Your National Conference of Standards Laboratories is vital and on the move! There are times when it may be appropriate for an organization to be "mature". We are not at that milestone and may never choose to reach it. Instead, we are in a stage yet of rapid growth and reaching out, similar to experiences with children when they seem to suddenly "shoot up" overnight. We wonder, what new and exciting revelation is to be encountered next?

It is my belief that there are two basic reasons for this: the first being the dedicated, competent members we have staffing NCSL, and the second — our decision to investigate and where appropriate, assume a position of advocacy. We have probably remained on the sidelines too long and assumed the nature of a passive throughput society. Advocacy now dictates that we become involved, investigate and pursue issues which are considered of major importance to our members.

NCSL's major focus has been and should remain at the Regional level. This is where the individual members find their greatest opportunity to exchange ideas, develop forums for issues of concern, and generate the spirit of NCSL — which is the informal, free flow of management and technical information so necessary for our members laboratories and operations. The Regional Coordinators, with the assistance of their Directors, continue to aggressively address innovative methods of providing wider dissemination of information exchange to their regions and have developed programs tailored to regional needs. Although we now have ten officially recognized Regions, some Directors are subdividing theirs into geographically convenient units which allows a larger overall attendance than previously possible due to travel budget and other restrictions. Some Coordinators combine a technical program with the more historic management oriented one — thus bringing both management and technical staffs from many organizations together but separately involved in their respective areas of concern. Our International Regions growth and Regional activity has been outstanding, largely due to our neighbors and friends in Canada. I foresee the time close at hand when at least one new Region will be established in Canada.

Your Vice Presidents and their Committee Chairpersons are developing new committees staffed with competent specialists at such a rapid rate that the process could best be described as explosive. At this time we have in excess of 80 committee and sub-committee chairpersons and members. This is the largest activity in this area in the history of NCSL. These committees are destined to expand and increase along with rapid growth in technology and educational needs everywhere. In addition to the on-going formal committees we have Ad Hoc Committees, now numbering 4, whose responsibilities are to pursue immediate issues of today. These committees are much the same as tiger teams, composed of four or five members each who must quickly develop data and special reports to the Board of Directors and membership. It is from these committees that our urgent concerns and possible advocacy positions are developed. Coupled with our standing committee memberships we count a staff of 100 plus.

Because we are an organization which reaches out to other societies and technical organizations, also involved with measurements and the National Measurement System, NCSL officially establishes information exchange channels through our Liaison Representatives. There are 9 of these at present with a probability of 2 additional ones to be recognized this year.

So you see that your Board of Directors and officers must also dedicate an increasingly larger segment of their personal and professional life toward keeping the National Conference of Standards Laboratories a viable and growth oriented organization, and a major force in the measurement community. We welcome new members and encourage those of you who are not members to join us. Although our aim is to increase our membership, our goal is to increase the active participation of all our members, to the benefit of their own organization and for the advancement of the measurement community as a whole.

We have an outstanding team to build on and welcome additional volunteers; the challenge is yours but the benefits belong to everyone.

H.C. Keith, President
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**THE 1983 NCSL CONFERENCE IS EARLY THIS YEAR: JULY 18 IN BOULDER. DON'T MISS IT.**

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**Editors Message**

In spite of this thick issue, caused by lots of 1982 Conference Papers, its a relatively slow news period.

In the June 83 issue I'll be looking for material again. So think about giving me some stories about automated CAL systems you may have successfully implemented. Or give me a set of photos and story text for a "Lab Tour" of your lab.

*John Minck*
THE 1983 NCSL ANNUAL CONFERENCE
HILTON HARVEST HOUSE
BOULDER, COLORADO
JULY 18-21, 1983

PLAN NOW TO ATTEND THIS YEAR'S CONFERENCE
KEYNOTE SPEAKER

Grace Hopper
U.S. Navy
"Future Possibilities: Data, Hardware, Software, People"

SPEAKERS ON CRITICAL CURRENT TOPICS

- A Plan for Calibration in a Research Environment
- NBS Center for Chemical Engineering
- New Generations of Test Equipment
- Calibration Interval Analysis
- Canadian Armed Forces M.A.P.
- NBS MAP Power Standards vs. Company Control Standards
- Zero Defects in Standards and Calibration
- Metrology of Airflow in Open Areas
- Automatic Calibration
- Modification of Intervals
- Metrology Training at NAVAIR
- Automation of Watt/Hour Meter Testing
- Office Automation
- Measurement Requirements Survey Report

WORKSHOPS FOR ON-THE-SPOT DISCUSSIONS WITH OTHER ORGANIZATIONS

- Attentional Control Training
- Calibration Intervals Survey
- Ask the Experts
- Education and Training
- Laboratory Productivity
- Biomedical/Pharmaceutical
- Data Acquisition
- Measurement Assurance

FOR MORE INFORMATION CONTACT:

Ken Armstrong
National Bureau of Standards
Room 4001, Radio Building
Boulder, CO 80303
CALL TO ORDER

The Board of Directors' Meeting of the National Conference of Standards Laboratories was called to order at 8:30 a.m. on January 17, 1983 by President Hartwell Keith.

PRESIDENT'S REPORT - Dean Brungart '82/
Hartwell Keith '83

Dean appointed Bryan Werner as the NCSL representative to Butler Community College's Metrology Program.

Dean appointed George Rice to chair an ad hoc committee to study all aspects of the NBS plans to increase fees related to MAP/RMAP and/or increase calibration fees to cover R&D costs as well as operational costs, a recommended course of action to be put forth at this meeting.

Dean reported that he had written to Mr. W. A. Long, Deputy Under Secretary of Defense for Acquisition, Management, to check action on the proposed Change 1 to the NII-STD-45662. A meeting was held on November 29 at which NCSL Industrial sector was represented by Dean Brungart and George Rice. Resulting from that meeting, agreement was reached and Change 1 went into effect 5 January 1983. Copies of the Change Notice 1 will be mailed to all members.

Bryan Werner has accepted chairmanship of an ad hoc committee to study computer program costs and needs of the Secretariat's office and consider other NCSL needs for computer uses/programs.

Organic Act Ad Hoc Committee to be continued as constituted except George Rice will replace Hartwell as Co-Chairman.

PAST PRESIDENT'S REPORT - Dean Brungart

Dean asks that members send names for 1984 NCSL officer nominations or for the Wildhack Award to him.

SECRETARY'S REPORT - Chet Crane

The current status of the membership using the agreed upon terminology of "unpaid" for those who have not paid dues and "delinquent" for any that have not paid 1982 dues is as follows: Paid - 211; Unpaid - 101; Delinquent - 33; Potential - 547.

The Board as a group wishes to express its appreciation to Selwyn and to RCA for all the fine work they have already done for us.

TREASURER'S REPORT - Gary Davidson

Financial status summary was entered as follows:

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Increase (Decrease) in funds 16,965.00

Current assets 45,073.36

See pages 8 and 9 for full report.

REPORT ON INTERNATIONAL RECOGNITION OF CALIBRATION CERTIFICATES - Art McCoubrey

Dr. Ambler of NBS has received a letter from Paul Dean of the National Physical Laboratories of England proposing an agreement for mutual recognition of National Reference Standards of Calibration. There is an agreement between NVLAP and Australia which mutually recognizes tests carried out by laboratories and the Australian National Association of Testing Laboratories. Paul Dean would like to carry this to calibrations performed also, which would result in reciprocal recognition of certificates issued in both England and the United States. Such an agreement exists between the German PTB and the English NPL which has been carried even further. They have exchange visits for technical audits and participate in programs of expertise technical program exchange.

Manufacturers of devices used for sole and controlled by legal requirements who wish to sell their devices in Europe would like to see such reciprocal agreements. This would eliminate the necessity of having their products certified in the country where sold.

Dr. Ambler has agreed to explore this at the level of establishing equivalence for calibrations performed at NPL and NBS, but there is no present intent to make these agreements for the private sector.
Question by Hartwell: Would an agreement such as this include Canada? Canada would be kept well informed and probably invited to participate in any such agreement.

SPONSOR'S DELEGATE REPORT - Robert A. Kamper

Members of the NBS staff who are involved in Measurement Assurance Programs are defining options for a response to the anticipated reduction in funds for these activities in FY'84 and are trying to predict their consequences. No decisions have been made yet. We will keep the NCSEL Board of Directors informed of any significant developments.

The 1982 edition of NBS Special Publication 250 (Calibration and Related Measurement Services of the National Bureau of Standards) has been printed and mailed. Anyone who does not receive a copy and wants one should call the NBS Office of Measurement Services at (301) 921-2005.

An effort is being made to revitalize the NBS Journal of Research. In its present format it preserves much valuable information, but makes heavy reading for a general audience of metrologists and does not fully represent the diversity of scientific work performed at NBS. Any suggestions that members of NCSEL have for restoring a balance would be welcomed.

SECRETARIAT'S REPORT - L. Kenneth Armstrong read by John Martin

The question has come up concerning possible restrictions on shipping of training aids from our training library to various countries. A list of the training aids has been submitted to Dr. Kurt Heinrich, Chief, NBS Office of International Relations, at his request. No further action has been taken. Because our tapes are not compatible with every player, a policy is now in force to attach a label to each tape stating that it is in NTSC, 525 lines, 60 fields, and can be used only on compatible players.

Capabilities questionnaires for the new directory have been mailed to 754 laboratories including 53 to state offices of weights and measures (50 states and Puerto Rico, the Virgin Islands, and the Federal Grain Inspector of the USDA. Of these, 502 were returned. If no response was received, previously listed laboratories were listed in the new directory with the same capabilities as in the old.

Three copies each of TA104 (Logical Troubleshooting) and TA111 (Sampling Oscilloscopes) are being made for the library by Mike Zall. We presently have no circulating copies of these tapes. A new order form which includes the microprocessor training tapes has been prepared and will be included in the next Newsletter.

SECRETARIAT COMPUTER SYSTEM - H. Bryan Werner

A committee has been established to look into all aspects of computer uses by the NCSEL. Roland Vavken has agreed to chair this committee.

VICE PRESIDENT'S REPORT - ADMINISTRATION - H. Bryan Werner

Honors and Awards Committee - Hillary A. Taff and Jay Wiener. All plaques and awards have been prepared and all bills have been paid while remaining within budget.

Education and Training Committee - John Martin. Motion was made and seconded to halt loan of training aids to delinquent members (members whose dues have not been paid by April 1). Motion carried without opposition.

George Rice will open a new section of the long range plan which will contain the general policies and procedures for normal operation.

A new questionnaire will go out with the next training aids list, soliciting an input on tape format one-half inch VHS or three-quarter inch BETA.

Metrology P.R. Subcommittee - Bill Towne has completed a metrology slide presentation which is a composite of metrology scenes from various member laboratories. These slides and the metrology display panel are available for use by members upon request.

Bill Gibbs will develop a brochure on metrology to be used for recruiting students into a metrology program. He is planning a "canned presentation" to go along with the brochure.

Kate Webster has accepted the position as Chairperson of the Adjunct Subcommittee. Her immediate task will be to gather material which is partially completed on "Basic Metrology" and determine what is required to complete the project.

Merrill Jones of Sandia National Labs has agreed to make a study of the existing computer assisted instruction to determine their feasibility for use by NCSEL.

The Metrology Program at Butler is recognized by the state as a model high technology program for retraining people laid off from the steel industry. It is expected that the state will begin to provide some financial assistance for the program in 1983.

Golden West College in Huntington Beach, California, has decided to start a metrology program. The program has been started with a scale technician training course intended to prepare for entry level positions. Dr. Norman Rich, Associate Dean, is in contact with Jim Tezza of Butler College to compare curricula.
Board Meeting

Joy Varvel reports that J. M. Perry Institute now has a room and is at a point where they need to know what equipment they need for hands-on training. They have a new instructor who has had practical experience and is a graduate of J. M. Perry Institute.

Carl Quinn reports that the program at Golden West has no equipment and will accept anything applicable. Dr. Rich has been encouraged by the Education and Training Committee to submit a "want" list.

**VICE PRESIDENT'S REPORT - Doug Dool, National Measurements Requirements Committee**

Del Caldwell has recruited group leaders for each of the National Measurements Requirements Survey technical working groups. The groups will meet in Palo Alto on Saturday, January 22. Del plans to complete the final survey report by March 1983.

Ron reports that his involvement with the NVLAP Advisory Committee is a lot broader than he at first thought it would be. He feels that this will be an advantage since he will have an input from the NVLAP program.

**Biomedical and Pharmaceutical Metrology Committee - William Fitzgerald.** Doug reported for Bill that one of the committee's goals is to establish liaison with the Association for the Advancement of Medical Instrumentation, Health Industry Manufacturer's Association, Pharmaceutical Manufacturer's Association and others in the area of metrology and calibration.

The draft copy of "Medical Products Industry Calibration Control System Guideine" was discussed. Concern was expressed with some of the wording.

**LABORATORY MANAGEMENT AND OPERATIONS - George Rice/Doug Dool**

**Calibration Systems Management - Phil May.**

The following subcommittee chairperson appointments have been made:

- Tom Tenna, Management Information Systems Selden McKnight and Howard Hopkins, Management Research
- Ernie Crisologo and Bill Smiley, Systems Management and Control
- Phil McCurry, Human Resources Management
- Woody Trammel, Surveys
- John Buck, Standard Practices
- Max Green, Workshops

An invitation has been given to Dr. Dennis S. Friday of the Statistical Engineering Division at the NBS in Boulder to participate in the calibration interval workshop.

**Product Design and Specifications - Warren Collier.** Warren has recently assumed chairmanship. Doug requested that any members have suggestions for the Product Design Committee contact Warren.

Brian reported that the Measurement Assurance workshop being held in Southern California the next week was well subscribed with about 40 persons signed up.

**COMMUNICATIONS AND MARKETING - Pete England/Ed Nemeroff**

**Newsletter - John Minck.** The cost of printing and publishing the Newsletter was discussed; a major component of this cost is mailing. If anyone is receiving too many or too few copies, let John know and he will make the adjustments.

**Information and Directory - Ralph Bertermann.** The NCSL Brochure is completed and 2,000 copies are with the Secretary.

It was determined that 1,000 copies of the Calibration Manager's Guidebook should be printed for a first printing.

**Membership - Hillary Taft.** A letter to coordinators requesting names of prospective committee members has received no response at this time. Regional coordinators are to submit the name of a regional, membership committee member to Hillary Taft.

**REGIONAL REPORTS**

Regions 1 and 2 - Harry Haymes, William Brennan. Region 1 held a regional meeting on October 27, 1982, at GenRad in Concord, Massachusetts. The next regional meeting will be held in April 1983. The new regional training coordinator is: Ted Majewski of AVCO. The new Regional Coordinator is: William Robinson, Raytheon Company, Submarine Signal Division, P.O. Box 360, Portsmouth, RI 02871, (401) 847-8000, ext. 4881.

There has not been a Region 2 meeting since the last Board meeting. A meeting is tentatively scheduled for February at Loral Electronics. Theme for the meeting will be Automatic Test Equipment. The new Regional Coordinator is: William Brennan, Loral Electronic Systems, 625 Bronx River Avenue, Bronx, New York 10473, (212) 378-2300, ext. 376.

Region 3 - Hugh Starling. Marlin Johnson has replaced Fred Kern as Region 3 Coordinator. Fred does plan to remain active and support Region 3 and NCSEL activities in all ways possible. In calendar year 1982, Region 3 held one meeting at COMSAT Laboratories in Clarksburg, Maryland. Marlin plans a minimum of two meetings for the region in calendar year 1983. The first of these is being planned to coincide with the Board of Directors meeting in Williamsburg, Virginia, in April and will probably be held in the Williamsburg area on Tuesday, April 26.

Region 4 - Bob Lady, John Riley. John held three regional meetings during 1982 and has scheduled two for 1983. One will be in April and the other in November. The one normally held in July will be omitted in order to encourage members to attend the
1983 Conference: The current membership in Region 4 is now 33, including 5 delinquent members.

Region 6 - Bob Lady, Bill Simmons. Meeting schedule for 1983:

February 24, 1983 - Dallas, Texas
Host: Ronnie Eubank - Otis Engineering
Main Topic: Measurement Assurance Programs

May 1983 (tentative) - White Sands, New Mexico
Host: Hand Gonzalez, Army Calibration Labs
Main Topic: Calibration Intervals

October 1983 (possible) - Austin or San Antonio, Texas
Host: TBA
Main Topic: Laboratory Productivity

Region 5 - Cliff Koop, Doug Smith. The winter meeting for Region 5 will be held in the Chicago area at the end of February 1983. The meeting format is as follows:

- NCSL Report by Director
- Guest speaker
- Workshop - Biomedical and Pharmaceutical Metrology Committee

A second meeting is planned for the fourth quarter of 1983. The location will be in the Ohio area.

Region 9 - Cliff Koop, David Goodhead. Region 9 held their last meeting for 1982 on Wednesday, December 1, 1982, at the John Fluke Manufacturing Company, Inc., plant in Everett, Washington. During 1983 Region 9 plans to hold three regional meetings:

1. Portland, Oregon
2. Richland, Washington
3. Seattle, Washington

Region 7 - R. Weber, C. Quinn. Membership of Region 7 is 33. Two meetings are scheduled for 1983, one in June and one in November. June's meeting will include a tour of Lockheed's new 48,000 sq. ft. Metrology Laboratory.

Region 8 - R. Weber, R. Schumacher. Two meetings were held in 1982 and two are scheduled for 1983. The first of these will be the last of May or the first week of June. The second will be in November. These meetings will be held in the Long Beach area since 70% of the membership is in Los Angeles County.

A plan has been formulated which will include having some NCRL area meetings in the areas where there are smaller concentrations of members. These areas would include San Diego, Phoenix, and Salt Lake City.

Bill Simmons, Coordinator of Region 6, requests that a combined meeting of Region 6 and Region 8 be held in the Phoenix-White Sands, New Mexico area.

International Region - Graham Cameron (Region 10). Graham was not present and his report was presented by Hartwell Keith. The International Region meeting held on October 5 at NBS, Gaithersburg, drew 40 attendees.

The Canadian Sector meeting, which was held at Canadian National Company, Ltd., in Montreal, had 42 attendees. Topics of general interest were "Movement of Battery Power or Shock Sensitive Standards/Instrument by Commercial Airlines," "Customs Clearance of Standards and Measuring/Testing Equipment," and "National Accreditation of Testing Organizations."

LIAISON DELEGATES REPORTS

Precision Measurements Association - Phil Painchaud. PMA Secretariat has been transferred from the GIDEP to the Metron Corporation. Phil Painchaud has been elected to the post of Executive Director and will coordinate office activities.

GIDEP Metrology Committee - Phil Painchaud. The Annual Workshop Meeting of the GIDEP Metrology Committee was held in Chicago on November 9, 1982.

Measurements Science Conference - Dean Brungart. Next year's conference is tentatively set for either the Marriott Hotel at the Los Angeles Airport on January 31, February 1, 1984, possibly the Queen Mary or the Hyatt Regency in Long Beach.

American Society for Quality Control - Karl Speitel. The Quality Congress of ASQC will be held on May 14 to May 16. The Metrology Technical Committee will hold its annual meeting during that conference.

Instrument Society of America - Mike Suraci. The Recommended Practice for Environmental Conditions for Standards Laboratories is being revised. The committee is in need of one or two additional members and they are also looking for people to review the RP after it has been revised.

ANSI - Rolf Schumacher. The revision worked out has been distributed for comments and it is hoped that the first draft will be ready for public review by the end of this year.

Conference on Precision Electro-Magnetic Measurements (CPEM) - Bob Kamper. The first call for papers for CPEM '84 will be sent in January 1983. If you are in need for further information, write to:

Dr. Robert Kaark
Hoofdstraat van het IJwezen
Van Swinden Laboratorium
Schoemakerstraat 97-Delft
Netherlands
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Increase/Decrease in Funds

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<td>Cash</td>
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<tr>
<th>Assets (Property)</th>
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<td>10 K ohm Resistor</td>
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-8-
# NCIL Budget for Calendar Year 1983

## 01/14/83

**NCIL Budget for Calendar Year 1983**

(January 1, 1983 thru December 31, 1983)

<table>
<thead>
<tr>
<th>ACCOUNT DESCRIPTION</th>
<th>DISBURSEMENT AUTHORIZATION</th>
<th>AUTHORIZED AMOUNT</th>
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<td><strong>EXPENSES - COMMITTEE ACCOUNTS</strong></td>
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| **EXPENSES - OPERATIONS ACCOUNTS** | | | |
| RI-001 WILDHACK AWARD (1983) | BOARD OF DIRECTORS | 1,000.00 | 1,000.00 |
| RI-001 PRESIDENTS EXPENSES | PRESIDENT (KEITH) | 4,300.00 | 4,300.00 |
| RI-002 REGION 1 MEETING SUPPORT | DIRECTOR (HAYES) | 100.00 | 100.00 |
| RI-003 REGION 2 MEETING SUPPORT | DIRECTOR (HAYES) | 150.00 | 150.00 |
| RI-004 REGION 3 MEETING SUPPORT | DIRECTOR (STARRY) | 100.00 | 100.00 |
| RI-005 REGION 4 MEETING SUPPORT | DIRECTOR (LABY) | 150.00 | 150.00 |
| RI-006 REGION 5 MEETING SUPPORT | DIRECTOR (KOPF) | 125.00 | 125.00 |
| RI-007 REGION 6 MEETING SUPPORT | DIRECTOR (WEBER) | 100.00 | 100.00 |
| RI-008 REGION 7 MEETING SUPPORT | DIRECTOR (WEBER) | 100.00 | 100.00 |
| RI-009 REGION 8 MEETING SUPPORT | DIRECTOR (WEBER) | 100.00 | 100.00 |
| RI-010 INTERNATIONAL REGION MEETING SUPPORT | SECRETARIAT (ARMSTRONG) | 7,000.00 | 7,000.00 |
| SI-001 SECRETARIAT EXPENSES | SECRETARIAT (D'ARMSTRONG) | 1,790.00 | 1,200.00 |
| **TOTAL EXPENSES - SELF SUSTAINING OPERATIONS ACCOUNTS** | | 9,000.00 | 3,500.00 |
| **SUBTOTAL** | | 70,505.00 | 56,174.00 |

| **INCOME ACCOUNTS - ESTIMATED** | | | |
| II-001 DUES AND NEWSLETTER SUBSCRIPTIONS | | 50,000.00 | 3,000.00 |
| II-002 INTEREST | | 3,000.00 | |
| **TOTAL INCOME ACCOUNTS** | | 53,000.00 | |
| **ESTIMATED INCREASE/DECREASE IN FUNDS** | | 4,874.00 | |

*Board Meeting*
TRAINING COURSE ANNOUNCED

Subject: Operating Techniques for Standards and Calibration Laboratories, Course #284DC.

