrid Microelectronics substrates thick films thin films
Metallic Materials	
Semiconductor Crystals	
Semiconductor Process Materials	Assembly encapsulation hermeticity interconnection
Semiconductor Measurements	
Quality and Hardness Assurance	

TABLE 5 — SELECTED DOCUMENTS OF ASTM COMMITTEE F-1 ON ELECTRONICS

HYBRID CIRCUITS

D2442	Alumina Ceramics for Electronic Applications, Spec.
F109	Surface Imperfections on Ceramics, Definitions
F356	Beryllia Ceramics for Electrical Applications, Spec.
F357	Solderability of Thick-Film Conductors
F390	Sheet Resistance of Thin Metallic Films
F394	Modulus of Rupture of Ceramic Substrates
7C07	Adhesion of Thin Metal Films to Substrates
7C09	Glossary of Thin and Thick Film Terms
7B10	Adhesion of Thick Films to Substrates
7A11	Determining Dimensions and Surface Characteristics of Substrates
7C16	Noise Quality of Resistive Films
7B20	Temperature Coefficient of Film Resistors
7B21	Viscosity of Pastes Used in Thick Film Electronics
7B22	Determining Thickness, Area, Texture of Thick Film Components
7B36	Specifying Thick Film Pastes
7C41	Thin Film Adhesion Testing

INTERCONNECTION BONDING

F72	Gold Wire for Lead Bonding, Spec.
3A04	Aluminum Bonding Wire, Spec.
8E04	Aluminum 1% Silicon Wire for Lead Bonding, Spec.
8E28	Glossary, Interconnection Bonding
8E29	Visual Inspection of Lead Bonding Wire
8E30	Pull Strength of Wire Bonds
8E31	Visual Inspection of Bonded Devices
8E33	Strength of Bonded Beam Lead Devices (Pulloff Test)
8E34	Strength of Bonded Beam Leads (Etch & Peel)
8E43	Non-destructive Bond Pull Test

CONTAMINATION CONTROL

F21	Hydrophobic Surface Films by Atomizer Test
F22	Hydrophobic Surface Films by Water-Break Test
F24	Counting Particulate Contamination on Surfaces
F25	Counting Airborne Particulate Contamination in Clean Rooms
F35	Identification of Particle Contaminants by X-Ray Diffraction
F50	Counting and Sizing of Airborne Particles by Light-Scattering
F51	Counting Particulate Contaminants on Clean Room Garments
F52	Silting Index of Processing Fluids
F59	Identification of Metal Particulate Contamination by Ring Oven Technique
F60	Detection of Microbiological Contaminants in Water
F71	Morphological Key Identification of Fibers for Contamination Control
F91	Leaks in Laminar Flow Clean Room Work Station Filters
5F35	Particle Concentration in Liquids, Class. for
5F36	Particle Concentration on Surfaces, Class. for

HERMETICITY

F78	Calibration of Helium Leak Detectors
F79	Hermeticity by Dye Penetration
F98	Hermeticity by Bubble Test
F134	Hermeticity by Helium Mass Spectrometer
8D05	Hermeticity of Electron Devices by Radioisotope Test

ENCAPSULANTS

F74	Hydrolytic Stability of Plastic Encapsulants
F100	Shrinkage Stresses in Plastic Embedment Materials
F135	Embedment Stress Caused by Casting Compounds
8C06	Completeness of Cure of Encapsulants
8C26	Microcircuit Coatings, Evaluating
8C33	Transfer Molding Compounds for Encapsulation

The Committee has three meetings a year during which work is planned, documents are reviewed and revised, and group and individual interactions take place in open, non-proprietary discussions. The membership includes some 230 individuals from over 100 companies, government agencies, universities, and other organizations.

7.3 International Society for Hybrid Microelectronics (ISHM)

Daniel D. Zimmerman
Johns Hopkins University
Applied Physics Laboratory
Laurel, MD 20810
(301) 953-7100, x2609

The International Society for Hybrid Microelectronics (ISHM) is a non-profit technical organization devoted to the advancement of hybrid microelectronics and the dissemination of knowledge in this field. Founded and incorporated in 1967 to provide a focus and common denominator for the diverse technical disciplines on which hybrid microelectronics is based, it now has more than two dozen chapters in the United States and six international affiliate chapters in Europe and Japan, having a total membership of about 2600. Its efforts in standards began with the creation of a committee on standards in 1972 whose efforts have resulted in the document Hybrid Microelectronics Standard Specification Guidelines. For the future, ISHM plans to conduct seminars on the use of this document, and plans to publish a Design Guideline for Hybrid Microelectronics, an annual business and market report, and a hybrid microcircuit reliability report.

Acknowledgement

Thanks go to the speakers for their full cooperation in the preparation of this report by readily providing me with the written materials, on which this report is based, and reviewing their edited sections. Special thanks go to E. Jane Walters for preparing the camera-copy draft of the report with care and dispatch.