Offered by: George Washington University
Continuing Engineering Education Program
Washington, D.C. 20052

Date: April 18 - 23, 1983

Fee: $855

To Register: (800) 424-9773 or (202) 676-6106

SEMINAR ON FREQUENCY STANDARDS AND CLOCKS

This seminar is a repeat of the seminar given August 23 and 24, 1982. It is intended for program managers, planners, and systems engineers.

Dates: July 14 and 15, 1983

Location: National Bureau of Standards
325 Broadway, Boulder, Colorado.

Topics Covered:
- A history of Time Scales (background)
- National and International Structure of Time & Frequency (background)
- Concepts, Definitions, and Measures of Short-Term Frequency Stability (theories)
- Techniques for Measuring Short-Term Frequency Stability and Noise in Oscillators
- Review of Performance of Commercial Frequency Standards (what's available, specifications)
- Limitations of Present-Day Atomic Frequency Standards
- Possible Advances in Future Clocks and Frequency Standards
- The Process of Timekeeping (clock modeling)
- Time Coordination: Methods for Comparison of Time Scales
- Propagation Effects on Radio Transmissions
- Optical Techniques and Propagation Effects

Registration Deadline: July 1, 1983

Registration Fee: $370

Make Checks payable to: Seminar on Frequency Standards and Clocks

For further Information Contact:

General Information: Sandy Howe
(303) 497-3212

Technical Information: Samuel R. Stein
Chief, Time & Frequency Division
(303) 497-3335

SEMINAR ON FREQUENCY MEASUREMENTS AND CALIBRATION

This is a new seminar that incorporates new material into the Time & Frequency User's Seminar given in previous years. It is intended for engineers and standards lab technicians involved in making frequency calibrations. The course will be taught at a practical level to satisfy those new in the field as well as more experienced users. Methods taught will use commercially-available equipment.

Dates: October 25, 26, and 27, 1983

Location: National Bureau of Standards,
325 Broadway, Boulder, Colorado.

Topics Covered: Crystal
- Crystal Oscillator Calibration
- Applications of Frequency Counters
- How to choose a Frequency Calibration Source
- Care and Use of Frequency Sources
- Using Loran-C and WWV for Frequency Calibrations
- Time and Frequency Measurement Assurance Services at NBS
- Organization of Time & Frequency in the U.S.
- NBS, USNO, and other publications.

Note: Although all of the above subjects will be covered, emphasis will be on making practical frequency calibrations and measurements.

Registration Fee: $575

Registration Deadline: October 11, 1983

Cancellation: Registration fee will be refunded in full only if notice of cancellation is received at NBS prior to October 11, 1983.

For further Information Contact:

General Information: Sandy Howe
(303) 497-3212

Technical Information: George Kanas
(303) 497-3378
TRAINING AIDS LIBRARY - Mike Zall

Mike Zall has taken over the position as Chairman of the Training AIDS Library Subcommittee, replacing Jay Varvel who has accepted the position as Chairman of Honors and Awards Committee.

A draft policy and procedure has been developed for retrieving overdue training aids.

A video tape was made from the slide presentation of the French "Bureau De Metrology" and it is being placed into the tape library.

A survey questionnaire was passed out at the 1982 October Conference asking attending members what tape format was normally used at their company (1/2 in. VHS or 3/4 in. Beta). The results of the survey, although inconclusive due to the small response, were as follows: 35 members returned the questionnaire, 24 indicated the use of 3/4 in. Beta, 7 indicated the use of 1/2 in. VHS and 4 indicated they use both 1/2 and 3/4 in. players.

TRAINING INFORMATION - Dave Lorenzen

The Training Information Directory was mailed to the members in October, however, due to a lost shipment between the printer and NBS Boulder, 200 additional copies had to be printed. A training information supplement announcing metrology-related books, papers and training courses was published in the December Newsletter. The Training Information Subcommittee held a meeting on November 20, 1982.

METROLOGY P.R. SUBCOMMITTEE - Milt Towne

Milt Towne has completed a metrology slide presentation which is a composite of metrology scenes from various member laboratories. They will be displayed along with the metrology display panel at the Measurement Science Conference. Both of the items are available for use by members upon request.

Bill Gibbs has volunteered to develop a brochure on the field of metrology to be used for recruiting students into a metrology program. Along with the brochure, he is planning on developing a "canned presentation" which will be available to the NCSL membership. Gene Watson of General Dynamics and Dick Lindsey of Hewlett-Packard are also going to assist him on this project.

ADJUNCT TRAINING - Kate Webster

Kate Webster of Bioetics in Cleveland has accepted the position as Chairperson of the Adjunct Subcommittee. J. Martin met with her in November and discussed the Adjunct Training concepts. Her immediate task will be to receive the partially completed "Basic Metrology" training course and other training materials from Will Loeffler who has resigned from the committee, review the subject material and make an assessment of what has to be done to complete this project.

The Computer-Assisted Training Course has been on hold due to the lack of someone to work on this project and the unavailability of a computer. Merrill Jones of Sandia National Labs has agreed to make a study of existing computer-assisted training programs such as PLATO and others and determine their feasibility for use by NCSL. A preliminary study was completed by Merrill Jones on 12-23-82. In summary, his report identified that there are many computer-assisted instructional (CAI) materials in existence or in the process of development using a wide variety of computers and software. Some of the CAI courses available are applicable to metrology such as mathematics, statistics, physics and science, but little or no courses aimed directly at measurement science. The quality of the programmed instructional material of the courses varies widely from superb to awful. Merrill feels that CAI is still in its infancy and possibly will be greatly improved by the end of 1983. He feels that CAI has great potential for training Measurement Science personnel, but developing that potential may take time and money, so that we should proceed cautiously and learn all we can and see what actually develops with CAI in 1983.

Merrill had volunteered to continue collecting material, learning all he can about CAI, and see what develops during the year of 1983. He also proposed that a questionnaire be developed to survey the NCSL membership on their CAI preferences. Short term objectives and a clear goal or task definition also has to be identified. These activities can be accomplished with minimal cost, however, sometime in the future if the decision is made to go ahead with CAI, funds will have to allocated for hardware and software development.
This activity will now be split out as a separate subcommittee under the Education and Training Committee.

**BUTLER COMMUNITY COLLEGE - J. Balog & J. Tezza**

The Metrology II, second year program, is continuing on schedule with five students expected to graduate in 1983. One will complete the curriculum in April of 1983 and the four remaining students will complete the program in August of 1983.

I regret to report that the sixth student, Scott Gray, was in a fatal automobile accident on December 12, 1982. I am sure his loss will be mutually felt by everyone who has been involved with the Butler Metrology Program.

The fourteen students enrolled in September in Metrology I are progressing well.

The metrology program at Butler is recognized by the state of Pennsylvania as a model high technology program for retraining people who have been layed off by the steel industry. It is expected that the state will begin to provide some financial assistance for this program in 1983.

An advisory board was formed, representing government and industry, to assist the metrology program in curriculum review and developing long range plans. They held their first meeting on December 10, 1982 and Bryan Werner was elected Chairman.

A Science Fair is again being planned for the spring of 1983 as the major student recruitment activity.

The college is presently working with local petroleum companies and refineries in developing a short course in measurements relating to the petrochemical field.

**GOLDEN WEST COLLEGE - W. L. Gibb, D. Pennecker & A. J. Plourde**

Golden West College, located in Huntington Beach, California, has decided to start a metrology program. The program has been started with a scale technician training course intended for entry level positions. Other areas of the metrology curriculum are in the process of being developed. The college has immediate needs for students, information on job availability, metrologists to teach and surplus equipment. Bill Gibbs of Xerox, Art Plourde of Metro and Dennis Pennecker of Rockwell International have volunteered to serve as an Advisory Committee assisting the college in curriculum development and in contact with Butler Community College for the purpose of comparing curriculums. Jim Tezza has volunteered to assist them with the development of their curriculum.

J. T. Martin, Chairman
Education & Training Committee

**NATIONAL MEASUREMENT REQUIREMENTS COMMITTEE**

D. H. Caldwell, U.S. Navy Metrology Engineering Center, Chairman

Chairman Del Caldwell held a special meeting of the NCSL National Measurement Requirements Committee on January 22nd in Palo Alto, California. The Saturday meeting followed the conclusion of the Measurement Science Conference and the attendees included his 5 new subcommittee chairmen and 19 other committee members and interested guests.

The informative and productive meeting included an outline of both the current and long-range objectives of the committee and also an overview of the results and status of his two recent surveys. The committee’s initial efforts will be in the areas of the NBS Calibration Service Requirements and also Calibration Standards and Techniques. Long-range goals of the committee will address Metrology Research, Development and Engineering Requirements. NMRC’s primary objective is to act as the focal point for identification and assessment of National Measurement Requirements.

Del has recently organized the NMRC committee into five technical working groups with the following subcommittee chairmen heading up each group:

- **RF/MICROWAVE METROLOGY** - Frank Kiode, Rockwell International (714/632-3923).
- **TEMPERATURE/PRESSURE METROLOGY** - Klaus Jaeger, Lockheed Missiles & Space Co. (408/742-7821).

Each subcommittee includes key representatives from the NBS, government and industry with recognized expertise in the applicable...
Committee News

Metrology areas. They will be reviewing and analyzing the 1982 NMRC surveys with the following objectives in mind:

- Analyze survey results and other data including new data and membership experience.
- Provide clear technical description of requirements.
- Provide overall assessment of requirements.
- Motivation/need
- Value/impact if requirement satisfied and cost/impact if requirement not met
- Relative priority of requirement
- Provide report by 1 March, 1983.

The NMRC Subcommittee's long-range objectives for 1983 and beyond include:

- To act as the NCSL measurement technology focal point
- Continuous assessment of new measurement technology requirements
- Forum for review, development and exchange of technical information
- Annual Measurement Technology Assessment Report

For everyone's benefit, the following overview of the initial 1982 survey is printed with the percentages of responses identifying needs/requirements in parentheses:

NBS CALIBRATION SERVICE REQUIREMENT AREAS
- Traditional Transfer Standard Calibration (35%)
- Measurement Assurance Programs (19%)
- Metrology Seminars (15%)
- Standard Reference Materials (13%)
- Product/Component Testing (6%)
- Other: (12%)
  - National Voluntary Laboratory Accreditation Program
  - Proficiency Sample Program
  - Standards Information Services
  - Standard Reference Data
  - Technical Information and Publications

LOCAL TEST/MEASUREMENT CAPABILITY AREAS
- Calibration and test equipment or techniques for:
  - Standards Calibration (42%)
  - Portable Test Equipment Calibration (19%)

As the new incoming Vice President of Measurement requirements, I am looking forward to this key NCSL Committee's ambitious plans and goals for 1983. The Committee is now organized, staffed and is ready and willing to serve and will need everyone's support and inputs to achieve their objectives. If you can serve or help, please contact Del Caldwell, any of his Subcommittee Chairmen directly or me personally. Also, Del has informed me that he is still accepting responses to the 1982 Surveys. If you are a new NCSL Member Delegate or other interested individual and would like a Survey Questionnaire, or if you previously failed to respond and would not like to, please contact Del Caldwell at (714) 620-0501 or myself at (714) 620-7511, extension 4745/4746.

Pete England, Vice President
Measurement Requirements

* * * * * * * * * *

A ROSTER OF COMMITTEE ASSIGNMENTS

VICE PRESIDENT
ADMINISTRATION - BRYAN WERNER

1A Meetings & Programs
Maurice J. Corrigan, Jr. (Moe)
Lockheed Electronics Co., Inc.

MEMBERS
John L. King
General Dynamics
John Cox
Lockheed Missiles and Space Co.

1B Honors & Awards
Jay R. Varvel
Rockwell Hanford Operations

1C Education and Training
John T. Martin
Westinghouse VES, Forest Hills

MEMBERS
Earl Amano
Training Directory Editor
TRW/OSG
Jim H. Bailey
Region 6, Training Coordinator
Metrology Specialists, Inc.
Committee News

Jack Balog
Butler College Subcommittee Chairman
Westinghouse Electric

Herb B. Barclay
Region 1 Training Coordinator
GTE Sylvania

Mike Bum
Region 8 Training Coordinator
Comtel Corporation

Joe R. Bunting
Region 2 Coordinator
Ford Aerospace Corp.

Paul Chasko
Westinghouse Electric Corp.

Stanley Crandon
Vice President
SAT CONSISTMOS

Edmond G. Franzak
Sandia National Labs

Bill Fry
GIDSP Administration Office

William Gibbs
Xerox Electro-Optical Systems

Fred J. Irabeta
J. M. Perry Institute

Merrill C. Jones
Computer Aided Training
Sandia National Laboratories

David A. Lorenzen
Training Info. Subcommittee Chairman
McDonnell Douglas Corp.

John T. Martin
Chairman, E&T Committee
Westinghouse NWS, Forest Hills

Dennis Pennicker
Rockwell International

Thomas A. Person
Automated Technology Assoc.

A. J. Plourde
Metron Corp.

Thomas J. Puzniak
Gulf Science and Tech. Co.

Ken Robinson
Training Info. Subcommittee Chairman
American Edwards Labs.

Joseph Rothlieber
California Dept. of Food & Ag.

Robert W. Schnepf
Region 4 Training Coordinator
RCA

George L. Sherback
Charles Stark Draper Lab. Inc.

Douglas M. Smith
Abbott Laboratories

Karl F. Speitel
ASQC Liaison
Eastman Kodak Co.

James Teza
Baker Co. Community College

Ali Tholen
Weights & Measures Liaison
National Bureau of Standards

Milton Towne
P.R. Subcommittee Chairman
Sanders Associates

Jay R. Verbe
Perry Inst. Subcommittee Chairman
Rockwell Hanford Operations

William Weaver
Region 5 Training Coordinator
General Electric Company

Kate Webster
Adjunct Training Chairman
Bionetics Corporation

Chester Wells
SERI

H. Bryan Werner
V.P. Administration
Westinghouse R&D Center

Bill Wexted
GTE-Sylvania

Michael H. Zoll
Training Aids Subcommittee Chairman

VICE PRESIDENT

MEASUREMENTS REQUIREMENTS - PTE ENGLAND

2A National Measurement Requirements

Delbert H. Caldwell
Navy Metrology Engineering Center

SUB-COMMITTEE CHAIRPERSONS

Frank Koford - RF and Microwave
John Nelson - Physical Measurements
Klaus Jager - Temperature & Pressure
Dr. Richard Miller - Electro-Optics
Lyle Schmidt - DC and Low Frequency

2B Laboratory Evaluation

Ron Kidd
Microwave Associates

2C Biomedical & Pharmaceutical Metrology

William F. Fitzgerald
Travenol Laboratories, Inc.
COMPUTER OPERATIONS - Bryan Werner

As requested by Hartwell Keith, Bryan will be establishing an ad hoc committee to improve the computer operations of the Secretariat.

This committee would look for changes which would result in more comprehensive and simpler handling of membership information, mailings, and the training aids library. They would also study the trade-off between leasing computer time and purchasing a separate unit.

Right now Bryan is looking for someone with some computer experience who could chair and assemble such a committee. Are you aware of any member delegates who might be eligible? If so, please send him the information! Thank you.

D. R. (Don) Tobey
Science Applications, Inc.

MEMBERS
Automatic Test & Calibration Systems Committee
Hardware-Chairman: H. P. (Hank) Gonzalez
Software-Chairman: Bob Smith
A POSSIBLE QUANTUM HALL EFFECT RESISTANCE STANDARD

M. E. CAGE, R. F. DziUBA, and B. F. FIELD
National Bureau of Standards
Washington, DC

ABSTRACT

The discovery of the quantum Hall effect by K. V. Klitzing, using semiconductor devices that are cryogenically cooled in large applied magnetic fields has opened up the exciting possibility that this effect could stimulate the discipline of electrical metrology to an extent analogous to that of the Josephson effect. This paper will describe the quantum Hall effect in an attempt to achieve a new resistance standard accurate to a few parts in $10^8$, in which the resistance is defined in terms of fundamental constants of nature.

INTRODUCTION

This paper describes a new phenomenon that promises to have the same kind of impact on electrical metrology that the Josephson effect has had. It is called the quantum Hall effect, and it uses specially made semiconductor devices that are cryogenically cooled to temperatures near absolute zero. They are placed in a large magnetic field produced by a superconducting magnet in order to achieve a two-dimensional electron gas in the semiconductor devices. The electrons in this two-dimensional gas can then be made to completely occupy all of the quantum states characterized by a known integer number $i$. Whenever this condition is achieved the resistance $R_H$ of the device, defined by the ratio $R_H$ of the Hall voltage $V_H$ across the device to the current $I$ through it, is found to have discrete, reproducible values that satisfy the relationship

$$R_H = \frac{V_H}{I} = \frac{\hbar}{ne^2} = 25,812.80 \ \Omega.$$  \hspace{1cm} (1)

$R_H$ is the quantized Hall resistance, and its value depends upon the quantum integer $i$, Planck's constant $\hbar$, and the electron charge $e$. Thus we have a resistance that can be determined solely in terms of fundamental constants of nature.

This astonishing result was first verified by Klaus von Klitzing in West Germany about two years ago. He demonstrated that the quantized Hall resistance satisfies Eq. (1) to at least the 10 ppm (parts-per-million) level of accuracy. His work has generated a large amount of excitement in the scientific community, and national metrology laboratories all over the world are starting to investigate this phenomenon.

MOTIVATION

Why are resistance metrologists so interested in this effect when they already have high quality, stable, wire-wound resistance standards? The reasons are two-fold. First, as is well known, wire-wound resistors do not travel well; their values can change due to mechanical and thermal stresses, as well as barometric pressure variations, during transport. The limited data available from international comparisons indicate possible resistance transport shifts in the range 0.05-0.2 ppm for 1 ohm resistors, and significantly larger shifts for higher value resistors. Second, these resistors are artifacts and cannot a priori be expressed in "absolute" (i.e. Système International or SI) units. In the United States, for example, the as-maintained unit of resistance is defined to be the average of five nominal value 1 ohm resistors that are kept at a 25°C mineral oil bath at the NBS. This does not imply, however, that the U.S. unit of resistance is not known in terms of the SI unit. It has been so determined via an extremely difficult measurement based on the NBS calculable capacitor.2 This measurement was last performed in 1974 and because of its difficulty is only now being repeated. The one standard deviation uncertainty of 0.03 ppm achieved in 1974 is 3 times better than any other attempt. This means that if the quantized Hall resistance is to be used as an SI resistance standard, von Klitzing's original work must be pushed about three more orders of magnitude. We believe that we are now within about a factor of ten of achieving this goal. But do not be alarmed: wire-wound resistors would continue to be used as working standards, with quantum Hall effect resistance standards being maintained in national metrology laboratories and perhaps eventually also in a few primary laboratories. They would be used in much the same way as the Josephson effect is used to maintain the unit of voltage: the national wire-wound resistance standards would periodically be calibrated against the quantized Hall resistance in order to know their time dependences and to assure that they are consistent with the SI units.

QUANTUM HALL EFFECT

With the above as an introduction and the motivation for doing this experiment, let us now investigate the quantum Hall effect in more detail. We first need a suitable semiconductor device. There are two device types which have been successfully used: laboratory versions of silicon MOSFETs (metal-oxide-semiconductor field effect
transistors) and GaAs-AlGAs heterojunctions (which are hard to fabricate; to date, no more than a dozen good GaAs heterojunctions have ever been made). We will only briefly describe how our Si MOSFETs are made at the Naval Research Laboratory in collaboration with R. Wagner. We start (see Fig. 1) with a single crystal substrate of p-type silicon and grow a thin SiO$_2$ layer on the top surface for electrical insulation. A metal film of gold or aluminum is then evaporated over the SiO$_2$ layer to form a gate and pads for the source and the drain (which electrically contact the substrate via diffused regions of heavily doped n-type material). The devices (see Fig. 2) are 1.3 mm long and 0.2 mm wide and can be seen with the naked eye. In addition to the source and drain pads, we have potential probes placed along the device which sample voltages in the channel under the gate.