Appendix A

Workshop Program

—— Monday, July 28 ——

WELCOMING REMARKS

F. Karl Willenbrock, Director, Institute for Applied Technology, National Bureau of Standards, Washington, DC 20234

INTRODUCTION TO WORKSHOP

Measurement Technology and the Pacemaker Community - Some Observations
Harry A. Schafft, National Bureau of Standards, Washington, DC 20234; (301) 921-3625

SESSION I: ELECTRONIC RELIABILITY
Chairperson: George G. Harman, National Bureau of Standards

Presentations

Reliability Data Banks and Services
Harold Lauffenburger, Reliability Analysis Center, RADC/RBRAC, Griffiss Air Force Base, NY 13441; (315) 330-4151

A System to Obtain and Assure Reliable Semiconductor Products for DoD and NASA
Clyde Lane, Rome Air Development Center (RBRM), Griffiss Air Force Base. NY 13441; (315) 330-3473

Hybrid Processing - General Areas
Robert A. Lowry, Jr., Micro-Rel, Inc., Tempe, AZ 85281; (602) 968-6411

Test and Procurement of High Reliability Parts
Robert Fischer,[1] Continental Testing Labs, Fern Park, FL 32731

Test and Procurement of High Reliability MOS Devices
John Heightley, Sandia Labs, Albuquerque, NM 87115; (505) 264-6303

Design and Development of High Reliability Hybrid Microelectronics for ERDA Applications
Charles Tapp, Sandia Labs, Albuquerque, NM 87115; (505) 264-3751

ISHM Standards for Hybrid Microelectronics
Daniel D. Zimmerman, Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20810; (301) 953-7100 x2609

Destructive Physical Analysis and Failure Analysis for High Reliability
John Devaney, Hi-Rel Labs, San Marino, CA 91108; (213) 357-6083

Panel and Open Discussions

Topic: *How to obtain reliable electronic parts and how to substantiate their long-term reliability?*

ADJOURN

---

[1]Now with Custom Devices, 4246 E. Wood Street, Phoenix AZ 85040; (602) 268-1371

SESSION II: HERMETICITY
Chairperson: W. Murray Bullis, National Bureau of Standards

Presentations

Moisture Myths and Microcircuits
Robert W. Thomas, Rome Air Development Center (RBRM), Griffiss Air Force Base, NY 13341; (315) 330-4632

Effectiveness of Commonly Used Hermeticity Test Methods
Ralph E. McCullough, Texas Instruments, Inc., Box 5012, Dallas, TX 75222; (214) 238-3931

Guidelines for Hermeticity Testing of Pacemakers
Stanley Ruthberg, National Bureau of Standards, Washington, DC 20234; (301) 921-3621

Discussion Period

SESSION III: RESOURCE AREAS
Chairperson: Harry A. Schafft, National Bureau of Standards

Presentations

Activities at the Rome Air Development Center
Clyde Lane, Rome Air Development Center (RBRM), Griffiss Air Force Base, NY 13441; (315) 330-3473

Information Resources
Carolyn P. Brown, National Bureau of Standards, Washington, DC 20234; (301) 921-3405

The Semiconductor Technology Program at NBS
Alvin H. Sher, National Bureau of Standards, Washington, DC 20234; (301) 921-3132

Efforts in Metallurgy at NBS
William Ruff, National Bureau of Standards, Washington, DC 20234; (301) 921-2991

Measurements Needed to Determine Pacemaker's Susceptibility to EMI
John W. Adams, National Bureau of Standards, Boulder, CO 80302; (303) 499-1000 x3741

SESSION IV: STANDARDS
Chairperson: Judson C. French, National Bureau of Standards

Overview of Organizations and Activities

Association for the Advancement of Medical Instrumentation (AAMI)
Guy S. Hammer, II, AAMI, Suite 602, 1901 N. Ft. Myer Drive, Arlington, VA 22209; (703) 525-4890

American Society for Testing and Materials (ASTM)
Committee F-4 on Surgical Implants
Emanuel Horowitz, National Bureau of Standards, Washington, DC 20234; (301) 921-2878

Committee F-1 on Electronics
Robert Scace, National Bureau of Standards, Washington, DC 20234; (301) 921-3625

International Society for Hybrid Microelectronics (ISHM)
Daniel D. Zimmerman, Johns Hopkins University, Applied Physics Laboratory,
Laurel, MD 20810; (301) 953-7100, x2609

SESSION V: LOOKING AHEAD
Chairperson: Harry A. Schafft, National Bureau of Standards

Open Discussion

ADJOURN

Appendix B

Measurement Technology and the Pacemaker Community — Some Observations

Harry A. Schafft
Electronic Technology Division
National Bureau of Standards
Washington, DC 20234
(301) 921-3625

The observations to follow on the technical areas of interest to the cardiac pacemaker community are based on visits between May and July, 1975, to most of the domestic manufacturers of cardiac pacemakers; and to a number of pacemaker hospital centers, hybrid device manufacturers, and testing houses. Visits were made to 15 organizations in all which involved about 11 days of interviews and tour time. The inputs were used as a guide to select topics to be addressed at the workshop, consistent with NBS's abilities to respond.

With that preface, what are the areas of interest to the pacemaker community? The list shown in table B1 is believed to contain all of the important ones. The listing is not meant to show an order of importance because no objective measures were available to assign degrees of importance. Before examining these areas a little closer, it should be pointed out that all of these areas, except perhaps for the last one, have a unifying element — measurement technology. In each area the problem or interest arises out of a deficiency in the associated measurement technology. This will be seen as the items in the list are reviewed.

For electronics, the questions of how to best obtain high reliability parts and how to make sure that they are, in fact, reliable to the degree desired consistently received the greatest interest.