We ground the source (see Fig. 3) and apply a positive d.c. voltage to the gate, thereby obtaining a parallel-plate capacitor, the metal gate being one electrode and the semiconductor substrate the other. The SiO$_2$ layer is typically 0.1 µm thick, so if the gate voltage is 30 volts, this means that the electric field across the insulator is 3 x $10^6$ volts/cm. Therefore, no pinholes can be tolerated in the SiO$_2$ layer. By increasing the gate voltage we induce more electrons near the top surface of the substrate. But it is not like a normal capacitor because these electrons are bound in a potential well and must therefore obey quantum mechanical laws. This potential well quantizes the electrons in the vertical direction and confines them into a two-dimensional electron gas. The gas is so near the SiO$_2$ interface that this surface must literally be atomically smooth, otherwise the electron gas will scatter from the rough surface and destroy the quantum Hall effect. Also, there are always impurity ions present and the electrons will scatter from them; we therefore require state-of-the-art devices to minimize these problems.

By applying an electric field in the vertical direction to a sample cooled to near absolute zero we have quantized the electrons in the vertical direction, forming a two-dimensional electron gas. Let us next apply a magnetic field that is also in the vertical direction. This must be a very large field, so we use superconducting magnets to produce fields up to 15 T, which is 150,000 gauss (or about 3 x $10^7$ lines larger than the Earth's magnetic field). The electrons in the vertical gas form cyclotron orbits about the vertical magnetic field lines, quantizing the electrons in the horizontal plane. The result is a completely quantized, two-dimensional electron gas. Since the gate voltage can induce more electrons into allowed cyclotron orbits and completely fill, for example, all of the $i = 4$ orbits, but none of the $i = 5$ orbits because the device is so cold, and the current is so low, and the scattering is so small that there is insufficient energy to occupy any $i = 5$ states.

Now assume that we have just filled the $i = 4$ states and then pass an electron current through the sample. There is the resulting flow pattern (see Fig. 4): the electrons emerge from one corner of the device and exit at the opposite, the reason being that magnetic forces cause the electrons to pile up in the upper left hand corner and along the top edge. The magnetic forces are exactly balanced by the electrical forces between the electrons within the sample, but there is an escape route at the top right hand corner. The electrons are accelerated at the ends of the device and drift with constant velocity in the interior. If the current is 5 µA and the $i = 4$ quantum states are just filled, then the source-drain voltage is about 32 mV. Let us next map the potential distribution around the periphery of the sample (as shown in Fig. 4) with the source at zero volts since it is grounded. We can measure voltages within the sample via the potential probes. For example, the voltage drop along the channel $V_x$ can be obtained with probe sets 1, 2 or 3, 4 and in both cases $V_x = 0$. The reason is simple: if the $i = 4$ states are filled and if there is insufficient energy to scatter into any $i = 5$ states, then there is no scattering. If there is no scattering there is no voltage drop. Thus the voltage drop along the channel becomes very small when all the quantum states are filled. There is, however, a voltage drop across the channel, $V_y = V_H$, and this Hall voltage can be measured with probe sets 1, 3 or 2, 4. In both cases $V_H$ is about 32 mV. K. v. Klitzing measured $V_H$ more carefully and found in sample after that $V_H$ was 32.266 mV. Divide this by 5 A and you get $R_H$ = 6.453, 26, which is precisely the value predicted in Eq. (1) for $i = 4$.

**MEASUREMENT SYSTEM**

Can this amazing result be pushed the three more orders of magnitude necessary for use as an ST resistance standard? Here is the measurement system (see Fig. 5) that we are using in our initial attempts to answer this question. The system is battery-operated and consists of a constant-current source that supplies current to the Hall device which is cooled to 4.2 K by immersing the device in liquid helium. We can further cool the sample of 1.5 K by pumping on the liquid helium bath. The Hall device is, of course, insulated in the central field of a superconducting magnet. The current also passes through a room temperature reference resistor constructed to have the same nominal resistance value as the quantum Hall resistance of interest, e.g., 6.453, 26, and the both voltages can be nearly bucked-out by the potentiometer. The electronic detector, $D$, reads the voltage.
differences and its isolated output is either directed into an X-Y recorder or is digitized for computer analysis. If we can assure ourselves that the same current passes through both the sample and the reference resistor, then the current can be eliminated in the equations for Vh and Vx and the quantized Hall resistance RH can be obtained from the ratio \( \frac{V_h}{V_x} \) and the calibrated value of the reference resistor RR. (RH will be given in SI units if RR has been determined in SI units via the calculable capacitor experiment.) The current is typically 10 \( \mu \)A, so for a part in 10^8 measurement this requires that any currents shunting the sample or resistor, or leaking to ground, must be less than 10^13\( \mu \)A. Another way of stating this condition is that the leakage resistance between the leads, and to ground, must be greater than 10^12 \( \Omega \)--except for the gate lead, which must be greater than 10^14 \( \Omega \) since it is at a higher voltage. (A fingerprint across terminals can be a short-circuit in this experiment)

RESULTS

Now for some data. Here are low sensitivity X-Y recordings of Vh and Vx, in mV, versus gate voltage for a silicon MOSFET at 13 tesla obtained at the Naval Research Laboratory (see Fig. 6). The voltage drop along the channel, Vx becomes very small when a quantum level is filled, whereas plateaus or steps simultaneously occur in the Hall voltage because the electrons have insufficient energy to occupy cyclotron orbits with larger quantum numbers. It is easy to identify the quantum states: for example, a step occurs at about 32 mV; divide by 5 \( \mu \)A and we have the 6,453.20 \( \Omega \) step. We have just filled all of the possible i = 4 cyclotron orbits.

We can investigate this step in more detail by bucking-out most of the Hall voltage with the potentiometer and reading the voltage differences with the electronic detector. Here is the Hall step on a scale expanded by 4 orders of magnitude (see Fig. 7). The arrow indicates the minimum Vx. There are large thermally-induced voltages in the leads between the sample at 1.5 K and room temperature; they are eliminated by obtaining a Hall step of the opposite polarity (by reversing the current) and by taking half the difference of the two polarities (since the thermal EMFs do not reverse on current reversal). The resulting Hall step is flat to within at least 1 ppm over a gate voltage range of \( 0 \mu \)V. It takes about 1 minute to obtain a Hall step plot at this sensitivity, so we can quickly obtain a lot of information about its overall shape. For precision results, we fix the gate voltage and digitize the data for 1-2 hours.

We have also obtained data on GaAs heterojunctions at Bell Laboratories in collaboration with D. C. Tsui and A. C. Gossard. Here are high sensitivity plots for three Hall steps (see Fig. 8), two for \( i = 2 \) (12,906.40 \( \mu \) steps) and one for \( i = 4 \) (6,453.20 \( \mu \)). (In GaAs heterojunctions we vary the magnetic field rather than the gate voltage to change the quantum state filling factor.) We believe that the different shapes on the sides of the steps are due to inhomogeneities in the sample. Our result for these three samples, expressed in SI units, is: RH = 6,453.2004(11) \( \Omega \) for \( i = 4 \), with a one standard deviation uncertainty of +0.17 ppm. This result is three to eight times more accurate than the other three quantized Hall resistance results obtained by workers in West Germany and Japan.

We have also made measurements on silicon MOSFETs, plus direct silicon MOSFET-GaAs heterojunction intercomparisons, at the Naval Research Laboratory (NRL), and find the values of RH to be sample-independent to at least the 0.1 ppm level of accuracy. However, much to our surprise, there is a problem because the values of RH obtained at NRL were found to be about 0.8 ppm larger than those we obtained at Bell Laboratories. We currently attribute this discrepancy to rectification of electrical noise in the highly nonlinear samples. This assumption is now being investigated in a much cleaner electrical environment at NBS using an 8 tesla magnet.

SUMMARY

If the results confirm our Bell Laboratories measurements, we will have advanced the experiment two of the three orders of magnitude necessary to achieve an SI resistance standard based upon fundamental constants of nature. What about the final order of magnitude? It will not be easy, but we believe that it is experimentally possible. A new measurement system is under construction for our second generation experiments, and a 15 tesla magnet should be delivered within a year. There are certain to be unexpected problems and surprises along the way but we remain optimistic.

ACKNOWLEDGEMENTS

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QUANTIZED HALL RESISTANCE MEASUREMENT

\[ V_H = I_{SD} R_H \]
\[ V_R = I_{SD} R_R \]
\[ R_H = \frac{V_H}{V_R} \]

Figure 5

SILICON MOSFET AT 1.5 K AND 1 ST WITH 5LA DEVICE CURRENT

Figure 6

\[ \Delta V_H \] (20 ppm/div.)

\[ V_G \] (200 mV/div.)

Figure 7

Sample 1 1=2

Sample 2 1=2

Sample 3 1=4

\[ \Delta B \] (Kg)

Figure 8
STATE REGIONAL MEASUREMENT ASSURANCE PROGRAMS

HENRY V. OPPERMANN
National Bureau of Standards
Washington, DC

ABSTRACT

This paper describes the regional measurement assurance programs (RMAPs) that have been established by state weights and measures laboratories. The RMAP technical meetings and round robin measurements are discussed as they relate to the internal measurement control programs of the state laboratories. Results of the internal control programs and round robin tests in mass calibration, problems encountered in conducting round robin tests, and measurement problems revealed by the programs are reviewed. Plans for the expansion of measurement control programs and RMAP round robin testing are presented.

1. INTRODUCTION

For the past decade or so, NBS has encouraged calibration and standards laboratories to utilize formal quality control techniques to ensure that their measurements are sufficiently accurate to meet their needs on a continuing basis. If such techniques are properly employed, it is possible to quantify the uncertainties of the measurements. Monitoring them over time can assure that they remain sufficiently small to meet operational requirements.

NBS has published technical reports describing these methods (1), has held training seminars on various aspects of measurement quality assurance, and is currently providing formal services called "Measurement Assurance Program Services," in several technical disciplines to make it easier for laboratories to implement effective measurement quality control programs. In recent years NBS has encouraged laboratories to implement regional or group programs, often permitting individual laboratories to improve their accuracy capabilities and reduce costs, while at the same time decreasing dependency on interactions with NBS. The Bureau believes that increasing self-sufficiency among these groups of laboratories is healthy. In particular, the NBS Office of Weights and Measures has been working closely with groups of state weights and measures laboratories to help them improve and demonstrate their ability to perform high quality calibrations. The purpose of this paper is to describe the progress that has been made.

The state regional measurement assurance programs (RMAPs) are groups of state and, to a limited extent, private industry laboratories that have joined together to conduct meetings and perform round robin testing to promote uniformity in test procedures and measurement results. The RMAPs, their activities, and round robin results will be discussed below, along with problems revealed as a result of round robin experiments. Because it is essential for a laboratory to have an internal measurement control program in order to obtain maximum benefits from round robin experiments, the internal measurement control program for mass calibration applied by state laboratories will also be discussed.

Measurement assurance is knowing within the limits of measurement process that a measurement is valid with respect to its stated accuracy and precision. This requires that both the standards and the measurement process must be in control. To achieve measurement assurance, a laboratory must have an internal measurement control program to establish the limits for random error in a measurement process and to document the validity of the standards and the laboratory measurements. Once this has been done, round robin experiments can be used to investigate the presence of systematic errors. The RMAP groups develop and coordinate the round robin testing and analyze the data that result from the experiments. The round robin testing is of particular interest to the RMAP members because it provides a definitive means of evaluating their ability to perform valid measurements.

2. CURRENT RMAPS AND THEIR OPERATIONS

Two RMAPs have already been established and two more are in the process of being established. The Northeastern Measurement Assurance Program (NEMAP), with major initiative and support from Toledo Scale Company, Columbus, Ohio, and Troemner, Inc., Philadelphia, Pennsylvania, initiated the state RMAP program when it was established in 1979. As a result of this success, the Office of Weights and Measures (OWM) assisted in the establishment of the Southeastern Measurement Assurance Program (SEMAP) in 1980. Two other RMAPs for the west, with California and Texas as the pivot laboratories, should be operating within the next six months. The NBS objective is for all states to participate in RMAPs distributed across the country. The number of RMAPs and their boundaries have not yet been fixed; the boundaries shown in Figure 1 are only for discussion purposes since the states will make the final decisions.
The RMAP objectives are to:

1. Promote uniform measurement results
2. Provide training through the presentation of papers prepared by members
3. Demonstrate test procedures to assure uniformity
4. Conduct round robin testing to investigate the presence of measurement errors
5. Improve data reporting and analysis
6. Increase communication among metrologists
7. Address mutual problems
8. Familiarize state metrologists with facilities in nearby states

The NE M AP and SEMA P groups meet twice a year, with members presenting technical papers on various segments of the laboratory operation or on test procedures. In this way, relatively new metrologists can learn from the more experienced metrologists, while the discussion of some topics provides a review of material for those who perform some measurements only infrequently. The preparation of these papers is also an educational process for the metrologist because they must review the reference material and prepare themselves to answer questions from their peers. The meetings are held at different sites to provide the metrologists the opportunity to see other laboratories and become better able to assess their own capabilities and facilities.

The standards of mass, length, and volume and the related laboratory equipment are the foundation of the state laboratories. The state laboratories are very similar to the National Bureau of Standards issued similar equipment. Each state, the District of Columbia, Puerto Rico, and the Virgin Islands. These standards were issued from 1966 to 1976. To obtain these standards, each state has to provide an adequate laboratory and metrologist. The OWM provides training for state metrologists, monitors the standards, and transfers NBS expertise to the states. This training and numerous NBS publications are the primary references for the technical papers presented at RMAP meetings.

Many states have purchased additional standards or equipment and offer additional measurement services, but they follow NBS procedures in all measurement areas.

The bulk of the workload in state laboratories is in mass calibration and certification to tolerance classes. The highest precision work is in mass calibration. The primary state mass standards are used in these calibrations. One of the main objectives of the OWM state laboratory program is to establish measurement control programs, combined with the round robin testing coordinated by the RMAP groups, are used to establish measurement assurances in the state laboratories.

3. INTERNAL MASS MEASUREMENT CONTROL

Since an internal measurement control program should be established before a laboratory participates in round robin measurements, the state measurement control program for mass calibration and some of the results will be discussed before results of the RMAP round robin tests are reviewed.

The measurement control program for mass calibration is the first control program implemented in the state laboratories because of the criticalness of the measurements. This program was implemented in 1979. Since virtually all of the mass calibration performed in state laboratories is on weight sets ranging from 100 g to 1 mg, the measurement control program summarized in Figure 2 was implemented.

The objectives of this program are to determine the variability of the mass calibration measurement process, monitor the standards, and document the validity of the measurements, while minimizing the additional workload imposed on the state laboratories. The groups of standards listed in Figure 2 were selected because two balances (a microbalance and either a 100-g or a 160-g capacity balance) are normally used to perform the mass calibrations. The 100-mg and 10-g decades of standards are intercompared on the microbalance, whereas the 100-g decade is measured on the larger capacity balance. The measurements are taken over an extended period of time, with only one measurement made on any given decade in one day. The fact that decades of standards are intercompared means that 12 standards are monitored with only 3 measurements, minimizing the workload for the metrologist. Only these three decades of standards are intercompared because they provide the information needed to document the variability of the measurement process at critical loads for the balance. Not all decades of standards are intercompared, thereby imposing little additional workload.

Figure 3 is an example of a good control chart, showing data collected over a seven-year period. The state had intercompared its standards periodically since they were received. In control charts, we look for stability of the standards and consistency in the variance of the measurement process.

Metrologists performing mass calibrations are to intercompare the decades of standards shown in Figure 2 as part of the calibration process. The results of the intercomparisons must fall within the limits of the control charts to conform and document the validity of the measurements. If any result falls outside the control limits, the calibration measurements reflected by the intercomparison of the standards must be repeated.
A problem arises when state mass standards change, as reflected by the control chart in Figure 4. This problem is much more prevalent than we had expected for approximately 20 percent of the monitored decades of standards appear to be changing. We believe that, in most cases, this problem is occurring because the standards get dirty. Cleaning the standards has brought many of them back into control. According to some state metrologists, several cleaning procedures in an attempt to eliminate this problem.

Care must be taken when computing the variance from this type of data because the variance is affected by the changing standards. On the other hand, the changing standards must be recognized, and larger uncertainty limits will apply if the standards are unstable.

The control chart in Figure 5 illustrates a change in the variance of the measurement process although the mean for the standards remained stable. This has been a relatively rare phenomenon. We did not expect to see much of this because metrologists normally become aware of balance problems soon after they occur. To test for a change in variance, the variance of a new set of data is compared to the variance of previous data through the statistical F-test. Additionally, the old and new means values are compared using the t-test. Following these tests, the control chart data are used to compare the mean value to the NBS reported values to determine if the standards still agree with the NBS values. Standards that do not agree with the NBS values will have to be recalibrated by NBS.

Explanations have not been determined for some of the variability in the data that have been received. Figure 6 illustrates one such case. The metrologist and NBS are continuing to investigate this and several other cases.

The importance of collecting data over time to determine the variance of a measurement process is illustrated in Figure 7. Before this measurement control program was implemented, the states performed several measurements on the same objects in a short period of time (for example, two hours), pooling the results of several measurement sessions to get the process variance. This graph shows that the uncertainty reported by some laboratories increased significantly when the uncertainty was based upon repeated measurements made over an extended period of time. These results were expected by NBS, but were surprising to several state metrologists who had years of data from the previous program.

The bold portion of the uncertainty band is the additional uncertainty present in the process as detected by repeated measurements on the standards over time. The repeated measurements over time more accurately reflect the variability of the measurements process than the previous method the states were instructed to use. This illustrates the importance of establishing a measurement control program that accurately reflects the measurement process.

4. ROUND ROBIN MEASUREMENT RESULTS

Once a laboratory has established the limits of its random error through an internal measurement control program, it is ready to participate in round robin testing. As mentioned earlier, the round robin testing is developed and coordinated and the data analyzed by the RNAP group. One laboratory is chosen as the pivot laboratory and is primarily responsible for the circulation of the standards and the data analysis. The pivot laboratory changes periodically to distribute the workload among the laboratories.

The initial round robin measurements performed by NEMAP and SEMAP were in mass calibration. Some of the data will be discussed. At the present time, NEMAP and SEMAP are also conducting round robin testing in small volume glassware and length.

One problem that has surfaced in the mass calibration round robin is illustrated in Figure 8. In this case, a decade of NBS calibrated standards was circulated among the SEMAP members. This graph shows the results of intercomparing the decade of circulating standards. As is evident from the graph, the standards suddenly changed and eventually began to stabilize at a new value. The cause of this problem has not been determined. The standards were calibrated by NBS following the round robin. The NBS results verified that the standards had indeed changed.

Each standard in this decade of circulating standards was calibrated individually in each SEMAP laboratory against the state standards. The graphs in Figure 9 show the results from the 100-g and 50-g standards. From these graphs it is obvious that the 100-g standard was stable, whereas the 50-g standard was changing rapidly. The data are graphed chronologically, clearly revealing the changes. The state values agreed very closely with the NBS value for the 100-g standard. These graphs are typical of the results obtained by SEMAP in this round robin experiment. These results were better than the author expected. It was thought that more round robin testing would be necessary before such good agreements could be obtained.

The proportion of mass standards that have changed during round robin testing has been
surprisingly high. This is particularly disturbing because the weights used in the round robin testing are typical of the high precision two-piece knob weights used in many laboratories. As a consequence of the changes in the standards used for round robin testing, NWMI is planning to purchase single piece weight sets for the round robin experiments to eliminate or minimize the possibility of unstable mass standards.

The NEMAP group also had circulating standards whose values changed. In this case, the standards were not circulated until several months after the NBS calibration. Figure 10 is a graph of the round robin test results on two 1-kg standards. Based upon the three measurements repeated on standard #3 by laboratories A, B, and C after the round robin had been completed, the standard appears to have changed. There is also evidence of systematic errors in some laboratory measurements. The lack of agreement among laboratories and with NBS indicates that there are problems that must be investigated further. This graph, together with Figure 11, indicates that standards covering a range of mass should be used for both internal measurement control and round robin testing because a laboratory may be in control at one mass value and out of control at a different mass value.

Figure 11 shows the results from a NEMAP round robin on four 20-g standards. In general, the agreement on these standards was quite good but the results for the #2 standard were not consistent. Once again, a definite cause of the measurement problems could not be determined. These results indicate that circulating several standards of the same denomination may reveal problems that a single standard may not reveal. Additionally, this type of round robin experiment lends itself to separating the results from each laboratory into random and systematic error components. This approach is particularly interesting because previously the state laboratories did not have a means to measure these error components.

In addition to the problems revealed by the round robin testing, both NEMAP and SEMAP have encountered a major difficulty in keeping the standards circulating among the laboratories on schedule. Most laboratories have heavy workloads, so circulating standards are commonly delayed in a laboratory until the metrologist can find time to calibrate the weights.

To eliminate this problem, the RMAP members have instructions that, if they are unable to perform the round robin measurements within two to three weeks after receiving the standards, they are to ship the standards to the next laboratory without per improved the scheduling of the testing, but the pivot laboratory must call the laboratories to be sure the standards are being shipped out on schedule.

5. CONCLUSIONS

The results of the internal measurement control programs and round robin testing have revealed problems that were not expected, such as, standards and measurement results that did not agree with NBS values and changing standards. State metrologists are taking corrective action by reviewing measurement procedures and cleaning standards more frequently. The states have generated uncertainty values that more accurately reflect the repeatability of the measurement process. Agreement of measurement results has improved as a result of round robin testing. The programs have increased awareness of the importance of measurement control in state laboratories. For these reasons, measurement control programs are under development in the areas of small and large volume measurement. The regional measurement assurance programs have been very successful and are strongly supported by the participants. It is because of the success of NEMAP and SEMAP that other RMAPs are being established.