Under the heading of high reliability of parts, the interest is in which fabrication processes are best, what should be specified in the fabrication and assembly stages of the part, and what should be included in the purchase specifications for the part. Some suggested that there should be a medical-grade set of specifications and processes for electronic parts used in pacemakers.

Table B1. AREAS OF INTEREST AND CONCERN

- Electronics
- Hermeticity
- Weld Inspection
- EMI
- Leads
- Materials
- Sterilization
- Power Sources
- Acceleration Tests
- Standardization
- Information and Service Resources

To substantiate reliability there is interest in such topics as reliability prediction, accelerated tests, screen tests, burn-in tests, and long-term wearout modes.

The problem of obtaining and assuring high reliability parts takes an added dimension as longer-lived batteries are introduced. Pacemakers will no longer be expected to operate for only a couple of years. The expectation is that the new power sources will allow pacemakers to operate 5, 10, or more years. With this extended time frame the problem of obtaining and assuring reliability is one for which people only have approaches to a solution.

With the push to longer-lived pacemakers there is a need to reduce power consumption and to reduce size and weight. For the electronics, this means greater interest in increased integration and in the use of newer and more sophisticated technologies. Hence, there is a general interest in evaluating and comparing discrete devices, integrated circuits, and hybrid devices; and in comparing different processes such as bipolar, CMOS, and even I^2L. Those who are using such technologies as CMOS, for example, are concerned about doing all things necessary to assure that they will continue to have a reliable product. Those who are considering using a new technology are wondering about the kinds of problems they may encounter.

There is also a good deal of interest in comparing the reliability of pacemaker electronic systems with high reliability systems of DoD and NASA. The feeling is that pacemaker reliability would compare favorably. Unfortunately, failure rate data for pacemaker electronic circuits are not readily available. Failure rate data need to be compared for circuits of comparable size and complexity.

In the area of hermeticity testing there is a general interest in the capabilities and limitations of the various methods used. There is considerable interest in determining if the test conditions used in the helium leak testers are adequate for the leak-rate levels desired. Also, there is much interest in determining the maximum acceptable leak rates for electronic parts and pacemakers, and how much internal moisture can be tolerated.

Related to interest in hermeticity tests is the interest in weld inspection technologies for pacemakers where nondestructive methods are desired.

The next area, electromagnetic interference or EMI is one where inputs range from "it is not a significant problem", to "the problem is overplayed and needs to be put in perspective", to "it is a problem of real concern and efforts in standardization and education are needed". Those who saw it as a problem said both that the electromagnetic environment is ill-defined, varied, and is at high levels which are expected to increase and that the proliferation of tests and test conditions make it difficult to compare and evaluate different pacemakers and pacemaker designs.

Areas of interest that were suggested for discussion for EMI are the characterization of the electromagnetic environment pertinent to pacemakers and the extent to which this environment can be controlled or modified to reduce EMI, standard test procedures and conditions for determining the susceptibility of pacemakers to interference, and design and material factors for reducing this susceptibility.

The electrical lead that carries electrical pulses between the heart and the pacemaker is another subject that received a varied response. It ranged from "it is no problem at all", to "it is a potential problem for longer-lived pacemakers to come", to "it is a problem of great concern". The last response came mostly from the physicians who were interviewed. Perhaps this is because the physicians have to deal with the lead problems and see it first hand. Manufacturers implicitly recognize that there is a problem with leads because while they guarantee their pacemakers, most do not guarantee their leads.

The manufacturers are made to be more remote from the problem because very few if any leads are returned to the manufacturers. Understandably, it is usually inconvenient and difficult to remove most leads. Nevertheless, this situation handicaps the manufacturer in being able to evaluate his lead's performance in the field and to obtain valuable input on lead life and lead failure mechanisms and modes. Perhaps there is a need here for better communication between physicians and manufacturers.

Specifically, problems with leads are fracture failure — adjacent to the connection to the pacemaker, at loops in the lead, and (curiously enough) at stress-relief suture sites. Fractures have been seen to occur at inclusion and tool-work sites in the wire. Another problem is corrosion at the connection to the pacemaker resulting from body-fluid seepage to the metal-metal connection. Again, the interest is in test methods, methods to determine, in a reasonable time, the quality or life of leads. So there is interest in accelerated tests. There do not appear to be any standard accelerated or stress tests for leads that are being used in the industry. Also, there is interest in methods to determine fatigue and life-span information about materials for leads.

The subject of leads is a complex one, one which may better be addressed in a later workshop. In the meantime, one possible avenue to explore is offered. This involves the use of acoustic emission techniques to monitor the approach of fracture in metals.[1] Studies have shown that as a metal is stressed,

[1]Acoustic emission work at NBS has been done by Dr. Melvin Linzer, NBS, Materials Building, Room A 367, Washington, DC 20234. Telephone (301) 921-2858.

it will emit acoustic noise bursts at a rate which increases as fatigue fracture of the metal is approached.[1] These studies have been made on metals different from those now used in pacemaker leads and on specimens considerably larger than the wire used in leads. However, if these results can be extrapolated to leads, it may be possible to monitor the approach to fracture failure, which could be useful in developing and using accelerated stress tests for leads, and it may be possible to anticipate fatigue fracture of the implanted lead.