Besides providing a wealth of information on the state standards and the measurement processes, the internal measurement control programs and round robin testing provide another major benefit to NBS. The individual laboratories and the RMAPs do most of the work associated with measurement control. This approach minimizes the NBS resources needed in the conduct of these programs. The strength of the measurement assurance approach is that it is applicable to a wide range of measurements and is flexible, permitting each measurement control program to be tailored to the particular needs of a given measurement area. The advantage of a properly designed measurement assurance program is that a large amount of information can be obtained with a minimum amount of work.

ACKNOWLEDGEMENTS

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Figure 1. The map shows the member states of RMAP and SEMAP along with the other RMAP's that are planned.

Measurement Control Program

Standards Intercompared:
- 100 g vs 50, 30, 20 g
- 10 g vs 5, 3, 2 g
- 100 mg vs 50, 30, 20 mg

One measurement per day on any one decade.
All decades may be intercompared on the same day.
Data to be collected throughout the year.

Figure 2. Summary of the internal measurement control program for mass calibration.

Figure 3. This control chart reveals a significant increase in the process variance.

Figure 4. This control chart shows that the standards are changing.

Figure 5. This is an example of a good control chart.
Figure 6: The cause of the changes in these standards has not yet been determined.

Figure 7. The uncertainties reported by some laboratories increased significantly when based upon measurements repeated over an extended period of time.

Figure 8. The Intercomparison of the SEMAP circulating standards immediately revealed that they were changing.

Figure 9. The SEMAP round robin results revealed that the 10g standard was changing while the 100g standard was stable. The first and last values are NBS values.

Figure 10. Apparently these 1-kg standards changed before the NEMAP round robin began but other measurement problems are indicated.

Figure 11. Round Robin results for four 20g NEMAP standards.
APPLICAT I ON S OF DC VOLTAGE MEASUREMENTS
FROM 10 kV TO 150 kV

BARBARA WICKOFF
Rockwell International
Golden, Colorado

ABSTRACT

A calibration and certification capability for direct-current (dc) voltages from 10 kilovolt (kV) to 150 kV has been developed by the electrical standards laboratory. Applications for the measurement of voltage, voltage ratio, and resistance at these voltage levels are described. The measurement processes and assigned certification tolerances for basic reference standards and calibrated devices in a production facility are covered.

INTRODUCTION

A new area of expertise was established in 1981 by the Electric Standards Laboratory at the Rocky Flats Plant for the calibration and certification of dc voltage, voltage ratio, and resistance at high voltages ranging from 10 kV to 150 kV. This service fulfills the requirements to accurately calibrate and certify voltmeters and voltage dividers over this voltage range in the Standards Laboratory in addition to the calibration and certification, in place of high-voltage electron beam welders.

Within the Electrical Standards Laboratory, the prime demand is upon dc or low-frequency quantities. All of the reference standards in the electrical laboratory are certified on a periodic interval by the Primary Standards Laboratory (PSL), Sandia Laboratories of Albuquerque, New Mexico. The Rocky Flats precision dc electrical measuring equipment is calibrated and certified at the Rocky Flats Plant utilizing PSL-certified standards. Because the PSL standards are calibrated by the National Bureau of Standards (NBS), the Rocky Flats standards have traceability to NBS.

I. High-Voltage Standards and Calibration Facilities

A high-voltage calibration facility was established in the Electrical Standards Laboratory. For safety considerations, it is contained in a caged area for separation from the other part of the laboratory. During a calibration, the high-voltage supply and both the reference standard and unit under test are within the caged area. When the high-voltage supply is energized, three interlocks are activated for personnel protection. The control panel for the supply and other measuring equipment are outside of the secured area. A photograph of the facility is shown in Figure 1. Figure II shows the controls outside of the caged area.

Two Spellman resistive voltage dividers serve as standards. One is a 200-kV dc divider with a total resistance of 2,000 megohms and the other is a 100-kV dc divider with a total resistance of 1,000 megohms. Both dividers are calibrated by the PSL for total resistance with a stated uncertainty of ±0.05 percent for a 6-month interval. Each unit was calibrated by NBS prior to calibration by the PSL. The results were in excellent agreement. The total resistance for both dividers has remained well within the certified tolerance of ±0.05 percent assigned by the Primary Standards Laboratory between the PSL calibrations. However, the metal film resistors in these dividers have both temperature and voltage coefficients. The change in resistance with applied voltage and time at 150 kV is approximately +0.028 percent over a 30-minute time interval as vividly shown in Figure III. This dictates accurate correlation of elapsed time with applied voltage during a calibration.

The changes in resistance with various applied voltages and time are shown in Figure III for the 200-kV divider. The data shown on the graph are the results from a PSL certification at voltages of 60, 80, 100, 120, 140, and 150 kV. Figure IV shows the changes in resistance at 60 and 150 kV between PSL calibrations of February 1981 and September 1981. As indicated, differences between calibration results have been less than 0.005 percent over a 7-month interval.

Utilizing two different dividers allows an intercomparison between the standards at 60, 80, and 100 kV by measuring the resistance at working voltages as described in the next section. This serves to assure no changes occur during shipment in addition to indicating no major shift has occurred in either divider between certifications. The intercomparison results for the 100-kV divider, shown in Figure V, are the resistance values as determined by NBS, PSL, and Rocky Flats for 60, 80, and 100 kV over a 30-minute time interval.
II. High-Voltage Calibration of Voltage Dividers for Voltage Ratio and Resistance

Two Universal Voltronics resistive voltage dividers, utilizing wire-wound resistors complete with guard circuits and mounted in oil-filled containers, are used as secondary standards for the electron beam welder calibration and certification. Both units are equipped with the same high-voltage receptacles as the electron beam welders. These dividers are calibrated for voltage ratio by the Rocky Flats Electrical Standards Laboratory. The range of certification of one divider is from 20 kV dc to 60 kV dc for one type of welder, and the range of certification for the other divider is from 60 kV dc to 150 kV dc for another type of welder. The stated uncertainty of the calibration of the secondary standards is ±0.15 percent for voltage ratio over a 12-month interval.

The results of two Rocky Flats calibrations and certifications of voltage ratio for the Universal Voltronics 150-kV dividers are given below in Table A for applied voltages of 60 kV and 150 kV. The root mean square (rms) value for the systematic error is ±0.051 percent derived from the PSL-certified divider uncertainty of ±0.05 percent for total resistance and the PSL-certified decade uncertainty of ±0.01 percent.

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</tbody>
</table>

Table A

Voltage Ratio of X = \( \frac{R_S + R_D}{R_D} = \frac{R_S}{R_D} + 1 \)

where

X = Voltage divider under test
RS = Total resistance of column of standard divider
RD = Resistance of decade box

Because the voltage ratio is dependent upon the ratio of a part of the resistance to the total resistance, if the calculated ratio of a voltage divider indicates a dramatic difference from a previously determined ratio, it is necessary to measure the total resistance of the working divider at working voltages.

A Wheatstone bridge arrangement is also used for this measurement. The schematic of the connections is shown in Figure VII. After the voltage is applied, the decade resistor is adjusted to a point of balance as indicated by the null detector. The unknown resistance is calculated from the product of known certified values of the standard divider, R_s, and the corrected value of the certified decade resistor, R_2, divided by the standard resistor, R_1.

\[ R_X = \frac{(R_s)(R_2)}{R_1} \]

The resistance of the tap resistor can be measured with a calibrated Wheatstone bridge, applying the same voltage across the tap resistor during the measurement as occurs when the total resistance is measured. For example, if 150 kV is applied to 150 megohms, and the tap resistor is
1500 ohms, the voltage across the tap resistor would be 1.5 volts.

Measuring the total resistance at working voltages is almost a requirement for any unit contained in oil. If the oil becomes conducting due to moisture or other materials, current leakage paths occur, with a resulting change in ratio. For this reason, any oil-filled dividers in use at Rocky Flats have the oil filtered to remove moisture and other material in addition to periodic replacement with new oil.

Other types of voltage dividers such as the Fluke 80E, 10-kV divider are calibrated and certified utilizing the PST-certified Spellman dividers and the ESI decade resistor. Again, both units are connected in a Wheatstone bridge configuration as described earlier. The voltage ratio for this type of divider is certified to ±0.1 percent.

III. Utilization of Calibrated High-Voltage Standards

Within the high-voltage calibration facility, electrostatic voltmeters ranging from 1 to 3 kV are calibrated and certified using a 10K to 1 divider. All high-voltage equipment is enclosed within the caged area during the calibration. The electrostatic voltmeter is set to several cardinal points, and the true or standard value is calculated from the product of the voltage divider ratio and the observed value of the digital multimeter connected to the divider output voltage tap.

The main high-voltage calibration and certification requirements at Rocky Flats involve electron beam welders in production areas. For this calibration, the Universal Voltronics dividers are transported to the production area. A special high-voltage cable connects the electron beam welder voltage supply to the voltage divider. A grounding strap is connected between the ground on the voltage divider and the ground on the welder supply. A calibrated differential voltmeter is connected to the tap point of the voltage divider.

Each welder has predetermined levels of voltage requiring calibration and certification. The electron beam welder voltage is set to the required voltage setting. After stabilization, the actual voltage is calculated from the product of the voltage indicated on the calibrated voltmeter and the certified ratio of the standard voltage divider. The procedure is repeated for the other required levels of voltage.

Figure VIII shows a divider connected to a 60-kV electron beam welder. Figure IX shows the other divider connected to a 150-kV electron beam welder.

IV. Conclusions

Due to the new high-voltage facilities and standards, PML can now calibrate voltmeters beyond 1 kV—a new service vital to certain areas of the Plant. In addition, the calibration of the high-voltage section of the electron beam welders at high voltage has improved. Future plans include (1) an error analysis of the results of these calibrations to indicate the true calibration tolerance applicable to each welder at various voltage settings; (2) evaluation of the effect upon the ratio of the secondary standard divider when the applied voltage of 150 kV is lowered to 20 kV and reset to various voltage levels over a short time interval to simulate actual conditions that occur when welders are being adjusted during a calibration; and (3) improved accuracy in measuring the current of the electron beam.

The Rocky Flats Physical Metrology Laboratory would like to acknowledge the guidance and technical support of Mr. P. J. Spellman of the DC High-Voltage Laboratory of the Sandia Laboratories in developing this technical calibration service.
TOTAL RESISTANCE MEASUREMENT OF VOLTAGE DIVIDER
TEST EQUIPMENT VENDOR QUALITY COMMITTEE

LAWRENCE A. POTARO
Teradyne, Inc.
Boston, Massachusetts

ABSTRACT

This paper will describe the events that led to the formation of the Test Equipment Vendor Quality Committee. The Committee’s goals, accomplishments and possible expansion through a nationwide affiliation will be discussed.

I would like to take this opportunity to introduce you to the Test Equipment Vendor Quality Committee. The Test Equipment Vendor Quality Committee consists of a group of New England companies that are concerned with the quality of test equipment that is being offered today.

It is our intent to work with our vendors to help bring about the desired improvements in the quality of their products through the interchange of quality data. Our member organizations represent a wide cross section of the electronics’ community covering most applications of instrumentation.

Since our Committee was founded some 17 months ago, we have succeeded in doing more than just getting the attention of vendors, who, prior to the Committee’s foundation, had been impervious to our individual complaints regarding the quality of their products.

We have established a formal channel for information interchange with most of our vendors via the Committee Chairman and a corporate level quality control manager who serves as our vendor delegate. It is the vendors’ delegate who receives all quality inputs that are pertinent to his organization and ensures that the information is distributed to the proper departments. The delegate also keeps the Committee informed as to the progress of the corrective action. The strategy is to eliminate organizational bureaucracy by channeling all quality inputs to one central office where dissemination to the proper division can take place.

Our Committee elects officers for a term of one year; a Chairman, Vice Chairman, Secretary and a Data Manager. The Data Manager compiles individual company reports into a summary report that is distributed to active members. We meet once per quarter at a time and place selected by the Chairman. The Chairman sets an agenda for the meeting pertaining to current and developing issues.

We consider membership open to companies that purchase test or calibration equipment and are willing to actively participate in the pursuit of the Committee’s goals.

During the relatively short period of time since the Committee’s formation, limited progress has been made, but I am confident that given a reasonable amount of time, solid improvements will be measurable. I base my confidence on over seven years’ experience as the Test Equipment Buyer for the Teradyne Corporation in Boston, Massachusetts.

The added responsibility of Buyer, along with my primary duty as Standards Lab Manager, has afforded me the unique opportunity to travel frequently both nationally and internationally on pre-purchase quality audits. I have witnessed the quality control programs of both foreign and domestic manufacturers, enabling me to make an objective comparison as to which instrumentation is likely to provide my company with the lowest cost of ownership.

The vast majority of foreign manufacturers that I visited had well-documented, meaningful programs in place and had, or were about to, enter the U.S. marketplace. Our domestic vendors, on the other hand, were addressing quality control in an arbitrary manner with most of their programs self-serving.

I have confronted our domestic vendors many times with my findings and presented them with solid data to support my views; but they remained impervious to my inputs. That was all true up until a year and a half ago when a sudden change in attitude was evident. It was about that time when I again visited vendors across the country to fill them in on the objectives of our newly-formed committee. I expected another bout with indifference; instead I was greeted with open arms by 100% of the vendors I visited. I met with people who were newly appointed to quality control positions; people who were sensitive to the issues by virtue of their careers. I don’t know where they had been hiding them for so many years, but hide them they did.

Impressive capital outlays dedicated to quality control were visible and
implementation of documentation had begun. It was obvious to me that they still had a long way to go in order to close the quality gap, but the commitment had been made and that was the most important step.

What caused the radical change in attitude towards quality control? The Test Equipment Vendor Quality Committee? No, the drastic change in philosophy is being forced on them by foreign competition, especially from the Japanese who are rapidly making their presence known in the high-technology area.

What can the Test Equipment Vendor Quality Committee possibly do to help our vendors compete with the incoming barrage from Europe and Japan? The answer to that question depends on how constructively they utilize our data base and the quality/quantity of data they receive from us. That is where we seek your help. It is very difficult for a small region like New England to provide enough data to impact events on a national scale. Our data base can be diluted by virtue of the vast amount of test equipment sold on a national scale, versus a single region.

If we could convince you to establish committees similar to ours in every region of the country, then dramatic results are sure to be realized. All that is required of you is a very small time commitment and a little enthusiasm to get the ball rolling in your region. Our Committee has already laid down the groundwork by adopting a charter that you could use as a guide.

The time commitment consists of keeping records of the data to be collected and a few hours once every quarter for a meeting with your colleagues. I realize that there are areas in the Southwest and other regions of the country where great distances exist between companies. That is a problem, but we can discuss possible solutions to the logistical issues.

If we look at the cost/benefit ratio of a national effort, then inaction cannot be rationalized. In the worst case, very little improvement will take place and our high-technology firms will follow the same path as the auto industry. In that unfortunate case, American jobs will be lost and communities will continue to break down; your time and effort would have gone for naught. On the other hand, if by your participation in a committee similar to ours you can help to influence the quality and reliability of the test equipment your company purchases, you could provide them with a cost savings that could help to finance growth and investment that would ultimately benefit you.

If by your participation in a committee you could provide our vendors with enough quality inputs to enable them to make rapid adjustments to their quality programs, it would help to secure their marketplace and the jobs of their employees. My scenario can go on, but in the final analysis I believe that positive results can only be realized if there is a concerted effort of national proportions by the vendors and committees such as ours.

Slogans like "Buy American" cannot work in the long run unless we back up our slogans with quality products. The following is a list of the type of data the Committee collects for summary:

1. Pre-purchase information such as vendor quality programs and philosophy. The sophistication of incoming/in process and final and test programs along with the thoroughness of documentation.
2. (a) In warranty/out of warranty turn around time
   (b) Multiple returns for the same failure
   (c) Not living up to warranty claims
   (d) Adjustment to warranty and loaners for time lost to warranty repair
3. Incoming acceptance figures
4. Life cycle costs:
   (a) Failures 1-5 years; 5 years and greater
   (b) Availability and quick response for parts
5. Individual company reject forms
6. Memos for inherent design problems
7. Manuals and documentation problems
8. Availability of local service
9. Training seminars (vendor), training aids and video tapes

If you are interested in the possibility of establishing a committee in your particular region of the country, please do not hesitate to contact me anytime throughout the duration of the symposium, or at the Committee's mailing address below.

Hopefully, there is enough energy out there in the audience to get this program started on a national scale immediately. Maybe by next year at this time we would have scheduled our first meeting of national delegates to coincide with the NCSL Symposium.

Test Equipment Vendor Quality Committee
P.O. Box 6132
Nashua, NH 03060
THE DISTRIBUTED NATURE OF EMF IN THERMOCOUPLES AND ITS CONSEQUENCES

ROBIN E. BENFIELD
CSIRO Division of Applied Physics
Sydney 2070

Presented by:
Dennis H. Gallagher
Leeds & Northrup Co.

ABSTRACT

The distributed nature of emf generation on thermocouples is explained. It is shown to have vastly different consequences for both the use and the calibration of thermocouples when compared to the more conventional but fallacious view that emf is localized at junctions. It is suggested that users are better served by the notion that all measurements are essentially wrong. These practices lead to more reliable measurements and hence clear the way for a greater use of thermocouples in quality control processes.

INTRODUCTION

Throughout industry the thermocouple is one of the most used devices for temperature measurement and yet it is possibly the least understood: a situation that frequently leads to serious error. The basis for such a misunderstanding can be related to the apparent simplicity of the thermocouple itself, being just a pair of leads with no hint as to its "modus operandi." Other electrical forms of temperature detection such as those utilizing resistance elements, thermistor pellets, IC chips and transistors, etc., consist, in each case, of a clearly defined sensor attached to a set of leads. The sensor produces the desired signal and the leads convey the information to an instrument. One is thereby tempted to regard the thermocouple tip as being the source of most, if not all, of the observed emf. Indeed, such an erroneous concept is common in the literature and was highlighted in Australia in 1966 (1) when it was shown that all the observed emf is developed in the thermocouple leads and that no emf can be generated at the tip. This important point is repeatedly emphasized at the biennial Division of Applied Physics Pyrometry Schools (2) and elsewhere (3).

This attitude to thermocouples, based on the realization that it is the wires rather than the tip that generates emf, necessitates a different practical approach to both the use and the calibration of thermocouples. The consequences of this are treated later in this paper.

It is popularly held that the total effective performance of a measurement system, such as a thermocouple with an instrument and associated compensation leads, etc., is given simply by the manufacturer's tolerances, and that such a performance or accuracy will continue until some self-evident failure occurs, at which time the replacement of the relevant component or a service adjustment would be called for. According to this approach, errors are either those inherent aspects already covered by the specified tolerances or those large self-evident changes in response seen at failure. It will be shown that this view is incorrect and dangerous, that many errors are independent of the stated tolerances, that they are not self-evident and that in practice errors of measurement can easily exceed the assumed accuracy level by some orders of magnitude.

Temperature measurement should be allowed to have a greater impact on quality control. It is suggested that much of the misuse and lack of use in this area can be attributed to a misunderstanding of the nature of thermocouples and of measurement—a situation that this paper should help to rectify.

THE NOTION OF DISTRIBUTED EMF

Electrons have both charge and thermal energy and so their movement, by whatever means, produces both an electric current and a heat flow. The electrons thus form a link between electrical and thermal processes: indeed it is this link that gives rise to three thermoelectric effects. Two of these processes (Peltier and Thomson effects) deal with the heat generation that always accompanies the flow of electricity. They occur because the thermal energy (entropy) associated with a drifting electron cloud (electric current) depends both on the material through which it passes and on the temperature. These processes have no significant bearing on the operation of a thermocouple because of the small currents (ideally zero) that are involved. The thermocouple is a direct consequence of the third thermoelectric process, the Seebeck effect. Indeed the Seebeck effect is the emf generation that occurs in a thermocouple as it responds to the temperature interval it spans.

As could be expected, all three effects are related to each other mathematically (4), a fact that led to an unfortunate history
for the thermocouple. In 1940 (5) the equations relating them were wrongly taken as a clear indication that the Seebeck emf is due, at least in part, to emf production at thermocouple junctions. This view has continued in various forms throughout the literature (6,7,8,9) despite the fact that the Seebeck coefficient is known to be a bulk property (10) and that emf cannot be generated at the junctions (11,12).

The emf produced by a thermocouple is due entirely to the Seebeck emf developed along its wires, but how and where is this emf produced? Put simply, emf production is a natural consequence or side effect of the attempt by electrons to manage the business of heat conduction. Wherever and whenever regions of wire (any wire) are not uniform in temperature, heat flow and emf production occur. The Seebeck emf is therefore distributed along each wire in a manner that conforms with the temperature profile experienced by that wire. Although this is a far more complex notion to grapple with than the common one of a localized junction’s emf, it can be reduced to a simple approximation in most cases (see Figure 1). The thermocouple, in bridging the temperature step from ambient at its cold junction to the temperature at its tip, experiences most of this change in a relatively short length (e.g., within a furnace wall). The two remaining sections, within the furnace hot zone and at ambient, are relatively uniform in temperature (or should be) and hence produce but a small part of the total observed emf. Most of the thermocouple signal is therefore localized in regions of greatest temperature gradient or heat flow.