There is general interest in material-related subjects, such as the corrosion of metals, lead wire, and connectors when exposed to body fluids. There is interest in the biocompatability of various sealants, and the bonding of epoxies and plastics to metals. Also, there is interest in means for evaluating epoxies, rubbers, and plastics. Such broad interests could not be responded to in this workshop except to have Dr. William Ruff describe some of the metallurgy work being done at NBS that is relevant to some of these topics.

Another area that was mentioned by some was the need for better methods to evaluate and qualify sterilization procedures. This is an area far removed from NBS expertise and should possibly be addressed elsewhere.

The subject of power sources came up repeatedly. When it was suggested that the pacemaker industry was probably as much aware as any group of the state-of-art technology of power sources, especially for long-term, very low power-load applications, the response was that the real need in the industry is for better tests and procedures for qualifying and comparing batteries, and for substantiating life and reliability. What is needed are effective accelerated tests that can be used to test their batteries in a time short compared with the expected life. Interviewees suggested that perhaps NASA had experience in battery testing that they could share. The Space Power Technology Branch at NASA Goddard Space Flight Center reports, however, that their work is solely in batteries used in space craft that can be recharged many times and are intended for much higher power levels than are of interest to the pacemaker people.

The subject of accelerated tests brought a gleam in the eyes when discussed. There is an interest in accelerated tests for entire pacemakers, for leads, for the electronics, for devices, batteries, and materials. The need for these accelerated tests is to qualify products, compare products, assure quality control, substantiate reliability. These are subjects for many workshops, not just one.

Standards is another subject of considerable interest which is heightened by the industry's vulnerability to liability suits. With a multiplicity of test methods, procedures, and processes, and with few clearly established standards,

[1] D. O. Harris and H. L. Dunegan, Continuous Monitoring of Fatigue Crack Growth by Acoustic Emission Techniques, Technical Report DE-73-2 (February 1973), Dunegan/Endevco, Livermore, CA.

there is concern that it may be difficult to substantiate in court that all due precautions and the best procedures and tests were used to produce the product which may, nevertheless, have not performed to expectations.

Finally, there is the matter of information and service resources which generated significant interest. There is great interest in reliability data and other information banks for electronic components. How do different device and circuit types and different technologies fare with time? Are there certain product lots that have developed problems?

Appendix C

Reliability Data Banks and Services

Harold A. Lauffenburger
IIT Research Institute
Reliability Analysis Center
RADC/RBRAC, Griffiss AFB, NY 13441
(315) 330-4151

1. Government Industry Data Exchange Program (GIDEP)

GIDEP is a program that is both funded and operated by the federal government. The program is directed to the acquisition, storage, retrieval, and dissemination of reliability test and usage information on parts and components, test equipment calibration procedures, and other reliability data obtained in the development, test, and field operation of weapon and aerospace systems, and such other equipment and systems as are of interest to GIDEP participating agencies. This information includes, but is not limited to, the results of controlled tests conducted and calibration procedures developed by contractors, subcontractors, and government activities engaged in the design, development, production, and support of equipment for the government. Primary emphasis is placed on the results of user tests rather than vendor tests. Government specifications, contractor proprietary information, and classified information is not within the scope of this program.

The data in the GIDEP System is readily accessible to participants through either remote terminals or 16mm microfilm with computer indexes. Data is stored in one of four data banks. These are the Engineering Data Bank, the Metrology Data Bank, the Failure Rate Data Bank, and the Failure Experience Data Bank. These data banks are supplemented by (1) an Urgent Data Request System which allows the participant to rapidly query all other GIDEP participants on his specific problems, and (2) the GIDEP ALERT System which provides information to participants on potential problem areas that may be encountered during engineering design and production of parts, materials, processes, or safety practices.

Participation in the GIDEP Program is open to government agencies, their contractors, commercial device producers, and equipment producers. While there are no direct charges for participants, all are required to submit data generated within their own organization.

Additional information may be obtained from the GIDEP Program Operations Center at:

Fleet Missile Systems Analysis and
Evaluation Group Annex; Code 862
Attn: GIDEP Operations Center
Naval Weapons Station, Seal Beach
Corona, CA 91720
(714) 736-4677 or Autovon 933-4677

2. Reliability Analysis Center (RAC)

RAC collects and maintains a comprehensive accumulation of information pertinent to the reliability of microelectronic and high-technology discrete devices, primarily. This information represents the combined experiences of hundreds of government, industrial, and independent organizations which have been systematically and aggressively solicited by RAC. Data acquisition is enhanced and extended through direct and continuous interaction with the reliability staff of the Rome Air Development Center.

RAC makes available this information by various means: (1) Reliability Data Compendia where validated failure rates and histories of environmental susceptibility and malfunctions are provided and regularly updated, (2) Reference Bibliographies of the current technical literature, (3) survey study reports, (4) quarterly issues of the RAC Newsletter, and (5) direct consulting assistance in such areas as reliability assessment and prediction, survey studies, data analysis, part selection and applications, and system reliability and maintenance support.

Detailed information on the publications and services available from RAC may be obtained by communicating with Harold A. Lauffenburger.

Appendix D

Brief Description of Hermeticity Test Methods[1]

Bubble Method: The package is immersed in a heated fluid, usually a fluorocarbon, and a visual inspection is made. A leak is indicated by the emanation of bubbles from the package as the interior gas expands and escapes through the leak.