Notice in Figure 1 that just as the heat flow at any point in the thermocouple is proportional to the temperature gradient (slope of the temperature profile) at that point, so also is the developed emf/unit length (electric field).

CONSEQUENCES OF A DISTRIBUTED EMF

The question as to where a thermocouple’s emf is generated is a vital one. The shift in emphasis away from the tip results in a complete change in attitude to both the use and the calibration of thermocouples (see Table 1). Users still following the notion of junctions are concerned that foreign substances, such as solder and oxides, introduced during tip manufacture, will upset emf production. They may conduct regular inspections for tip contamination with no attention given to the wires, and if the thermocouple calibration drifts, the change is attributed to the tip. The simple remedy of cutting off the offending tip and rewelding may be followed by disappointing results. Alternatively, the thermocouple could be sent to a laboratory for recalibration without realizing that such a calibration is misleading and pointless, as is shown later.

Certainly the thermocouple tip is important. It needs to survive mechanically and maintain good electrical and thermal contact between the two conductors. However, its importance, thermoelectrically, is slight and the user is advised to think of the temperature profile and hence identify those regions that produce most of the emf. It is the condition of the wires in these regions that matters most (Table 1).

The notion of distributed emf must be taken a stage further before arriving at a practical approach to use and calibration. Because the emf is a distributed one, every part of the thermocouple has a role to play. There is, therefore, a need for the wires to be thermoelectrically homogeneous, i.e., for the Seebeck coefficient of each wire to be the same everywhere along its length. It turns out that only if the thermocouple is homogeneous does it behave as one would like, i.e., as a sensor that depends on the tip and cold-junction temperatures but not on the actual shape of the temperature profile itself. Unfortunately, real thermocouples have inherent inhomogeneities when new and become worse with use. The initial level of inhomogeneity is small enough to be of little concern, being roughly +0.01 - 0.1% of emf, but the inhomogeneities that develop from later use may easily cause errors of 10% or more. These levels of inhomogeneity simply reflect the degree to which a thermocouple’s output depends on the temperature profile (Table 2). If the tip temperature is held constant as a thermocouple is progressively inserted into a furnace its calibration will fluctuate or change by an amount of this order.

The Seebeck coefficient is very sensitive to effects such as contamination, oxidation, strain and change in the nature of the metal lattice brought about by heat treatment. Since all these processes depend on temperature, a non-uniform change will take place in a thermocouple because of its non-uniform temperature profile. The Seebeck coefficient will change by an amount that varies from point to point along the wires depending on the different temperatures experienced. The wires thereby acquire a thermo-electric imprint or signature that characterizes the particular thermal history being accumulated. This signature or inhomogeneity is an unwanted complication in temperature measurement but it can be exploited under certain conditions when it is realized that it is, in effect, a thermoelectric photograph and, as such, could be later examined with a suitable scanning device in order to give a plot of the temperature profile that produced it. In practice, however, every attempt should be made to minimize the effects of a thermocouple’s signature which usually has as its cause a complex history involving heating and cooling.
cycles as well as changes in (tip) operating temperature.

A new thermocouple placed in a fixed position in a typical industrial furnace will begin life with a homogeneity and the observed emf will be a unique function of tip temperature assuming, of course, that the cold junction has been compensated for. As shown in Figure 2, a new thermocouple has a featureless signature and its emf distribution simply reflects the position of the main temperature gradient region. As time passes, the developing signature produces a change in the emf distribution (Figure 2) and a net change in thermocouple output. The latter change is seen as an in situ drift in calibration and even though it was produced in response to the temperature profile, its magnitude does not depend on the shape of this profile. New thermocouples cut consecutively from the same reel and placed in different furnaces operating at the same temperature would have similar initial calibrations and would drift by similar amounts. But the emf distributions and the signatures would, of course, be different depending on the various temperature profiles that apply. The effects of a growing signature, as shown in Figure 2, would be typical of a nickel-based thermocouple but with some local contamination introduced near the center of the temperature-gradient region for emphasis. Small fluctuations due to inherent or "as new" inhomogeneity are omitted for clarity.

A thermocouple fixed in a particular application and undergoing an in situ drift, as just described, is in a unique situation. The temperature that caused the change in signature is the one reacting with it to produce the emf distribution and hence the total output sensed by the instrument. The re-positioning of the thermocouple at a different immersion or in a different furnace would change its calibration since the established signature now reacts with a different temperature profile (see Figure 3). The degree of change to be expected from re-siting of a thermocouple is difficult to quantify as it depends on so many factors. However, there is one rule of thumb that seems to apply in most cases, namely that the change in calibration, relative to the initial "as new" state, of a re-sited thermocouple can be at least 5- to-1 greater than the in situ drift that occurred before the move. Such a change assumes that the section of wire most affected by the earlier history now extends over the main temperature-gradient region (see curve A, Figure 3). At the other extreme the calibration can revert back to its "as new" value (curve B, Figure 3) if the immersion is increased sufficient to place only unused wire in the gradient region.

For example, a 0.5 mm wire diameter (24 AWG) type-K thermocouple, fixed in position while monitoring a temperature near 1100°C, will drift by the equivalent of -10°C in 100 hours (4 days) [14]. If the thermocouple is now withdrawn sufficiently, the output will rise a further -40°C. Since high temperature degradations in nickel-based alloys are roughly proportional to the inverse of the wire diameter [14] the performance of other gauges can be readily judged. The above values apply to clean oxidizing conditions. Far greater changes are likely in vacuum, a reducing atmosphere or one with a low but significant oxygen content ("green rot"). By contrast, the changes in the platinum-based thermocouples, types B, R and S, while in a clean oxidizing atmosphere are considerably less, being almost two orders of magnitude smaller for the example given above. However, this potential performance is realized only when extreme care is exercised and in the industrial context they should be treated as being prone to significant drift and hence suffer the 5-to-1 degradation when moved. This is because of the extreme sensitivity to impurities and the difficulty of avoiding contamination in the long exposure times encountered in industry.

The fact that a thermocouple can develop a significant thermoelectric signature must inevitably lead to a more complex notion of calibration. The concept of junction eaf suggests the simple calibration procedure of simultaneously measuring the developed emf and the single temperature that produced it. The use of equalizing blocks and other special features of calibration furnaces are merely to make the measurement of this tip temperature easier. As already noted, however, the thermocouple output depends not only on tip temperature but also to some extent on the shape of the temperature distribution along the wires. This suggests, in principle at least, that the temperature profile in the calibration furnace be "tuned" to exactly match that experienced by the thermocouple in its previous application—an impractical proposition. Alternatively, it suggests that a two-pronged approach to calibration be taken. When a thermocouple is known to be homogeneous, in the practical sense, it may be calibrated out of its position of use, i.e., in a calibration furnace, since its featureless signature produces a small (<0.1%) response from the temperature profile. On the other hand, a thermocouple suspected of having experienced a drift in calibration or showing some sign of contamination should be checked only in situ, i.e., in that temperature profile which produced the change.

Calibrations of the first type, sometimes referred to as "laboratory calibrations," are worth considering for new wires, for thermocouple types B, R and S provided prior use is limited to 1300°C, and for base metal types when limited to 250°C. However, one can never be sure that the assumption of homogeneity is valid, particularly if the thermocouple has had a previous use. Furthermore, if the calibration uncertainty
is to be realistic the level of inhomogeneity should be assessed to allow calculation of its contribution to this uncertainty. Hence a laboratory calibration should not only be restricted in this application, but involve changes in the immersion to enable an assessment of inhomogeneity.

**ERRORS OF MEASUREMENT**

A common approach to measurement is to assume the result is right until proven otherwise. By "right" I mean that every component of the measurement system is operating as it should (within specification) and that if everything looks OK, it is. In other words, if there are any errors present outside those covered by the manufacturer's tolerances they would be self-evident by their very nature, i.e., erratic and/or large enough to produce a ridiculous result. In my view this is a somewhat naive attitude that encourages one to overlook various possibilities of error, and is based on the incorrect assumption that the stated tolerances do in fact cover all possible discrepancies in measurement. It is not generally realised that with all components functioning normally and with a stable instrumental reading the measurements can still be out by a considerable extent (±10-100°C, say). The three most common reasons for this are as follows:

1. The signal produced by a thermocouple is small relative to other electrical signals in its vicinity, e.g., a thermoelectric signal equivalent to 1°C is at least 6 million times (135 dB) smaller than the AC mains voltage and yet a good quality instrument would have but 60 dB normal mode rejection capability. The possibility of AC pick-up should therefore be given much attention, particularly since an instrument may easily respond to AC by a shift in reading without a significant increase in fluctuation.

2. Whereas the tolerances stated for instruments are meant to apply for a reasonable period of time, and in any case they can be adjusted back of course at will, those given for thermocouples are not. They apply only to the unused state and, as was mentioned above, one should expect a steady growth in thermoelectric signature as well as the possibility of more dramatic changes due to contamination. Errors of 1-10% from such causes are common (even 50% is possible) and should be compared with +0.75%, the manufacturer's tolerance for standard grade wire.

3. Temperature measurement using a thermocouple is at best just a measurement at the tip. An assumption of equality is then required to relate this temperature with some other more useful parameter, such as the average temperature of a heat-treatment load. It is because this assumption is ignored that considerable error can creep in. For example, it is common to choose the position of a thermocouple within a furnace simply on the grounds of keeping it out of the way and hence avoiding breakage. There is a general tendency to gloss over the fact that an infinite variety of temperatures are to be found within a furnace. Even the best of furnaces (e.g., air-recirculation types) would have a uniformity of no better than ±1°C when empty. The industrial thermocouple, because of its heavy gauge, shielding and short immersion, could be much cooler than the air temperature nearby. Alternatively, because of radiation from the heaters, it could be much hotter. Furthermore, the presence of the load itself could greatly disturb the level of uniformity.

The "she's right until proven otherwise" approach is a natural partner to the practice of not supplying an estimate of uncertainty whenever a result of measurement is expressed. After all, the measurement is "right"! In practice, however, a statement that the temperature is 480°C, for example, is virtually useless unless accompanied by an expression of uncertainty to indicate how reliable it is. It could be quantitative (+10°C, say) or even qualitative ("roughly 480°C") when the value is not critical. When a quantitative statement is made it should be given in terms of a suitable probability level [2] because otherwise the magnitude of the uncertainty is arbitrary.

It is suggested that a far safer and more useful approach is to be continually conscious of the axiom that "every measurement is wrong!" This has the advantage of being a constant reminder to watch out, and it naturally leads to the question of "by how much is the result wrong?" and hence to some form of uncertainty expression. Even if the latter is only a rough estimate, it nevertheless represents how good the measurement was thought to be at the time and my prove invaluable on some future occasion. A simplified approach to the estimation and treatment of uncertainties in temperature measurement is dealt with elsewhere [2]. The somewhat novel attitude to measurement suggested above better emphasizes the true nature of measurement. In terms of effort, measurement should be an exercise in seeking out and minimizing errors and then in estimating the total effect of those that remain. In other words, in assessing how wrong the measurement result was. Obtaining the actual reading is the easiest part.

Three major sources of error have been mentioned already. There are many others [2], but there are two in particular that are
worth mentioning here because of their frequent occurrence. One is the human observer who is capable of all sorts of mis-reading and transcribing errors and the other is the compensation/extension lead. This lead is not only an inherent source of error, which becomes large (-5-10°C or more) when the "head" temperature is high, but if it is of the wrong type, the error could be -10-100°C, or if connected with the wrong polarity (easily done because of the variety of color codes), the possible error is 20-100°C.

The potential sources of error should be given careful consideration in each measurement; this is a particularly difficult requirement for the once-off measurement in which the equipment is set up for a single result and then dismantled. If doubts arise later, it is often not possible to repeat the event. It is more common, however, for the industrial thermocouple to have a temperature-monitoring role in some heat-treatment or thermal-conditioning process where it is effectively at fixed immersion and forms part of a long-term measurement set-up. In such cases the measurement system remains indefinitely to be checked and re-checked at will. Furthermore, the advantages of in situ calibrations can be exploited. Such a calibration is a check on the total package and includes all errors present at the time. It involves the effective calibrations of all components of the system under the exact conditions of use, including the systematic error arising from a growth in thermoelectric signature. Naturally an in situ calibration transfers the responsibility of measurement from the user of the fixed installation to the relative "specialist" called in to conduct the check using especially-looked-for apparatus, including a suitable reference thermocouple, and hopefully the necessary skills.

CONCLUSION

It has been explained that the emf in a thermocouple is not localized at the junctions but is distributed throughout the circuit especially in the main temperature-gradient regions. Because of this notion the types of remedy that can usefully be applied when faults develop and the requirements of meaningful calibration are somewhat different from conventional industrial practice. The reader is asked to pay greater attention to those regions of wire that contain most of the temperature drop spanned by the thermocouple. In most applications there is only one such region, e.g., where the wires pass through the furnace wall.

This is not to say that temperature changes taking place at or near the tip are not important. The thermocouple output is after all the integrated effect of all the emf along the wires and includes that developed near the tip. If, for example, the tip is fluctuating in temperature because of the dynamic state of its environment, the corresponding fluctuations in temperature profile in the wire adjacent to it instantaneously produces a corresponding change in emf. Hence this section of wire from which little emf is derived produces most of the fluctuation seen by the instrument. The main temperature-gradient region would, of course, experience far less change because of its isolation.

Misunderstanding as to the nature of both the thermocouple and measurement accuracy leads to a wasteful and inefficient use of temperature measurement in industry. The not infrequent lack of correlation between the apparent temperature during heat treatment and the assessed properties of the end product creates a lack of confidence in, and a reduced role for, temperature measurement. Temperature is often treated as just one of those somewhat arbitrary process parameters that are continually tweaked to give the desired outcome, as judged at the end product state. Unfortunately, this places a greater reliance on the quality-control checks applied to specimens sampled from the end product. Temperature measurement should be used to improve production efficiency by reinforcing this quality-control procedure. Since the temperature required to achieve desired physical properties is known, its correct measurement during the heat-treatment process becomes excellent insurance that the sought-after properties are being produced.

REFERENCES


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**TABLE I**

The Consequences of Two Notions on Thermocouple EMF

<table>
<thead>
<tr>
<th>Construction &amp; Care of Tip</th>
<th>Common View (Localized)</th>
<th>Correct View (Distributed)</th>
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<td></td>
<td>VITAL</td>
<td>minor importance</td>
</tr>
<tr>
<td>If TC drifts</td>
<td>yes</td>
<td>not unless</td>
</tr>
<tr>
<td>If TC drifts</td>
<td>yes</td>
<td>not misleading</td>
</tr>
<tr>
<td>Care of Wires</td>
<td>minor importance</td>
<td>VITAL</td>
</tr>
</tbody>
</table>

---

**TABLE II**

Dependence of EMF on Temperature Profile (inhomogeneity)

<table>
<thead>
<tr>
<th></th>
<th>Dependence on Temperature Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal TC (homogeneous)</td>
<td>0</td>
</tr>
<tr>
<td>New rare metal TC</td>
<td>$-0.01%$</td>
</tr>
<tr>
<td>New base metal TC</td>
<td>$-0.1%$</td>
</tr>
<tr>
<td>Used base metal TC</td>
<td>$-0.1-10%$</td>
</tr>
</tbody>
</table>

**FIGURE 1** - DISTRIBUTION OF EMF IN THERMOCOUPLES
FIGURE 2 - BUILD UP OF SIGNATURE WITH USE

FIGURE 3 - THE EFFECT OF MOVING A USED THERMOCOUPLE
THE PRODUCTIVITY - QUALITY CONNECTION

JOSEPH J. IERVOLINO
Lockheed Electronics Co., Inc.
Plainfield, New Jersey

ABSTRACT

One of the key reasons for productivity problems in the United States is the quality of our industrial output. Quality and productivity go hand-in-hand. Producing more—at the expense of quality—is no way to increase productivity.

Decreased efficiency, wasted money, and lower productivity are by-products of not having done it right the first time. Simply stated, improved productivity and improved profitability are the inevitable result of improved quality. Management will better understand the value of its quality programs if it's made to realize the true cost of not having them.

It is the prime responsibility of the quality professional to develop a meaningful quality measurement system to identify major obstacles to productivity improvement resulting from waste, delays, poor workmanship (i.e., rework, scrap, supplier rejects and late deliveries, etc.). Reduction in any of these factors will improve productivity and herein the connection is made.

INTRODUCTION

I am delighted to have this opportunity to speak to you today about a tremendously important subject—productivity and quality.

I wish to explore with you the concept that productivity and quality are intimately related and that wide application of quality insurance techniques will provide dramatic increases in productivity. Such increases are essential to the long-term growth, profitability, and economic stability of any business and to the United States industrial economy. Productivity and quality share a fundamental relationship. Increasing the quality of goods and services promotes increases in productivity. In the United States, it is estimated that 15 to 40 percent of manufacturer's productive capacity may be devoted to resolving quality problems. When we consider the cost of scrap, rework, warranty and liability costs, these nonproductive costs to industry become truly staggering.

The increased prices necessary to pay for these costs become unjustifiable to consumers who relate price with quality. Recent studies have indicated that consumers perceive the quality of American products is not as high as that of our competition, most notably the Japanese.

We have already lost large market segments to the Japanese and West Germans, in the automotive, appliance and consumer electronic industries. Even in industries where we have held technological leadership, such as the semiconductor industry, insiders agree that the Japanese are making significant inroads. In fact, recent Japanese success with the 64k bit RAM places them in contention for leadership in this market. The commercial aircraft arena has also witnessed change as Boeing is being challenged seriously by a European consortium, Airbus Industries.

These facts should not be new to us, for few subjects have been more studied by both government and industry recently than the subject of productivity. The time, however, has come to act. Not only has the time arrived, but to some extent, it has passed us by. While study commissions and government committees can have positive effects, the responsibility for promoting quality awareness and sound quality programs falls on all quality professionals. The responsibility for engineering quality as a world marketing strategy rests with top management.

I would like to share with you, today, some thoughts regarding the relationship of productivity and quality. The specific areas I will be addressing which help to make this connection are as follows:

- The issue of productivity and the nature of change in productivity programs.
- Natural barriers to making the productivity—quality connection: namely, the search for simple solutions and the lack of management awareness.
- Different approaches to the productivity—quality connection in the United States and Japan.
- How quality can contribute to enhancing management awareness using measurement as a source of management information.
- Shifting quality from implicit to explicit responsibility.
- The 1980s or, where do we go from here?

I am of the firm belief that the fundamental issues underlying the quality management philosophy which I propose must be addressed by industry management if we are to realize that quality is to become a significant
contributor to productivity improvement in the 1980s.

THE ISSUE OF PRODUCTIVITY

One of the greatest problems facing U.S. management today is the decline in our productivity growth rate. This problem has many roots. It is not simply a result, as many people believe, that people don’t work as hard as they once did. It is, today more than ever, a broad strategic issue. It will and must concern the highest levels of management, labor and government.

The focus of productivity efforts has changed considerably over the past 50 years. In the 1940s and 1950s the measurement of productivity focused on output, or the production of as much as possible in as short a time as possible. In the ‘60s and ‘70s quantity was no longer as important as economic efficiency, or production at the lowest possible cost.

Now, in the ‘80s, given the constraints imposed by regulation, inflation, shifts in job skill levels, service and quality demands, and greater international competition, the productivity emphasis is increasingly on effectiveness. Our performance will not only be judged on whether we produce the right things, but whether we produce things right and at the lowest cost.

The public has come to expect a great deal more from a corporation than simply large quantities of efficiently produced goods. Corporations are increasingly being challenged in the marketplace on the quality of the products and services they offer. Productivity programs, therefore, are changing in their interest, definition and focus. In 1973 only 16% of all U.S. companies had productivity programs. Today, nearly five times that number have installed, or are in the process of implementing, productivity improvement programs. So the good news is that the declining rate of productivity growth which has been talked about so intensely over the past several years, is now widely recognized in industry as a problem. The bad news is that like many quality programs, talking about it does not necessarily improve it. In recognition of this, the scope of many productivity programs has broadened substantially. Originally viewed as a direct labor issue, current programs extend to indirect labor, clerical and knowledge workers, and, in most cases, management. Productivity programs consider more than just people. They include materials, quality, capital, technology, information and motivation, to name a few.

In keeping with this broader approach to the productivity problem, I suggest that we examine new approaches. One such approach, I believe, is the thorough examination of the productivity-quality connection. We ought to manage our quality programs for effectiveness and bottom line results.

THE SEARCH FOR SIMPLE SOLUTIONS

In my opinion, one barrier to solving the productivity problem facing U.S. management is our proclivity to search for simple solutions. My objection is not that all simple solutions are bad—they have their place—but there are no quick-fix pills we can take for improving productivity. Improvements in productivity, like improvements in quality, cannot simply be mandated by management. They must be cultivated through the difficult process of problem solving. The real difficulty in this area is not in understanding that there is a problem, but in solving it.

Our approach to value analysis and reduction in product cost focuses on the plant and, in fact, does result in driving these costs down. Meanwhile the so-called “hidden plant” costs increase astronomically in the areas of quality costs, such as rework, scrap, warranty, service, engineering change orders, software changes, purchase order changes, supplier rejects and late delivery, inspection errors and quality labor costs. There is today no more effective way to improve productivity than for quality programs to convert these “hidden plant” costs to productive use.

We tend to have less interest in why we have achieved good results than why we have had bad results. In fact, this situation places in question the whole concept of management by exception. Where is the curiosity and desire to determine why some countries and companies are really doing better? We are more interested in goals and plans than we are in results when things are going poorly, and we are only interested in results when things are going well.

Consider the barriers to management awareness, for example:

1. Productivity, much like quality, has not been a discipline in the business world.

2. Members of management lack hands-on experience with the leverage points of productivity...as is true in the case of quality.

3. Too much of a short term vs. long term goal orientation.

4. Top management often tries to achieve too much, too fast, by proceeding through the awareness, planning and detailed assessment phases required for adopting a successful approach to improving productivity and quality.
5. The responsibility for productivity or quality improvement is delegated to an individual or unit without the involvement of top management.

6. Productivity, like quality improvement, is implemented as just another program.

These barriers are certainly not all inclusive.

HOW TO MAKE THE PRODUCTIVITY/QUALITY CONNECTION

This topic, the "Productivity/Quality Connection," is not as visible, glamorous or intriguing as Quality Circles, Employee Suggestion Systems, or styles of management, which seem to be major topics of conversation throughout the U.S. today. I want to share with you my perception of the connection.

Dr. Edward Deming, known by many as the father of the Japanese quality movement, comments, "nobody seems to understand except the Japanese that as you improve quality, you improve productivity."

If we think for a moment, the operative word is "understand." If something is good and we understand it, then perhaps we take action and see results. In Japan, quality and productivity are almost synonymous. They see the by-product of quality as productivity and they have taken action and achieved results.

In the U.S., quality and productivity are too often regarded as distinctly different issues, having different meanings. To a significant degree, quality is not defined or measured. I submit to the Quality professionals seated here today, whose fault is this?

If in Japan the terms productivity and quality are nearly synonymous, in the U.S. they appear to be driven by different drivers. The question arises, shouldn't there be just one driver? And if we believe that quality begets productivity, who in the corporate structure should that one driver be?

I know of some examples that suggest who that driver should be. ITT - 1965 to 1979, Harold Geneen, Chairman and President. Phil Crosby, Vice President For Quality in 1970 reported that defect prevention saved ITT $579 million in 1978. General Instrument Corp. - Chairman, Frank Hickey, is so convinced that quality, straight through to the bottom line, is the key that he said "managers are graded on the quality of the products for which they are responsible."

There is so much that is abstract about quality that unless you put it in profit and loss terms, it isn't as motivating. In short, quality must be portrayed in a manner relevant to top management.

There are other companies that recognize the leverage for productivity improvements through a quality focus. The big three automakers (perhaps these days not so big), and others like Texas Instruments, National Semiconductors, Hewlett-Packard, and the Tektronix Corporation all have something in common—they are in highly competitive markets.

The purpose of these examples is to point out that the industries which are focusing on quality for productivity improvements, like the automobile, electronic, and semiconductor industries, are those which are being aggressively challenged in the marketplace.

People talk and write about many issues that hold us back from significant improvements in the quality area: management, union organization, lifelong employment, Quality Circles, etc. But let us focus, for a moment, on just two: total product quality and management.

Let's take total product quality first. More often than not, engineering conducts its design reviews, rarely in practice are they conducted in a meaningful way. Next consider our production people, they set schedule goals for production and delivery. Quality people set goals of ensuring product quality. There is a natural tendency for an adversary relationship to develop here. This is pervasive in our society—reference government vs. industry, labor vs. management, engineering vs. manufacturing, etc.

Now management's turn. Without a doubt, both production and quality organizations should be moving toward a common goal, that is, "producing a product that meets specifications, at the lowest reasonable cost." Consider the additional strife created by a poorly designed product, and this, I submit, is a major challenge facing us today. There is no question that engineering, production and quality working together as a team can achieve a worthwhile common goal. We are not, however, moving toward a common goal. The end result can be easily predicted. If we in management go to our manufacturing arena and see what is happening among the engineers, production, and quality people, we'll readily make this observation.

Observe specifically what happens when it's time to give the product its final blessing before it goes out the door. Without an attitude that reflects quality (total product quality) as everyone's responsibility, there is little hope for our ability to
maximize smooth flowing, functioning processes with maximum productivity at minimum cost.

Dr. Deming states it succinctly as, "you don't get ahead by making products and separating the good from the bad, because that's wasteful. It wastes time of men who are paid wages, it wastes time on machines and it wastes materials." That is a result of not doing things right the first time. It is not an example of total product quality responsibility.

Let me give you some startling information; more than half of your total quality cost is generated by the inspection process. Unfortunately, you can never catch everything matter how much you inspect. A recent government study of 21 contractors revealed they were processing over 370,000 material review actions per year. One company was processing over 1800 material review actions per month with a scrap and rework cost of $275,000. This equates to over $3 million per year. Is any company so big now that it can't be bothered with $3 million? Certainly not!

Japanese firms have learned to design and build quality in, while in the U.S. firms are still trying to inspect it in. Unfortunately, neither the marketplace nor our company can afford the price tag of inspecting quality into make up for inefficient management, engineering and manufacturing processes.

Perhaps it is a reality in the U.S. that participation and responsibility for quality is still, in most cases, the responsibility and property of the quality department. In other words, maybe we still have the wrong driver to make productivity and quality synonymous.

Perhaps if we had a more specific definition of quality this wouldn't be the case? We could better make the connection and take more advantage of this productivity leverage point.

I would like now to deal with productivity measurement and quality.

PRODUCTIVITY MEASUREMENT AND QUALITY

I believe developing measurements of productivity is essential to getting our manufacturing and service industries back on the track of higher productivity growth rates. Measurement transforms rhetoric to definition which can then be measured. How do we know where we stand if we don't have a credible and reliable productivity measurement system? One measurement, taken from thousands of corporate annual reports in this country, might be "profitability." But does profitability tell the whole story considering U.S. competitiveness in the international marketplace? Perhaps we need to examine why we are profitable and if we are on stable ground.

Many rationalize today that productivity measurements commonly used do not take quality of output into account. Maybe we have been looking at the wrong part of the productivity equation. Let us focus now on the input.

The first question is, do we agree that waste and delays defy measurement in our country? Let us respect Deming's wisdom and assume it is true even though it may require an assessment of our own people and processes. Now that we have made this assumption, what do we do next? If we want to improve, we need to measure where we are today, set some goals and track our performances. Further, we need to measure and track quality to ensure it is increasingly productivity, which we define as output over input where input equals labor plus capital plus material plus energy. It is positively clear to us, that a clear definition of quality is required before we can understand why improved quality gets us improved productivity, then we can take actions to improve.

As straightforward as this philosophy may seem, it cannot work without a basic quality measurement system to identify the controllable elements of failure that affect productivity and cost improvement. The exact potential for improvement cannot be known until these measurements are established and analyzed. This is perhaps the most basic and vital role of the quality function.

Now the question is what do we measure so we know we are improving productivity? This is the control point on the critical path to successful results.

First, Rework:
For every defect or error that we have to do over, it takes extra labor or machine hours. Extra hours decrease productivity.

Scrap and Waste:
Focusing on eliminating scrap and waste allows us to decrease the material required and that's increased productivity.

Warranty Repairs:
Focusing on measuring for a reduction in warranty repairs can result in decreased material costs and labor costs.

Service:
Focusing on measuring for their reduction in increased productivity results in decreased labor costs again, and in increased productivity.
Engineering Change Orders:
Focusing on doing it right the first time in design and development could be one of our bigger leverage areas.

We all recognize that some Engineering Change Orders (ECOs) are necessary but the question is how many. The U.S. Navy had a $2.8 billion overrun charge against it from private shipyards several years ago. The first Trident submarine, the Ohio, was a more recent example.

Complaints from the shipyard were that so many Engineering Change Orders came down during the shipbuilding process that missed completion dates and cost overruns were a natural result. Naturally, there are those who argue over the extent to which those changes caused the cost overrun. Here, I believe, responsibility was the real issue.

What about the effects of poor production quality on Work In-Process (WIP) inventory? In examining these two factors, however, it is easy to overlook the effect they have on each other. It is possible to significantly improve the WIP inventory picture by improving product quality. The synergistic effects of doing both at the same time can yield a powerful boost to your efforts to cut costs and improve productivity.

Excessively high WIP inventory can indicate production problems. Design deficiencies, poor yields and excessive rework all cause bottlenecks and hence inflate WIP. Even when high WIP is due only to poor production planning and scheduling, you can expect quality problems due to shipping panics, high overtime, customer threats of cancellation, and other disturbances.

Other than totally ineffective production planning and control, no single factor causes WIP inventory to be excessive more than the lack of production quality. With the high costs of money these days, inventory carrying costs can be substantial for extra WIP inventories that are maintained because of down time, unscheduled processing, or extra lead time. Thus it can be seen where the impact of poor quality can be enormous with respect to productivity and financial performance.

What about supplier rejects and supplier days late on delivery? Providing materials any other way but right the first time and on time must become unacceptable to us. Before we issue a contract to the supplier with the lowest bid, we should consider some frequently overlooked hidden costs, such as: supplier control costs, costs resulting from delayed receipt of material and when materials are not to specification, those costs associated with rework and repair of discrepant material. Only when we add these costs to our initial purchase costs will we know the true cost of a given supplied commodity—perhaps, when we add in the hidden costs to be purchased material cost, we may find that the supplier with the apparent lower material cost was in fact not the low bidder.

Suppliers must be made to know that we expect their material to be to specification and that we will accept nothing less. When our suppliers universally supply material that we can depend on, that is to specification, we then can reduce our inventory backlog, thus reducing our inventory costs.

Most, if not all, of us are aware of the tremendous productivity—quality improvements realized by Quasar, their supplier certification program took seven years of hard-nosed leadership to have achieved its present state. Another example often referred to as a benchmark for suppliers, is Toyota's "just in time" production system. Clearly, Japan has organized and mastered the control of supplied materials.

I hope returning to basics in this way enables us to understand better how quality improves productivity, the importance of measuring both, and how this basic figure can allow us to focus our efforts. Management must be made to understand what is involved in the never-ending cycle of improved methods of product design, of manufacturing, testing, consumer research, and redesign of its products. We need to focus our efforts on all these elements simultaneously before diving into quality circles or some other techniques. What good are quality circles if we don't understand the whole system?

The overall objective of the preceding section was to define elements for measurement and fix responsibility for corrective action. Rework, scrap, inspection errors and inaccuracies, warranty, services, engineering change orders, software changes, purchase order changes, supplier rejects, supplier days late as well as cost of inspectors, quality engineers, audit teams, and other are all part of the equation. Perhaps we have neglected to focus on the quality impact of the input side of the equation for too long.

I also hope the "Total Product Quality" concept provides insight as to why engineering, production and quality organizations must get back on track working together toward a common goal, rather than going their separate ways in an adversary manner. And that requires top management involvement. It is not important who it is, but rather that someone is driving for results.
OUTLOOK FOR THE EIGHTIES

The United States has the potential for an explosive renewal of its quality and productivity leadership in the decade of the 1980s. It will require, however, a recommitment by the people who hold our success in their hands—U.S. industry top management. We should not expect miracles—the road will be hard and long—top management will need our help. We need to make sure we know what to copy from Japan. We need to understand what is involved in the never-ending cycle of improved methods of design, manufacture, test, consumer research and redesign of products.

The first step of this process is understanding and believing that productivity and quality are intimately related. We need to identify sloppy, slipshod work. We must refuse to accept mediocrity throughout our organization and do something about it for the long run. We must adopt a "no-waste" ethic. Any time and material lost to poor quality must be considered a part of waste. The Japanese goal is to eliminate waste in the U.S. we believe perfection is unattainable—this must change. This means long range defect/error prevention attitudes. It will require a productivity perspective based on awareness, strategic planning, and assessment followed by tactical planning, execution and follow-on efforts.

We will witness a changing of attitudes regarding the role of the quality function in productivity improvement and the interactions that can exist among the competing alternatives. It is then that see industry management desiring and supporting quality efforts.

The quality function will then play a true managerial role. It must communicate its efforts with respect to how it can affect productivity. Measurement systems must be put in place to determine the effectiveness of engineers, manufacturing and quality in the realm of their quality efforts. What is basic to quality efforts is to determine the proportions of prevention, assessment and failure efforts that are expended in achieving the productivity improvement task.

In this latter area, I believe quality professionals must take heed. They must prepare themselves for a change of image. They must examine their present levels of technical competence and the industry and society credits of their organization (i.e., degrees, ASQC certifications and the like). They must ask what kind of performance measurement system is in place—if any; Is it effective? Can it be used as a management tool? The quality professional must examine the quality of all documentation generated by the quality organization including reports, memos, and letters. Do they tell us something? Can they motivate someone to improve quality and productivity? Keep management informed.

Finally, the quality professionals must examine the proliferation of quality procedures with emphasis on reducing or consolidating them—when were they last reviewed, how good are the procedural interfaces etc. These items which I bring to your attention may seem overly simplistic; however, it has been my experience that most quality managers are unprepared to raise themselves from the "nuts and bolts/digital go/no-go" aspect of the quality business. This in fact leads to the supression of quality's contributions to the enterprise—a feeling shared by many members of industry management. In short, we must promote a state-of-the-art image within our quality organizations, so that we may project this image outwardly.

Improving the measure of professionalism of our organizations will give a much needed boost to the credibility of the quality function. Perhaps, then, management and others will begin to listen, understand and believe.

I also believe American workers of the eighties will be standing by waiting for the opportunity to get involved in this productivity challenge. When all else is said and done, the American workers are proud; they want to be members of a winning team. They realize where their paychecks come from. They are ready to focus in and be constantly alert to an kind of problem that could adversely affect the quality of the product. This will happen when we start measuring and put the data on visible charts so we can all see how we are doing and task ourselves with goals of where we want to be. The workers' participation, I submit, is one of our most important leverage points in the eighties.

In summary, productivity can be measured and so can quality. Quality can be measured and it affects the same equation; all we have to do is roll up our sleeves, get down into the plants and start making some measurements and asking the right questions. Yes, we can reverse the trend of declining productivity growth rate and declining product quality. It's in each of our hands. It will take getting down to the manufacturing floor, asking the people what needs to be done, and they will tell us. I also submit that after we've done that, we will be glad we did. We'll also see the most satisfying results when top management gets involved in measuring those quality or non-quality cost elements and challenging for improvement.

The message I've tried to convey today is that the pendulum is about to swing from the far left where quality is considered by top management as abstract and obscure to the far right, where it is a significant
contributor to a company’s success. Now I
don’t mean to suggest that all quality pro-
essionals seated here today should run out
tomorrow and implement broad sweeping
changes in their quality programs. What I
am saying is that the time is ripe for the
quality professional to make his presence
known. We in quality should not keep the
responsibility for quality to ourselves.
We should examine what we are measuring in
the way of quality performance and ask our-
selves what are we saying and does our
measurement system satisfy the objective of
providing information to management. If it
doesn’t. I suggest you select a small area
of it (cost center) and make changes—
inform manufacturing, solicit their in-
puts. You may be surprised at the coopera-
tion you get. If you don’t have a measure-
ment system at all. I suggest you move to
implement one—start out in a small scale,
prove your theory and then proceed to make
change and “grow your system.” Consider
Gray’s Law: “Purity, precision and procras-
tination kill a measurement system.”

Remember, you need a measurement system to
identify and correct your non-quality prob-
lems as much as you need a roadmap to find
your way through an unfamiliar city. Mea-
surement directs the attention of management
to what is wrong. Measurement does not so-
lve problems, it merely provides the data
which allows decisions based on facts
rather than speculation and hunches.

Give it a try, you may find management
highly receptive to your information. This
high order of receptivity may be an indica-
tion that management has awakened to the
productivity-quality connection, or perhaps
it is a result of the competition driving
them to do so.

I submit to you that “opportunity knocks”;
it is the task of all industry profes-
sionals to grasp this opportunity for
improving productivity and quality. To
those members of top management seated here
today: You have the challenge to develop
your thoughts and actions.

PRODUCTIVITY INDEXES THAT CAN BE INFLUENCED
BY A QUALITY FUNCTION

Some of the productivity indexes that are
easily measurable and can be directly
affected by the quality function are as fol-
lo ws:

1. Scrap Costs/Total Sales
2. Rework Costs/Total Sales
3. Warranty Costs/Total Sales
4. Product Liability Costs/Total Sales
5. Quality Department Costs/Total Sales
6. Number Design Changes/Total Sales
7. Testing Costs/Total Sales

Some of the productivity and business
indexes that are easily measurable and can
be directly influenced by the quality

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<tr>
<td>1. Percent Market Share</td>
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<tr>
<td>2. Profit/Employee</td>
</tr>
<tr>
<td>3. Profit/Share</td>
</tr>
<tr>
<td>4. Total Sales/Employee</td>
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</tbody>
</table>
| 5. Number of Production Hours/Unit of Pro-
| 6. Maintenance Costs/Units of Product |

Some of the quality of worklife indexes that
are measurable and can be directly affected
by the quality function are:

1. Hours Spent in Prevention Activities/
   Total Hours
2. Proportion of Absenteeism
3. Number of Employees Terminating Jobs/
   Year

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A RESISTANCE MEASUREMENT ASSURANCE PROGRAM WITH COMPUTER PROCESSED HISTORIES

ROGER ALCANTARA
San Jose, California
CARL QUINN
SIMCO
Santa Clara, California

ABSTRACT

Over the years, instrument manufacturers have improved our electrical measurement equipment's accuracy in such a way that, roughly speaking, an order of magnitude has been gained each ten years. This accuracy was attained by circuit design and hardware improvement. In many cases, the cost of such hardware increases asymptotically as state-of-the-art precision is approached. The typical measurement standards laboratory is reaching physical limits, such as thermal noise and other effects, that mask useful information contained in measurement data. It is, therefore, safe to assume that the past rate of improvement will be diminishing in the future.

New efforts to extract information from data marred by noise has paid off by the use of waveform analysis and statistical inference. These methods were beyond practical reach until the advent of computers. We now see equipment that includes microprocessors and necessary firmware, that perform many of these complex functions. Ironically, the greatest advance has been made in the so-called "test equipment," where the size of the market justifies the development costs, and not in "electrical standards equipment," where it is, academically speaking, most needed.

The same old tools are very often inadequate for providing the low uncertainties required by industry.

INTRODUCTION

This paper briefly describes a resistance measurement assurance program maintained at SIMCO electronics. Initially the program consisted of maintaining data in logbook form. In 1981, software was developed that would produce measurement reports, history reports, and plots with control limits. The accumulation of over a decade of historic data permits us to review computer analysis of that data which was collected by the manual system. A similar scheme may be used for capacitance, inductance, voltage, and other single parameter standards.

The generation of these reports in a timely and accurate fashion becomes of paramount importance for a commercial calibration laboratory.

SELECTION OF THE COMPUTER

The choice of a TRS-80 was made because other machines of this kind are used throughout the SIMCO laboratory for automated measurements, so compatibility was a main consideration. The function of this computer is that of "data manager," as opposed to the other computers whose functions are "control and data acquisition." All data is entered manually and how this data is obtained is irrelevant for the process to work. Most microcomputers with 48k bytes of random access memory and two disk drives with 1/4 megabyte of "on line" storage should be suitable.

In retrospect, I must say that these would be minimum systems to perform the task as designed. Big system users may find that computation speed and mass storage access are too slow using an interpreter language such as BASIC and 5 inch floppy disks. Hope is within sight though, for there are already hard disk drives and compilers available that greatly mitigate these problems.

SOFTWARE ARCHITECTURE

The application software is arranged into two separate Data Base Management Systems. The Standards Data Manager resides in the secondary drive and it is always "on line" regardless of the programs used to certify other equipment. The Unit Tested Data Manager resides in the primary drive and contains all the units tested for the same type of instrument and the same type of test. This is a general arrangement used for non-adjustable, single parameter standards such as inductors, capacitance, voltages produced by chemical cells, etc. In our particular case the Unit Tested Data Manager contains data used to generate measurement reports for STANDARD RESISTORS.

These two programs have all the features of commercially available data base management systems. Figure I and Figure II show data entry forms as they appear on the screen. The Unit Tested Data Base is then utilized by the Measurement and History Report Generator Programs. The Measurement Report Generator requires a job number as input. The program then searches the data bases for
additional information, computes temperature corrections and prints the report (Figure III).

The history report generator requires manufacturer, model and serial number as input. After searching the data base for all matching records, it sorts these by date and considers the last six, but not less than three, for computation. A mean linear regression is performed and the report is printed with temperature and time corrections charts and a control line plot (Figure IV and V).

Emphasis was placed on simplicity. Insertion of the appropriate disks and the push of a button produces a menu in plain English, keeping operators away from system commands that are cumbersome and many times dangerous. The arrangement allows a way to infinitely expand the system with new types of tests, and it also provides protection by fragmenting the software into many units that operate independent of each other. 

MEASUREMENT ASSURANCE

If measurement is thought of as a product, ways must be found to ascertain the quality of such product. A decision process has been implemented at SIMCO by which the acceptability of the product is established. Measurement assurance is the quality control of measurement. In the case at hand the process is rigidly established, most of it implicit in the software (Figure VI). The product is information regarding electrical parameters of a resistor, one of the most important of which is time stability. Single measurements cannot provide such information. Hence the need for historic data. In the absence of quality control of measurement, historic data is still useful to determine repeatability. But one thing is to determine repeatability, another is to control it. The acceptability of measurement is done at two levels. The first is a verification of the repeatability of the measurement. A series of sequential readings provides this information. Values "at the time of measurement" are thus obtained. The second verification consists of checking whether the average of the readings falls within the control limits established. Historic data is required for this second phase. If the criteria is satisfied, the measurement has passed the quality control test.