Pressure-Bubble Method: The package is immersed first in a relatively low boiling-point fluid under pressure and then in a heated fluid where a visual inspection is made. A leak is indicated by the emanation of bubbles from the package due to the escape of the low boiling-point fluid forced into the package during the first immersion.

Weight Gain Method: The package is weighed before and after immersion in a liquid under pressure to force the liquid into the package cavity. A leak, whose magnitude may be calculated, is indicated if after the package is removed from the liquid and dried a gain in weight is measured.

Differential Pressure Method (for large-volume packages): The package is placed in a test chamber which is then evacuated. A source chamber at known internal gas pressure is connected to the test chamber by opening an access valve. A gross leak is indicated if the pressure in the combined volume is lower than expected, for the volumes of the package and of the source and test chambers. If a gross leak is not indicated, a smaller leak rate may be detected by opening a valve between the test chamber and a reference chamber until an equilibrium pressure is reached, after which the valve is closed. A growing differential pressure between the two chambers indicates a smaller leak in the package, the magnitude of which may be calculated.

Helium Leak Detector Method (Indirect Mode): The package is held under pressure in a helium atmosphere for a period of time to force helium into the package cavity through any leak channels that may exist. After pressurization, a measured leak rate is determined by measuring, with a mass spectrometer, the quantity of helium escaping from the package.

Helium Leak Detector Method (Direct Mode):

Prefill Procedure: The package is sealed in a helium atmosphere. A measured leak rate is determined by measuring the quantity of helium escaping from the package.

Flush Procedure: The procedure requires that a vent be part of the package which can be connected directly to a mass spectrometer

[1]mentioned in the report.

to detect the penetration of any helium that is used to flush the outside of the package. The integrity of the seal off of the vent may be tested in a number of ways. One way is first to fill the package with helium and then seal off the vent while it faces downward (to keep the helium in the package, by buoyancy), and test in the same way as in the prefill procedure.

Radioisotope Method: The package is held under pressure in an atmosphere of the radioisotope isotope krypton-85. After pressurization, a measured leak rate is determined by measuring, with a scintillation crystal, the amount of the radioactive gas that is inside the package.

Appendix E

Information Resources

Carolyn P. Brown
Library
National Bureau of Standards
Washington, DC 20234
(301) 921-3405

1. Federally Sponsored Information Sources

The National Library of Medicine[1] administers a Regional Medical Library Program in which the country is divided into 11 regions with one library designated as the central resource library for the region. Radiating from these 11 libraries are many others which are Medline centers, where the on-line system, Medline, is available. Medline is the name of a data base composed of citations from the most important biomedical journals, some 3000 in number, going back several years. Some of these centers provide Medline service free to authorized users; most charge a fee to outsiders. Priority of use is given to those in the health care and medical research fields, but the pacemaker community should come somewhere next in line. Call the local hospital library or medical school or the Regional Medical Library to find the name of the nearest Medline center that will serve you. Regional medical centers in the areas of the pacemaker manufacturers are listed in table E1.

TABLE E1

REGIONAL MEDICAL LIBRARIES[2]

NEW ENGLAND REGION (CT, ME, MA, NY, RI, VT)
Francis A. Countway Library of Medicine
10 Shattuck Street, Boston, MA 02115

SOUTHEASTERN REGION (AL, FL, GA, MS, SC, TN, PR)
A. W. Calhoun Medical Library
Emory University, Atlanta, GA 30322

NEW YORK AND NORTHERN NEW JERSEY REGION (NY and the 11 northern counties of NJ)
New York Academy of Medicine Library
2 East 103 Street, New York, NY 10029

MIDWEST REGION (IL, IN, IA, MN, ND, WI)
John Crerar Library
34 West 33 Street, Chicago, IL 60616

PACIFIC SOUTHWEST REGION (AZ, CA, HI, NV)
Center for the Health Sciences
University of California
Los Angeles, CA 90024

[2]Serving areas where most cardiac pacemaker manufacturers are located.

---

[1]The National Library of Medicine, 8600 Rockville Pike, Bethesda, MD 20014. Telephone: (301) 656-4000.

The National Technical Information Service[1] (NTIS) is a part of the Department of Commerce and is charged with the handling of technical information produced by Federal agencies and Federal contractors and grantees. It stores and makes available, in paper copy or microfiche, reports in many subject areas.

Reports filed by NTIS are listed in an abstracting journal, the Government Reports Announcements and its index, the Government Reports Index. From these are selected 24 subject categories to appear as weekly newsletters, the Weekly Government Abstracts; annual subscriptions may be ordered. Subscriptions to Selected Categories in Microfiche may also be ordered so that the full publication, on microfiche, of reports in a subject field selected may be received.

In addition, NTIS will do custom searches of its files on request and has some Published Searches in anticipation of requests. The reports in these searches may then be ordered from NTIS. Paper copy prices are according to the number of pages. The basic price for all titles in microfiche is $2.25, with a few exceptions.

The Defense Documentation Center (DDC) services are extended to all Federal Government agencies and their contractors, subcontractors, and grantees. DDC reports that are not classified become available to the public through NTIS. There is a possibility for organizations without current Defense Department contracts to be declared eligible for services under the Defense Potential Contractors Program. This requires that some Defense Department agency make a request that the organization be listed as a potential contractor.