DEFINITIONS AND CONCEPTS

A MEASUREMENT is a procedure by which a measurement value and a measurement uncertainty is obtained, usually by a series of comparisons between a known standard resistor and an unknown resistor whose values we are trying to establish.

The TREND LINE is defined as the line in the value-time plot that produces the minimum variance with respect to the measurement values. The TREND LINE VALUE is the value defined by the trend line for a particular date. The MEAN PERIOD is the average time between calibrations.

The MEAN PERIOD UNCERTAINTY is the standard deviation of the measurement values about the trend line times three. INTERCOMPARISON UNCERTAINTY is calculated as three times the standard deviation of the unknown resistance values obtained from sequential intercomparisons. UNCERTAINTY AT THE TIME OF MEASUREMENT is the period uncertainty of the resistor used as standard plus the intercomparison uncertainty. The ADMINISTRATIVE PERIOD is the period assigned between calibrations.

CONTROL LINES are the lines in the value-time plot within which a new measurement value must fall to be considered under statistical control. Many ways may be devised to define control lines. At SIMCO they are obtained as follows:

UPPER CONTROL LINE: At the time of the last measurement, draw a point at the trend line value plus the measurement uncertainty. At the time of the last measurement plus one mean period, draw a point at the trend line value plus the period uncertainty. The UPPER CONTROL LINE is defined by these two points.

LOWER CONTROL LINE: At the time of the last measurement, draw a point at the trend line value minus the measurement uncertainty. At the time of the last measurement plus one mean period, draw a point at the trend line value minus the period uncertainty. The LOWER CONTROL LINE is defined by these two points.

The region within the control lines represents a PREDICTED UNCERTAINTY which is a function of time. The period uncertainty may be used as the predicted uncertainty, which is safe except in the case where the mean period is shorter than the administrative period.

CONCLUSION

The use of this program can improve significantly our methods by the use of controls. Values accepted by the original manual method are obviously out of control and they are now part of the data base. Some of these values were supplied by other primary laboratories. This triggered the use of this scheme for incoming inspection. Validating suspicious data after the fact would be arbitrary since we really cannot say whether the resistor really changed value or it was a measurement error. Since resistance calibrations are done annually, application of controls has not yet noticeably affected period uncertainties. Nevertheless, a great reduction of total uncertainties can be expected in the future.
MEASUREMENT ASSURANCE PROGRAMS IN A FIELD ENVIRONMENT

WOODWARD G. EICKE, JR.
THOMAS LINDY
National Bureau of Standards
Washington, DC

BRIAN MOORE
CHARLES BROWN
U.S. Army Trade Support Group
Redstone Arsenal, AL

ABSTRACT

To date most measurement assurance programs have been carried out between the National Bureau of Standards and various standards laboratories in the U.S. For the most part, these have been conducted at the highest accuracy levels. In the spring of 1982 the Army Missile Command and NBS conducted two special, lower accuracy, measurement assurance programs (S-MAP) at a field location at Redstone Arsenal, Alabama, in the areas of dc voltage, dc current, dc resistance, ac voltage, and ac current. This paper describes the experiments performed, presents the results, and discusses them in light of a number of externally imposed constraints.

INTRODUCTION

The extensive use of automatic test equipment (ATE) and precision electronic instruments and equipment in the United States has necessitated new concepts to ensure measurement accuracy. This new generation of equipment, unlike early instrumentation, is characterized by complexity. It is often comprised of numerous sophisticated electronic instruments operating as an integral unit, often under computer control, and is frequently used in field locations where the environment is uncontrollable. Traditionally, in order to support the accuracy requirements of such equipment it is calibrated in the standards laboratory; however, such calibrations may be meaningless when the instrument is returned to its normal operating environment. To obtain a meaningful calibration it is often necessary to calibrate the instrument in its normal operating environment. Such an on-site calibration requires that standards, auxiliary equipment and personnel from the standards laboratory be transported to the site, perform the necessary measurements, analyze the data, and report the results. In addition, they must measure the transport standards to ensure that they have not changed during the calibration interval. This process is essentially that of a measurement assurance program (MAP). Unfortunately, most MAPs are operated among NBS and standard laboratories, are aimed at the highest level of accuracy attainable for a given measurement area, and are usually limited to certain specific values of standards. Such MAPs employ sophisticated transport standards, are labor intensive, and require extensive data analysis. Because of their complexity, present MAP techniques are not readily applicable to modern electronic equipment requiring many calibration points or to calibration equipment which is located in less than an ideal environment. Therefore an extension of the present MAP techniques is needed to serve as a link between the standards laboratory and equipment requiring field calibration. MAPs for this type of activity should be efficient, require a minimum of equipment and manpower, be tailored to the particular instruments and locales, and should provide calibration results in real time (on-site).

Early in 1982 NBS and the U.S. Army Missile Command (MTCOM) at Redstone Arsenal, Alabama, as a part of a larger project, carried out special measurement assurance programs in five electrical measurements areas:
- dc voltage, dc current, dc resistance, ac voltage, and ac current. The nature of the NBS involvement provided an ideal opportunity to explore the possibility of developing MAPs between the standards laboratory and instruments located in a field environment. The objectives, within the available resources, were to (1) investigate the feasibility of carrying out on-site calibrations, (2) identify measurement problems, (3) make preliminary assessment of uncertainties of such calibrations, and (4) investigate the use of desk-top computers for on-site data acquisition and processing.

At Redstone Arsenal (RSA), most of the work described was carried out at a field site on the arsenal grounds. The building had only limited temperature and humidity control, and no control over the electrical environment. In addition it was necessary to frequently move the measuring equipment from one location to another within the building. Short-term temperature variations were as large as 6 deg. C and relative humidity exceeded 65 percent on several occasions. NBS hand-carried transport standards, digital multimeters, and auxiliary equipment to and from Redstone on two occasions: in late March and in mid-May 1982. All measurements at Redstone had to be made within a specific time frame and had to be integrated into a larger on-going Army program at the field site. The NBS transport standards, with one exception were measured in terms of local standards at the field site which were provided and calibrated by the Electrical Standards and Development Laboratory, U.S. Army TMOD Support Group. All NBS transport standards were calibrated by NBS before and after each trip. At Redstone measurements were performed using the procedures described in this paper. The results of all measurements described in this paper are expressed as the differences, d.o., in parts.
per million, between the measured values at RSA and NBS obtained from the equation
\[ \frac{X_{RSA} - X_{NBS}}{X_{NBS}} \times 10^6 = \text{d.d. ppm}, \]

where \( X_{RSA} \) and \( X_{NBS} \) are the measured values in terms of local Army standards and the NBS standards respectively. In this paper we will present an overview of the experiments, pertinent results, and give some conclusions.

**DC MEASUREMENTS**

The NBS dc measurement package contained (1) a temperature-controlled standard cell enclosure with four cells, (2) a voltage divider, (3) standard resistors, (4) six-digit digital multimeters (DMM), and (5) auxiliary equipment which included a desktop computer, low thermal leads, and switches. The DMMs had 0.1 microvolt resolution, an input impedance in excess of 100 megohms, were IEEE-488 bus compatible, and were used as the measuring instrument for all dc measurements at Redstone. In order to minimize the effect of parasitic emfs in the measuring instruments and some of the leads, two observations were taken, one with the DMM connected normally and the other with its input leads reversed. Typically the observed differences rarely exceeded 2 ppm. At NBS the linearity of the DMMs was determined to be approximately within ±3 ppm over the full scale. For the lower three digits the linearity was within ±1 ppm or less.

**DC VOLTAGE:** Two different experiments were conducted to determine dc voltage. The first was a direct intercomparison of the RSA local voltage standard and the NBS transport standard, the other a comparison of two measuring systems at nominally 1, 10, and 100 volts. Using standard Volt Transfer Program techniques (VTP) the four cells in the RSA standard cell enclosure were directly compared to the NBS transport standard using a DMM to measure the differences between the cells connected in series opposition. From the measurements at Redstone and NBS the following results were obtained:

**March 1982**  
\[ \text{ERSA - ENBS} = 0.8 \text{ ppm} \]

**May 1982**  
\[ \text{ERSA - ENBS} = 0.7 \text{ ppm} \]

The observed differences are consistent with those of the normal VTP even though the settling time was short and only one set of measurements were made at Redstone. The estimated uncertainty at the three common voltage levels in this experiment is no greater than 1.5 ppm.

The second experiment consisted of RSA and NBS making concurrent voltage measurements using stable voltage sources on several days. RSA and NBS each used a precision voltage divider and a DMM as the measuring system. The voltage dividers were connected to the source and the divider output (at the 1 volt level) was measured with a DMM having 1 ppm resolution. Using their respective standard cells as the reference the RSA and NBS DMWs were calibrated in terms of the local units of voltage. RSA and NBS each calculated a voltage in terms of their respective standards and the differences in these calculated voltages are summarized below.

<table>
<thead>
<tr>
<th>Nominal Voltage (V)</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+0.2</td>
<td>+0.2</td>
<td>+0.2</td>
<td>+0.2</td>
</tr>
<tr>
<td>10</td>
<td>-3.1</td>
<td>-2.7</td>
<td>-0.7</td>
<td>-2.17</td>
</tr>
<tr>
<td>100</td>
<td>-0.5</td>
<td>-7.1</td>
<td>-3.1</td>
<td>-3.57</td>
</tr>
</tbody>
</table>

At the 1 volt level the results are consistent with the differences from the cell comparison. At the other voltages there is clearly an offset which may be voltage dependent. This technique is very simple, can be carried out quickly, and could lend itself to automation.

**DC CURRENT:** A traditional approach to measuring dc current was used and consisted of simply measuring the voltage drop across calibrated resistors mounted in a temperature-controlled oil bath. RSA and NBS each concurrently measured nominal currents at the 0.1 A, 0.0001 A levels in terms of their local standards (resistance and voltage). Current measurements were made in March and May using several stable current sources. The results of these measurements are summarized below.

<table>
<thead>
<tr>
<th>Current Level</th>
<th>Difference (ERSA - ENBS) in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 A level</td>
<td>ERS - ENBS = +42 ppm</td>
</tr>
<tr>
<td>0.1 A level</td>
<td>ERS - ENBS = +9 ppm</td>
</tr>
<tr>
<td>0.0001 A level</td>
<td>ERS - ENBS = +14 ppm</td>
</tr>
</tbody>
</table>

The large difference at the 10 A is attributable to the self-heating of the 0.1 ohm resistors. The difference at 0.1 A, in as far as can be determined at this time, was mostly caused by thermals at the potential terminals and temperature gradients in the resistor caused by problems with temperature control and oil level. At the 0.0001 A level a 10 k ohm resistor was used as the shunt. From other work we concluded that leakage problems in the oil bath could cause differences of the magnitude observed. Certainly if more accurate current measurements are required than self heating, leakage, and thermal problems must be addressed.

**DC RESISTANCE:** Resistance intercomparisons were conducted at the 1 ohm, 10 k ohm, and
The NBS transport standards were two RSA type 10 k ohm, and two NBS constructed 10 M ohm resistors which were intercompared with the RSA local standards. All resistors except the two 10 M ohm were in an oil bath operated at a nominal temperature of 25 deg. C. At the one ohm level the resistors were measured by applying a constant current of 100 mA to the three resistors connected in series (one RSA and two NBS) and measuring was used in the ohmmeter mode. In each case the value of the transport standards was calculated from the relationship

\[ R_x = R_s \left( \frac{E_x}{E_s} \right) \]

where the subscripts s and x designate the RSA standards and the NBS transport standard, respectively, E the DMM reading, and R the resistance. The May measurements were performed when the bath temperature sometimes exceeded 25 deg. C. The results are summarized below.

<table>
<thead>
<tr>
<th>Nominal Resistance</th>
<th>( R_{\text{RSA}} - R_{\text{NBS}} ) in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ( \Omega ) ohm</td>
<td>+0.8</td>
</tr>
<tr>
<td>10 ( \Omega ) ohm</td>
<td>+0.8</td>
</tr>
<tr>
<td>10 M ( \Omega ) ohm</td>
<td>+0.8</td>
</tr>
</tbody>
</table>

During March, measurements were made when temperature conditions were relatively stable, there was little variability among the runs, and the measurement process was well behaved. In May, temperature and humidity conditions were far more variable and there was much more variability in the results. In all cases the measured differences were consistent with the estimated uncertainties for the measurements made. The difference between the two NBS transport standards, at the 10 M ohm level, when measured using the DMM, at both Redstone and NBS, consistently differed from those obtained by the normal NBS calibration process.

**AC MEASUREMENTS**

**AC VOLTAGE:** The NBS transport standard was an unmodified commercial ac-dc thermal transfer standard which was hand-carried between NBS and Redstone. Two types of measurements were made at Redstone: (1) the direct measurement of the ac-dc differences of the transport standard and (2) a comparison of the Army field site measuring system and the NBS transport standard. In both March and May, the ac-dc differences of the transfer standard were measured directly in terms of the Army standards in their standards laboratory rather than at

\[ V_{\text{RSA}} - V_{\text{NBS}} \]

was calculated for each measured value. The mean difference for all voltage observations was +23.2 ppm and the standard deviation of a single observation was 7.5 ppm. Although well within the NBS assigned uncertainty of 50 ppm the observed difference is larger than can be accounted for by the standard deviation of the measurements made. It was not possible, within the time available, to investigate the origin of this difference.

\[ D_{\text{RSA}} - D_{\text{NBS}} \]

where the D's are the mean ac-dc differences measured by the respective laboratories.

The mean of the three is -0.1 ppm and the pooled standard deviation is 5.0 ppm. The agreement of ac-dc difference is remarkable considering the fact that the NBS uncertainty assignment for this type of calibration is 50 ppm. Furthermore the NBS transport standard remained quite stable over the whole period of the work. These results suggest that a MAP service for ac-dc difference might easily be developed.

The May comparisons at the field site of the RSA measuring system and the NBS transport standard were performed at the same voltages and frequencies as were used in March. However, the May observations included measurements at the 50 volt level. Measurements were made as nearly concurrently as practical using the two systems and stable ac and dc voltage sources. After applying the appropriate corrections to the measurements the difference

\[ V_{\text{RSA}} - V_{\text{NBS}} \]
AC CURRENT: The measurement of ac current was performed using the ac-dc transfer standard and three current shunts designed to operate with the unit. In May the transport standard and the 3 A, 0.1 A, and 0.01 A shunts were calibrated as a unit in terms of the Army primary standards. Except for the 3 A shunt, the applied current was the rated shunt current. In the 3 A case, the Army used 2 A and NBS used 3 A. The mean difference between the Army and NBS corrections was +7.7 ppm and the standard deviation was 3.2 ppm. Although the uncertainty is somewhat larger than that obtained for voltage, these results are in good agreement with the voltage data.

Comparisons of the measurement system at the field site and the NBS transport standard were conducted in both March and May. The mean difference in the measured currents was -3 ppm with a range of 58 ppm. Again, time constraints prevented further investigation of the sources of the observed differences. However, it was observed that certain of the equipment was very temperature sensitive. Since it was designed to operate in a standards laboratory environment, this observation is not surprising.

AUTOMATED MEASUREMENTS AND DATA PROCESSING

Automation of the NBS electrical measurements described in the preceding sections provided a logical and practical means of increasing the efficiency of taking measurement data. Specifically, automation afforded several advantages over manual methods. First, automation improved the integrity of the data taken. Since the data was in machine-compatible form, it was possible to record, print and analyze the measurement results during the measurement process. This eliminated the manual data recording process in which errors are highly likely. Second, automation increased the speed at which data was taken. The NBS experience in two field tests at RSA consisted of performing similar tests both with and without the aid of an automated system. The automated measurements permitted much more data to be taken in approximately 30 percent less time. This increased efficiency and allowed more measurements to be made, thus increasing the experimenters' confidence in their data. The third benefit that was realized by automation was the consistency of performance of the measurement. Each time and measurement program was run, the same action took place. In our case, the measurement procedure coded into the software was simple. It consisted of the commands to set a digital multimeter to the desired function, to wait for a specified length of time, and to print the results. By having these commands in software, errors introduced by the operator and the operator's assignment of uncertainties to the NBS transport standards, the NBS measurements of the Army primary standards, the Arm

The final advantage of automation realized in this work was to provide a documentation of the procedures used to make the measurements. The software provided an unambiguous record of the sequence of events that occurred during the measurement process. This may be valuable, especially in the field tests such as reported here, where further data analysis depends on the knowledge of the details of measurements made.

In fairness, it should be pointed out that there were some disadvantages to automating the measurements. Foremost, care must be exercised to assure that the software operates properly. This was accomplished by writing software in modular form, proper documentation throughout the software with remarks and comments on what was being calculated, and proper testing of the software under all conditions of data input.

For the implementation of automation techniques in measurement systems, it is desirable that the test instrumentation be easily interfaced to the controller being used. The approach used in this work was to use an IEEE-488 (1978) interface among all instruments. The IEEE-488 bus is a "party-line" bus in which instruments are attached in parallel to all the wires of the bus all of the time. Thus, only one instrument can be sending data at any given moment. Software in the controller determines the sequence of messages that will be transferred on the bus. In the NBS experiments, the most used software program was a simple routine, written in BASIC, which issued instructions to the digital multimeter to make ten readings in the group of ten. Additionally, a time was printed which could establish the order of the measurements should the need arise. The results were printed on a standard paper printer integral to the controller. These records then provided the raw data that was further evaluated using the controller as a simple calculator. By processing the data promptly, a potentially serious problem one of the NBS procedures was discovered immediately. This procedure was then modified, the measurements repeated, and satisfactory results were obtained. The next logical step to further improve the system described would be to record the measurement data directly onto magnetic tape or disk files and to immediately process the data and display the corrected results. Such a procedure would give virtually real-time information on the calibration of complex equipment.

SUMMARY AND CONCLUSIONS

For the most part no uncertainties have been assigned to the particular measurements because of the complexity of the overall measurement processes involved. Any assigned uncertainty must include an error analysis and the evaluation of uncertainties to the NBS transport standards, the NBS measurements of the Army primary standards, the Arm
surveillance process, the local Army standards at the field site, variability of the voltage and current source, effects of the local environment on the measurement process, and, above all, the measurement processes used by both the Army and NBS for this work. As of this writing the differences reported seemed to be consistent with the preliminary estimates of the uncertainties for the various measurements. It is heartening to note that we were able to conduct a series of measurements between two metrology laboratories and obtain the quality of agreement reported in this paper. In closing, the following tentative conclusions have been drawn based on this work.

1. There is a need to develop standards that can operate in the type of environment that was encountered in this work.

2. In the area of ac measurements there is a need to develop transfer standards that will reduce the time required to make the necessary measurements. It was found that the ac measurements were the most labor intensive of all the measurements made.

3. It is essential that calibrations of the type described in this paper be carried out in real time so that problems can be resolved as they occur rather than simply be identified after the fact. NBS experience in these experiments indicates that the microcomputers are useful for this purpose because they provide on-site data analysis and may be used for control of the calibration process.

4. Finally, this work, even though limited, shows that (a) field calibrations are one alternative to returning the equipment to the standards laboratory; and (b) that such calibrations can be carried out to a high accuracy and over a broad range of values for different electrical quantities using a relatively small number of standards and instruments.
ABSTRACT

This paper addresses the implications of MIL-STD-45662 for a commercial instrument manufacturer. The conditions are addressed under which it would be appropriate for contracting officers to invoke the requirements of MIL-STD-45662 on a commercial instrument manufacturer such as Hewlett Packard. Finally, some ideas are offered about how Hewlett Packard divisions could meet the requirements of MIL-STD-45662.

INTRODUCTION

In this workshop we are addressing the certification requirements of MIL-STD-45662, specifically the requirements noted in paragraphs 5.7 and 5.8. Are these certification requirements applicable to a commercial instrument manufacturer? Under what conditions should the Calibration Systems Requirements be imposed?

The requirements of MIL-STD-45662 could be invoked on a commercial instrument manufacturer such as Hewlett Packard in two ways:

1. The Department of Defense could award a contract to Hewlett Packard that includes the requirements of MIL-STD-45662 in the terms and conditions.

2. A DoD prime contractor could "pass through" the requirements of MIL-STD-45662 as part of the terms and conditions of a subcontract.

I contend that in a few cases, but very few, it may be appropriate for the Department of Defense or a prime contractor to invoke the requirements of this standard on Hewlett Packard. In those few cases where it is appropriate, I think that HP will be able to conform to the requirements of MIL-STD-45662, but most probably only at added cost.

To help you understand the reasons for my contentions regarding applicability of MIL-STD-45662 to Hewlett Packard, I want to give you my impressions of the changing interpretations of MIL specs, particularly MIL-Q-9858A and MIL-I-45208A, over the years. Then I will describe the conditions under which it would be appropriate to impose the Calibration Systems Requirements on HP. Finally, I will tell you how HP could organize to meet the requirements of MIL-STD-45662 when imposed.

CHANGING INTERPRETATIONS OF MIL SPECS: THE HP PERSPECTIVE

MIL-Q-9858A, MIL-I-45208A and MIL-C-45662A were adopted by the Department of Defense in 1962 and 1963. They superseded specifications that were developed in 1959, 1960 and 1961. The specifications themselves are very general and describe the elements that should be included in a quality program, an inspection system and a calibration system. The specifications were generally acceptable to Hewlett Packard because they defined the kinds of systems that we wanted to implement to assure the quality of our products, the overwhelming majority of which were sold and are still sold to commercial customers. The detailed interpretation of how the quality, inspection and calibration effort should be organized and implemented was left to the individual divisions. In general, government inspectors understood HP's commitment to quality and accepted the divisions' interpretations of the three specifications.