2. Non-Profit Information Sources

Two examples are given of the kind of services that may be found locally. Both of these institutions, which are non-profit, are willing to accept assignments from anywhere.

The coordinator of Service to Business and Industry,[2] Georgia Institute of Technology, is connected to a large technical library of some 750,000 volumes and 600,000 technical reports, and to a computer search center. A literature search service (manual or computerized, as needed) is offered at a fee of $15.00 an hour plus charges for computer time and other actual costs. Reference assistance is offered free, by telephone, as long as it does not take more than about 15 minutes.[3] Interlibrary loans can be arranged and a photocopy service is available at a handling fee of $2.50 plus 10 cents a page. Personnel

---

[1]National Technical Information Service, U. S. Department of Commerce, Springfield, VA 22161. Telephone: (703) 321-8543.

[2]Coordinator of Service to Business and Industry, Library, Georgia Institute of Technology, Atlanta, GA 30332. Telephone: (404) 894-4526.

[3]Call James B. Dodd.

training in elementary information retrieval can be arranged and some published technical material for this work is available.

The Illinois Institute of Technology Research Institute[1] (IITRI) offers some of the same services and some different ones. It offers on-line literature searches at a price based on the number of terms entered, and batch retrospective searches with the same kind of costs attached. It offers document delivery, but only of material available through the Institute of Scientific Information to be mentioned later. An alerting service on a recurring basis can be arranged. A weekly service for individual profiles is $125 or more, a year. The group rate for seven or more requestors of the same topic is about $50 per year, each. The Institute also provides the service of searching private data bases.

In any search for information, the local public library should not be forgotten. Some libraries, especially the larger ones, have excellent programs for supplying many kinds of information. Many states have a central resource center. For example, the Pennsylvania State Library System has an information service for small businesses that is run through the Carnegie Library of Pittsburgh.

3. Commercial Information Sources

Two major suppliers of on-line access to a number of data bases are the Lockheed Information Retrieval Service[2] and the System Development Corporation Search Service.[3] The information in these data bases range from chemical data to up-to-date business and manufacturing statistics.

Generally, it is advisable to use the expertise of a service organization or a library to perform searches. Effective personal use of the data bases requires a significant investment in time. While it is not difficult to learn to use these systems, they are sufficiently complicated and change often enough to require considerable training and continuous practice to acquire and maintain adequate skill. In addition to personal time, minimum costs for access to these data bases are approximately $1200 a year for terminal rental, and from $50 to $150 a month for computer connect time and line charges, depending on location and rate of use.

---

[1]Illinois Institute of Technology Research Institute, Computer Search Center, 10 West 35 St., Chicago, IL 60616. Telephone: (312) 225-9630.

[2]Lockheed Missiles and Space Company, Information Retrieval Service, 3251 Hanover St., Palo Alto, CA 94304. Telephone: (415) 493-4411.

[3]System Development Corporation, Search Service, 2500 Colorado Avenue, Santa Monica, CA 90406. Telephone: (213) 829-7511.

The Institute for Scientific Information[1] (ISA) has an agreement with publishers of scientific journals whereby the contents pages of journals are sent to ISA before publication. These contents pages are then published in one of several weeklies called Current Contents - Life Sciences, Current Contents - Physical and Chemical Sciences, etc. Subscription rates are dependent on the subject field and the number of copies ordered. An individual subscription will cost from about $100 to $150 a year. Original Article Tear Sheet (OATS) is a service by which ISA will supply any of the articles it cites. The price depends on the number of pages (about 30 cents a page).

The Automatic Subject Citation alert (ASCA) is a subject profile drawn up individually from Current Contents. ASCA Topics are regularly-run profiles. An individual ASCA subscription may cost as little as $115 a year. Citation alerts may be ordered by author or combination of authors, organization name, journal, or articles citing a particular earlier work or author, as well as by subject terms.

---

[1]Institute for Scientific Information, 325 Chestnut Street, Philadelphia, PA 19106. Telephone: (215) 923-3300.

Appendix F

Companies Offering Services in the Microelectronic Field

(Partial List)[1]

IC Package Assembly

AMKOR Electronics, Inc.
P. O. Box 801
Valley Forge, PA 19482
Tel: 215-666-9040

Barry & Associates, Inc.
745 Distel Drive
Los Altos, CA 94022
Attn: Garry Barry
Tel: 415-968-0688
TWX: 910-370-6574

Howard Boysen
8945 Complex Drive
San Diego, CA 92123
Tel: 714-279-0961

Cal-Tex Semiconductor, Inc.
P. O. Box 2808
Santa Clara, CA 95051
Tel: 408-247-7660

Caribbean Electronic Services
P. O. Box 878
Adelphi, MD 20783
Attn: Douglas R. Price
Tel: 301-439-8890

Carter Semiconductor, Inc.
Bay View, Amityville
Long Island, NY 11701
Tel: 516-842-5660

Custom Devices
4246 E. Wood Street
Phoenix, AZ 85040
Tel: 602-268-1371

Dana Laboratories, Inc.
2401 Campus Drive
Irvine, CA 92664
Tel: 714-833-1234

ELE Corporation
535 S. Magnolia Avenue
Ontario, CA 91761
Tel: 415-984-5919

Electronic Arrays
55 Middlefield Road
Mountain View, CA 94043
Tel: 415-964-4321

Interlek
400 El Camino Road
P. O. Box 332
San Mateo, CA 94401
Tel: 415-348-8222

Komy Corporation
1199 Worcester Road
Natick, MA 01760

Microcircuits Eximport Services
3080 Olcoff Street Suite 101D
Santa Clara, CA 90505
Attn: R. Vincent Bert
Tel: 408-246-0896

Ness International Corp.
196 Tuscaloosa Avenue
Atherton, CA 94025
Tel: 415-323-4681

Pacific Trading Co.
2390 Walsh Avenue
Santa Clara, CA 95050
TWX: 910-338-0123

Pantronix, Inc.
2396 Walsh Avenue
Santa Clara, CA 95050
Attn: Stanley Wong
Tel: 408-248-5646

Semiconductor Services, Inc. (SSI)
One Harrison Avenue
Salem, MA 01970
Tel: 617-745-2450

Unicorp
625 N. Pastoria Avenue
Sunnyvale, CA 94086
Tel: 408-738-1700

IC Testing

American Electronic Labs, Inc.
M/S 1377, P. O. Box 552
Lansdale, PA 19446
Tel: 215-822-2929

Approved Engineering Test Laboratories
15037 Ventura Blvd.
Sherman Oaks, CA 91403
Tel: 213-783-5985
213-872-3701

Associated Testing Labs
Wayne, NJ
Contact:
Engineering Sales Assoc.
P. O. Box 544
Scottsdale, AZ 85252
Tel: 602-945-5781

California Test Labs Div. AETL
619 East Washington Blvd.
Los Angeles, CA 90015
Tel: 213-747-4235

Continental Testing Labs, Inc.
763 U.S. Highway 17-92
Fern Park, FL 32730
Tel: 305-831-2700

DCA Reliability Lab, Inc.
645 Clyde Avenue
Mountain View, CA 94040
Tel: 415-964-9700

---

[1]Most of the entries were provided by Integrated Circuit Engineering. No attempt was made to make the listing complete. The inclusion of an organization in this list does not imply recommendation or endorsement by the National Bureau of Standards.

Data Test Service, Inc.
822 Challenge Drive
Concord, CA 94520
Tel: 415-825-9322

Electro Fab
P. O. Box 2111
537 S. Raymond Avenue
Pasadena, CA 91105
Tel: 213-795-5613

Electronic Test Center
2031 E. Cerritos Avenue
Anaheim, CA 92806
Tel: 714-774-4820

Electronic Test Center
69 Hickory Drive
Waltham, MA 02154
Tel: 617-890-1340

GCA Technology Division
GCA Corporation
Bedford, MA 01730
Tel: 617-275-9000

Integrated Circuit Engineering (ICE), Suite 211
6710 E. Camelback Road
Scottsdale, AZ 85251
Tel: 602-945-4564

Lithic Systems, Inc.
P. O. Box 869
10010 Imperial Avenue
Cupertino, CA 95014
Tel: 408-257-2004

Microelectronic Evaluation Center, Inc.
1735 Kaiser Avenue
Irvine Industrial Complex
Santa Ana, CA 92705
Tel: 714-546-5551

Microelectronic Testing Laboratories
Division of Datatron, Inc.
17312 Gillette Avenue
Santa Ana, CA 92705
Tel: 714-546-5551

Semiconductor Services, Inc. (SSI)
One Harrison Avenue
Salem, MA 01970
Tel: 617-745-2450

Scanning Electron Analysis Laboratories, Inc.
5301 Beethoven Street
Los Angeles, CA 90066
Tel: 213-398-2720

Trio-Tech, Inc. of California
100 Fountain Street
Framingham, MA 01701
Tel: 617-879-8520

Analytic Services

Alpha Analytical Labs.
(Div. of Alpha Metals)
Jersey City, NJ 07304
Tel: 201-434-6778

Applied Space Products
825 San Antonio Road
Palo Alto, CA 94303
Tel: 415-326-7425

Commonwealth Scientific Corp.
500 Pendleton Street
Alexandria, VA 22314
Tel: 703-548-0800

Continental Testing Labs, Inc.
763 U.S. Highway 17-92
Fern Park, FL 32730
Tel: 305-831-2700

GCA Technology Division
Bedford, MA 01730
Tel: 617-275-9000

Hi Rel Laboratories
2116 Huntington Drive
San Marino, CA 91108
Tel: 213-289-3818

Integrated Circuit Engineering (ICE), Suite 211
6710 E. Camelback Road
Scottsdale, AZ 85251
Tel: 602-945-4564

Interpretive Analytical Services, Building 574
Dow Chemical USA
Midland, MI 48646
Tel: 517-636-5314

Walter C. McCrone Associates, Inc.
439 East 31st Street
Chicago, IL 60616
Tel: 312-842-7100

Microanalysis Laboratory
15825 Shady Grove Road
Rockville, MD 20850
Tel: 301-948-7480

Scanning Electron Analysis Laboratories, Inc.
5301 Beethoven Street
Los Angeles, CA 90066
Tel: 213-398-2720

SEM-Tec
P. O. Box 492
Tempe, AZ 85251

Structure Probe, Inc.
230 Forrest Street
Metuchen, NJ 08840
Tel: 201-549-9350

Uthe Technology International
325 N. Mathilda Avenue
Sunnyvale, CA 94086
Tel: 408-738-3301

BS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS SP 400-28	2. Gov't Accession No.	3. Recipient's Accession No.

TITLE AND SUBTITLE	
Semiconductor Measurement Technology NBS/FDA Workshop Reliability Technology for Cardiac Pacemakers	5. Publication Date June 1976 6. Performing Organization Code
AUTHOR(S) Harry A. Schafft, Editor	8. Performing Organ. Report No.
PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234	10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address (*Street, City, State, ZIP*) National Bureau of Standards, Washington, DC 20234 Food and Drug Administration, Bureau of Medical Devices and Diagnostic Products, Silver Spring, MD 20910	13. Type of Report & Period Covered 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

Library of Congress Catalog Card Number: 76-600030

16. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.*)

Brief summaries are presented of 20 invited talks on the following topics: procurement and assurance of reliable, long lived semiconductor electronic parts; leak testing of device packages and pacemaker systems; activities of standardization organizations; and availability and use of resources for information and expertise. The purpose of the workshop was to address technical questions relevant to the enhancement and assurance of cardiac pacemaker reliability, and to bring together representatives from the pacemaker, military, aerospace, and other communities to discuss areas of mutual concern. The technical sessions highlighted the problems of pacemaker manufacturers associated with obtaining high reliability electronic components - problems shared with the most demanding users in the military and space communities. It was also noted that no government agency has the authority or responsibility for the development of methods to permit assured procurement of high quality electronic components for critical applications by organizations in the civilian sector. These organizations must rely on spin-off from military and space programs even when parts of this civilian sector have reliability requirements which are more severe than all but the most stringent military and space requirements. Included in appendices are measurement technology areas of concern identified by the pacemaker community; information about utilizing reliability data banks and facilities for searching literature and data; and organizations offering services in the microelectronics field.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*) Cardiac pacemaker; data banks; failure analysis; failure modes; hermeticity; hybrid devices; leak testing; measurement technology; microelectronics; MOS devices; process control; reliability; semiconductor devices; surgical implants.

18. AVAILABILITY [X] Unlimited	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[ ] For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	49
[X] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13.10:400-28	20. SECURITY CLASS (THIS PAGE)	22. Price $1.25
[ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED	

USCOMM-DC 29042-P74

U.S. GOVERNMENT PRINTING OFFICE: 1976 210-801/280 1-3

Announcement of New Publications on
Semiconductor Measurement Technology

Superintendent of Documents,
Government Printing Office,
Washington, D.C. 20402

Dear Sir:

Please add my name to the announcement list of new publications to be issued in the series: National Bureau of Standards Special Publication 400–.

Name ____________________

Company ____________________

Address ____________________

City ____________ State ____________ Zip Code ________

(Notification Key N-413)

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH reports National Bureau of Standards research and development in physics, mathematics, and chemistry. It is published in two sections, available separately:

- **Physics and Chemistry (Section A)**

Papers of interest primarily to scientists working in these fields. This section covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year. Annual subscription: Domestic, $17.00; Foreign, $21.25.

- **Mathematical Sciences (Section B)**

Studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programming of computers and computer systems. Short numerical tables. Issued quarterly. Annual subscription: Domestic, $9.00; Foreign, $11.25.

DIMENSIONS/NBS (formerly Technical News Bulletin)—This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS. The magazine highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, it reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing.

Annual subscription: Domestic, $9.45; Foreign, $11.85.

NONPERIODICALS

Monographs—Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a world-wide program coordinated by NBS. Program under authority of National Standard Data Act (Public Law 90-396).

NOTE: At present the principal publication outlet for these data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St. N. W., Wash. D. C. 20056.

Building Science Series—Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The purpose of the standards is to establish nationally recognized requirements for products, and to provide all concerned interests with a basis for common understanding of the characteristics of the products. NBS administers this program as a supplement to the activities of the private sector standardizing organizations.

Federal Information Processing Standards Publications (FIPS PUBS)—Publications in this series collectively constitute the Federal Information Processing Standards Register. Register serves as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations).

Consumer Information Series—Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

NBS Interagency Reports (NBSIR)—A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution is by the National Technical Information Service (Springfield, Va. 22161) in paper copy or microfiche form.

Order NBS publications (except NBSIR's and Bibliographic Subscription Services) from: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

BIBLIOGRAPHIC SUBSCRIPTION SERVICES

The following current-awareness and literature-survey bibliographies are issued periodically by the Bureau:
Cryogenic Data Center Current Awareness Service

A literature survey issued biweekly. Annual subscription: Domestic, $20.00; foreign, $25.00.

Liquefied Natural Gas. A literature survey issued quarterly. Annual subscription: $20.00.

Superconducting Devices and Materials. A literature survey issued quarterly. Annual subscription: $20.00. Send subscription orders and remittances for the preceding bibliographic services to National Bureau of Standards, Cryogenic Data Center (275.02) Boulder, Colorado 80302.

Electromagnetic Metrology Current Awareness Service Issued monthly. Annual subscription: $24.00. Send subscription order and remittance to Electromagnetics Division, National Bureau of Standards, Boulder, Colo. 80302.

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

OFFICIAL BUSINESS

Penalty for Private Use, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-215

SPECIAL FOURTH-CLASS RATE
BOOK

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

75 YEARS NBS 1901-1976