In 1965, Handbook H 50 was published by DoD; it "provides guidance to personnel responsible for the evaluation of a contractor's quality program when military specification MIL-Q-9858A is invoked." Similar handbooks relating to MIL-I-45208A (H 51, published in 1967) and MIL-C-45662A (MIL-HDBK-52, published in 1964) were also released by DoD. After the handbooks were published, contractors were still allowed considerable latitude in their quality programs. Handbook H 50 says that "MIL-Q-9858A requires contractors to design and use a complete quality program. The program must be designed to assure adequate controls throughout all areas of contract performance." Handbook H 50 does contain detailed criteria for evaluation of the requirements of MIL-Q-9858A, but the criteria call for "yes" or "no" answers subject to differences in interpretation. For example, the criteria include the following questions:

"Are unsuitable inspection or monitoring methods corrected promptly?"

"Is this test and measuring equipment properly maintained?"

Handbook H 50 states that MIL-Q-9858A is intended to be applied to "items of complex design such as missiles, aircraft, tanks,
ships ..." and "major components such as fire control systems ..." Notwithstanding the DoD's intended application of MIL-Q-9858A, contracting officers continued to apply the specification to many orders for HP products for which it was not really intended. This posed no particular problem to HP because of the latitude we were given in the design and implementation of our quality programs.

In August, 1973, DoD issued DSAM 8200.1 which "addresses itself to the policy, procedures and actions that are required to be implemented at the site designated for contract performance." It provides detailed instructions to the QAR's for evaluating the contractor's quality program and inspection system to assure compliance with the applicable specifications and contract requirements. Among its many provisions is the requirement that each division develop a detailed checklist for evaluating the contractor's written quality procedures.

In January, 1977, DCRL Form 407 was issued by DCASMR Western Region. It is a "guideline and checklist for evaluation of quality program requirements" to be used by QARs to determine a contractor's compliance to MIL-Q-9858A. It is based on the evaluation criteria contained in Handbook H 50 but spells out very specifically what must be included in the contractor's quality program. DCRL Form 408 is a similar checklist for evaluation of a contractor's compliance to MIL-I-45208A in DCASMR Western Region.

MIL-C-45662A was generally intended by the DoD to define the calibration requirements that would be imposed on a contractor when either MIL-Q-9858A or MIL-I-45208A was called out in a contract. Similarly, MIL-STD-45662, issued in June, 1980, is intended to be invoked by the DoD as part of an integrated inspection or quality system that will assure compliance with contract requirements. This intended linkage is spelled out in paragraph 4.1 of MIL-STD-45662, which states, "The contractor shall establish or adapt and maintain a system for the calibration of all measuring and test equipment used in fulfillment of his contractual requirements. The calibration system shall be coordinated with his inspection or quality control systems...."

As the requirements of DSAM 8200.1 and the checklists were invoked, contractors no longer had license to interpret the military specifications and to determine how the quality, inspection and calibration efforts should be organized and implemented within the individual contractor organizations. Instead contractors' quality, inspection and calibration systems had to comply exactly with the detailed requirements spelled out in the checklists.

By 1980, it was evident that Hewlett Packard's policy with regard to MIL-Q-9858A and MIL-I-45208A had to be changed. During the fall of 1979 we evaluated the two alternatives that seemed to be open to us:

1. We could continue to claim general compliance with MIL-Q-9858A and MIL-I-45208A, and we could bring our calibration systems into compliance with the new Calibration Systems Requirements MIL-STD-45662. Major changes in all our quality systems would be required, and each product division would have to work with DCAS and the assigned QAR to implement a Single Standard Quality Program. Each division's quality, inspection and calibration systems would be evaluated in great detail using the appropriate checklists by the assigned DCAS QAR. After "deficiencies" were corrected and the division was qualified, the assigned QAR would conduct a follow-up survey every six months to determine whether the division could remain qualified.

2. We could discontinue the practice of claimed general compliance to MIL-Q-9858A, MIL-I-45208A and MIL-STD-45662. Individual divisions with a large enough base of "military" business to justify it could become qualified to operate a Single Standard Quality Program. Other divisions could accept specific contracts that required compliance to the military specifications; such divisions would have to establish quality, inspection and calibration systems that would be used in the production of specific items called for by the contract.

Only a relatively small percentage of all the products manufactured by Hewlett Packard are sold to the Department of Defense and DoD prime contractors. Most of the products that are sold to the DoD and DoD primes are identical to those sold to commercial customers throughout the world. Careful attention to new product design, process control and component selection have earned for Hewlett Packard a solid reputation for high quality products. The quality and reliability of commercially manufactured electronic instruments is well recognized by the Department of Defense. A recent solicitation states: "Based on the high cost of testing and support of specially designed equipment, it is the government's intent to consider 'or equal' items which have existing commercial applications, and the quality and suitability of which is evidenced by substantial market acceptability. Items which do not exist commercially will not be considered."

Making extensive changes to time-tested, very successful quality programs just to bring them into conformance to the detailed requirements of MIL specs as they are now interpreted did not seem to be justified. Bringing HP Standards Labs into conformance with the requirements of MIL-STD-45662 as it
was being interpreted by some cognizant government representatives would have been particularly costly and of questionable value to our customers. The Department of the Army Rationale for Changes, sent out on June 10, 1982, along with Proposed Change Notice 1 to MIL-STD-45662, clearly states the concern we had: According to industry associations (NSIA, AIA, EIA and NCSL) a reporting system to accomplish this would be very costly and its requirements are questionable because there are no known documented cases where out of tolerance test and measuring equipment has resulted in defective products being delivered to DOD."

We discussed the alternatives we were considering with DCAS officials; they indicated that qualifying HP divisions to operate to a Single Standard Quality Program was probably not in the best interest of the government, considering the small proportion of our total business represented by DOD contracts.


HOW WILL HP MEET REQUIREMENTS OF MIL-STD-45662 WHEN INVOKED?

Historically managers and engineers in HP Standards Labs have defined traceability as the ability to relate individual measurement results to national standards or internationally accepted measurements systems through an unbroken chain of comparisons. Years ago this traceability was achieved through Phil Hand's Standards Laboratory in Palo Alto. As the company divisionalized and as divisions were moved out of the Palo Alto area, some standards capability moved out of the division locations. Generally each division developed and maintained a high level of sophisticated standards capability in areas of the division's primary technology. For example, at Loveland Instrument Division, where voltmeters are manufactured, voltage standards were emphasized. Standards located at various HP standards labs are compared with one another, and some are submitted to the Bureau for calibration; in this way, traceability is maintained.

The definition of traceability within Hewlett Packard is undergoing some modification. The second of the four possible definitions cited by Dr. Brian Belanger in his paper "Traceability: An Evolving Concept" is receiving considerable attention. According to this definition, measurements have traceability if, and only if, scientifically rigorous evidence is produced on a continuing basis to show that the measurement process is producing measurement results for which the total measurement uncertainty relative to national or other designated standards is quantified. Engineers in HP standards labs are becoming more involved in defining calibration systems for products being manufactured and determining how the calibration systems themselves are to be calibrated. Measurement uncertainty of the entire instrument manufacturing, calibration and quality assurance process is being addressed. Because of the growing use of automatic test systems, software quality is becoming an important concern of HP Standards Managers and Standards Engineers.

After Proposed Change Notice 1 to MIL-STD-45662 Calibration Systems Requirements is adopted, it would be possible to bring the
standards labs in HP divisions into conformance with MIL-STD-45662. In some cases the changes that would have to be made would be minor, and in other cases the changes would be more extensive. Once the changes were made in any standards lab, the lab would have to be surveyed by a government representative as required by MIL-HDBK-52A. Whether or not the cost to make the necessary changes in a division's standards lab would be justified would have to be evaluated case-by-case.

An alternative that is being explored is the possibility of setting up a standards lab at one of the major HP repair centers, perhaps the repair center at Mountain View. This standards lab could be organized to comply with all the requirements of MIL-STD-45662, and could be regularly surveyed by a government representative for conformance to the standard. The repair center could accept calibration contracts from the DOD or DOD primes when compliance with MIL-STD-45662 is required, and could supply variables calibration data when requested. If a DOD prime contractor had to invoke the requirements of MIL-STD-45662 on HP, the manufacturing divisions could ship the products directly to the repair center, where a standard calibration charge, the products could be recalibrated, using a calibration system that meets all the requirements of MIL-STD-45662. I think this is an attractive alternative that we will be carefully evaluating over the next few months. Customers who really needed to invoke on HP the requirements of MIL-STD-45662 would be able to do so, and the special calibration system that would be established to comply with these customers' requirements would be paid for by the special calibration charges. By performing special calibration services and compiling variables data at one HP location, HP could consistently provide data and meet all certification requirements in the required formats spelled out in MIL-STD-45662.

Within the product divisions we could continue to concentrate our energies on supplying products of the highest quality to all of our customers. The standards organizations within the divisions could continue to develop measurement processes capable of producing measurement results for which the total measurement uncertainty relative to the national or other designated standards is quantified.
PROPERTY RECORD FOR EQUIPMENT SERVICING AND SHARING

JERRY J. PILEZYNISKI
McDonnell Douglas Corporation
St. Louis, MO

ABSTRACT

This paper describes an on-line, real-time, record system installed at McDonnell Douglas Corporation, Saint Louis, Missouri, in April 1980. The system titled "Property Record for Equipment Servicing and Sharing (PRESS)," contains 136,000 active property records. Interaction between five data bases for on-line data retrieval and update via 16 different CRT terminal views. In addition, batch weekend processing is used for scheduled reporting on paper or microfiche. A duplicate system was installed at Douglas Aircraft Company, Long Beach, California, in October 1981 and achieves standardized information exchange between corporate components. Although PRESS is a record system for accounting, tracking, and service of property, this paper emphasizes calibration administrative tasks related to service scheduling, work backlog monitoring, service history, and service specifications for 5,500 equipment items within the St. Louis PRESS property record inventory.

SYSTEM OVERVIEW

The PRESS system is maintained within one of IBM's Information Management Systems (IMS) at McDonnell Douglas Automation Company (MDCAUTO), St. Louis, Missouri. Access is provided by use of any device compatible with IBM's 3270 family of terminals. IMS currently supports 85 in-house systems (120 on-line data bases) accessed by 1550 terminals and is available 24 hours each day except Sunday, when the systems are taken down to allow for a variety of maintenance activities.

PRESS data resides in 5 logically related data bases summarized as follows:
1. The property data base contains all data elements unique to a single item. Included in this structure are equipment service related data elements for update or retrieval of service history and service specifications. The key to this data base consists of two fields: a property control number field and a corresponding file designator number. There are approximately 136,000 property control numbers distributed among the three major user groups.

2. The Manufacturer-Model data base provides standardized manufacturer name and model number descriptors as dictated by a seven position catalog coding scheme assigned to an item. All common equipment have the same coding information. Included in this data base are supporting service related data elements such as service intervals, service specifications, and service procedure numbers that are unique to a Manufacturer-Model class.

3. The Service Backlog data base contains selected data from the other four data bases for items awaiting work assignments in the Calibration Laboratory. This data base structure has a variety of search and display options that categorizes a workload.

4. The Tables data base contains technical nomenclature descriptors and are related to the Manufacturer-Model data base. Also included in this data base is a coding scheme for test and measuring equipment used as standards traceable to the National Bureau of Standards.

5. The Employee data base provides employee name, department and location data used in the assignment of property. The data base is also used to obtain employee information when property is submitted for calibration service. The MDC, St. Louis Telephone Directory Master File is used as the source file.

An independent Equipment Management System (EMS) allows for ad-hoc search and display inquiries of equipment catalog code assignments. The catalog code is the common link between EMS and PRESS. Its purpose is to obtain uniform and accurate information that describe equipment by manufacturer, model number, and function.

Weekly system maintenance activities are conducted in an off-line environment, and include:

- Property record purges (deletions)
- Depreciation system update (monthly)
- Plant Engineering reporting system update
- Employee data base update (monthly)
- High volume transaction update (Mass Changes)

- Output files for scheduling batch reports
- Database image copies (for recovery, if necessary)
- Update EMS catalog files

Weekly system maintenance and scheduled reporting for calibration related activities include:

- Generate and mail service alert/overdue notices.
- Generate on-line visibility of alert/overdue notices mailed to remote sites.
- Update service history master file
- Purge complete work from Backlog data base
- Create summary reports of week's activities

THE PRESS "MENU"

PRESS users have access to the data bases via the "MENU." Entry of a SCREEN NUMBER and KEY data element display a screen and, with proper security provisions, allow data update. Four access keys are available: (1) catalog code for SCREENS 04, 09, and 14, (2) Employee number on SCREEN 05, (3) Service group on SCREEN 13 and, (4) Property control number on all remaining screens except 15. Screen 15 provides access to Equipment Management System data via the EMS "MENU." A mass change screen (16) is not accessible via the "MENU" to assure only authorized sources implement data changes.

Separate and distinct Master and Calibration Service Screens are provided for Engineering, and Quality Assurance divisions. This is related to differences in internal organization job responsibility. Within Quality Assurance, Equipment Management and Calibration functions reside within the same group's jurisdiction. As a result a number of service related screen activities originate on the Quality Assurance Master Screen. Within Engineering the two job
functions are separate, and the screens are designed accordingly. The remainder of this document accentuates the Engineering Screens with reference to others as necessary.

THE ENGINEERING MASTER SCREEN

PRES S Engineering property records must originate via 1 of 2 Master screens. When record is under the control of Property Administration (PA), data elements that are unique to Engineering Equipment Management (EM) functions are added to the record via the Engineering Master Screen. When not under PA jurisdiction, the entire record may be added or deleted via the Engineering Screen.

Data element unique to the EM function generally include: status code and date, equipment crib number, generic codes to group similar equipment, planned action code and date, used in location, manufacturer's part number, and assigned-to-employee identification. Service assignments are added to the "S-ORG" field to initiate a service alert notice for first time service. Once assigned, this field is protected, and any changes must originate via the Engineering Service Record Screen. Status codes are classed as active, idle, or service. If a property status is active or idle, the field is updated via the EM screen. Service codes are protected and updates must originate via the Engineering Service Record Screen.

Other unique features of the screen include: (1) entry of a nine digit catalog code produces the manufacturer's name, model number, and a technical description that assures that all occurrences of a specific model will have these elements formatted identically, (2) entry of an employee number will extract the name, department, etc., of the employee data base, thereby assuring that entries are valid for employees (non-employees may be added to the master telephone directory by separate input) and, (3) a change in property control number, or a change from an active to an idle status code produces an informative message on the service history master file for service record continuity purposes.

SERVICE RECORD REVIEWS (SCREENS 06 & 07)

The service record views were designed to meet the needs of a calibration and standards laboratory that has support from a separate equipment management group. The last completed service and a service currently in process can be displayed. Switching to other service related screens are available for ease of access without a return to the "MENU."

The service views allow equipment staging personnel to place items in the calibration backlog by appropriate entry of receipt data on two data lines (starting with an employee number under the "SUB-By" field). At subsequent serviceings, equipment receipt data is normally limited to one data entry (staging area "BIN-LOC" field) for routine scheduled work, and three entries ("P/DATE," "USER REMARKS," and "BIN-LOC" field) for unscheduled work. The "P/DATE" field is a priority code and date scheme for sequential work assignments as displayed on the Backlog screen (13).

SERVICE CURRENTLY IN PROCESS

An update of the PRESS data bases with equipment receipt data automatically changes equipment status to ICL (in calibration lab) on all screens displaying the "STATUS CODE" field. Service group assignments ("SERV-ORG" field) are related to job discipline, and is a key field for automatic sort and distribution of incoming work as displayed on the Backlog screen. Currently

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the Engineering Calibration and Standards Lab have 20 groups with a total weekly average backlog of 1200 items. Total property in Engineering Service Recall 32,500 items supported by 64 non-union personnel.

Routine recording of pertinent service data on Service Record View 1 begin with "HOURS-SERVE" on the third data line and continue to the "TECH-CODE" field. Based upon service coded data for: (1) equipment receipt condition ("REC"), (2) repair and/or modification required ("RM/M"), (3) operating test performed ("OTP"), and (4) interval adjustment code ("IAC"), PRESS computes and displays the date completed, new service interval, and next service due date. A message will also appear at the bottom of the screen informing the user that an explanation of non-routine codes, when used, are required on Service Record View 2.

**COMPLETED SERVICE RECORD**

Service Record View 2 provides a means of recording the procedures followed, all the standards used during a calibration or validation process, and pertinent remarks related to the service (if any). These must be completed prior to an approval on Service Record View 1. The "PROCEDURES-USED" fields are automatically edited to assure of correct user data entry. Three 16 position fields are available. "STANDARDS-USED" are 3 position codes representing a PRESS property control number. The purpose of these codes is to simplify update entry in lieu of a 12 position property control number, thus reducing a potential typographic error. Program edits are provided to assure that a "STANDARDS-USED" has a valid service due date. The "SERVICE REMARKS" field is a text update field with provisions for 99 lines of data. A permanent message "Explanation of Codes Required" appears on the first text line when non-routine service codes are used on View 1.

Upon review and entry of a non-display approval code, and approval initials, the PRESS data bases are updated, and completed service records are protected from any further update. During weekend system maintenance, completed service records are copied to the service history master file for monthly reproduction on microfiche, and any prior service records are removed from on-line display.

Service Record View 1 offers other features that enhance workload management and simplify administrative tasks, and include:

1. The "SERVICE DESCRIPTION" field is controlled by calibration personnel thus allowing creation of supplemental data independent of catalog code descriptors. The "SERVICE DESCRIPTION" field is available on the Backlog screen when an optional display mode is selected.

2. Entry of an employee number in the "EUH-BY" field will extract remaining employee information, for display, from the employee data base.

3. Routine incoming backlog equipment are automatically assigned the same priority code with a corresponding current receive date unless specifically updated otherwise. This allows a sequential, when received, listing for the Backlog screen. Laboratory standards and accessories equipment are automatically placed in the backlog 2-1/2 weeks prior to their service due date and automatically assigned a higher priority than routine work.

4. Service records which require documentation action are placed in the backlog with an automatic priority code assignment based on programmed edits for specific update entries in the "Bin-Loc" field.
5. The Job Category ("JOB CAT") field is used to define workloads at the service group ("SERV-OGN") level. The concept allows each group to classify work unique to their job discipline for efficient servicing, etc. The McDonnell Bureau of Standards Microwave Group, for example, utilize this field to define measurement systems used in the validation process. Code assignments are arbitrary and unique to each service group, and a listing of all property within the same "JOB CAT" is available as an optional display on the Backlog screen.

6. To optimize calibration service schedules for test consoles, the service groups must identify console components and control service due dates to minimize system down time for recalibration. The "CHILD-OF-SYSTEM" field serves this purpose. Service records of components subordinate to a "parent" property within the console contain the "parent" control number in the "CHILD-OF-SYSTEM" field. Selection of the "parent" number is arbitrary within system limits to allow for equipment user "ad-hoc" defined configurations as well as test consoles. The field may also be used to group like items for service recall. A request of a "parent" property number on the Scheduling-System Details Screen displays an itemized listing of system components along with other pertinent data.

7. Data entries normally remain static, and are re-displayed at subsequent servicing. Other mandatory updates required at each service cycle appear with blank data fields when property is placed in the backlog.

8. Provisions have been made to preschedule work on the Backlog screen prior to receipt, and distribution of service alert/overdue notices continue until the property is received.

9. An optional hard-copy worksheet is available on request (PF1 key) for "scratch pad" recording of data prior to PRESS entry.

THE BACKLOG SCREEN

This screen was designed to administer the various group workloads in an efficient and practical manner. Day-to-day operational logistics differ at the service group level. To effectively satisfy a group's administration of work assignments, optional selection of six different screen search and display modes are offered.

Selection of a backlog is made by input of service group, either from the "MENU" or Backlog screen, prefixed with an optional coded input to select: (1) all items in the backlog, (2) items currently in-work, (3) items held for some action, and (4) items completed during the week. Within the first two above selections a coded suffix may be optionally input, after the service group indicator, to extract just those items with a specified priority code.

The Backlog screen displays select information found on Service Record View 1. After the screen headers, each data line is unique to a property arranged in a priority sequence. Except for priority codes "B" (lab standards and accessories) and "D" (documentation action only), the listing may be sequentially manipulated by manual update of priority codes and/or priority data. Priority codes not currently defined are used for temporary assignments, as necessary.

The STANDARD HOURS ("SH") field is an estimate of service hours required to complete a job. It is program generated, and derived by averaging actual service hours expended, taken from the last completed service record for all like items within a manufacturer/model class. The last backlog page displays a total of STANDARD HOURS as well as a total property count. It is used by management to assist in decisions regarding short-term group staffing, overtime, etc.

The "SH-LOC" field is used to denote when an item is placed in-work ("WKX"), and all PRESS screens that display the "STATUS-CODE" field are automatically updated to "WKX." The "STATUS-REMARKS" field ("USER-REMARKS" on Service Record View 1) is used as a "scratch pad" to record relevant data such as assigned technician, etc.

The bottom of the screen lists the remaining search and display options. Entry of a job category code adjacent to the "PF4-JC"
will retrieve and display all like occurrences of a selected code, and the "SH" field is automatically changed to display the code. By "marking" a data line and use of the FP7 key, all like occurrences of the "TECH-DESCRIPTION" field can be retrieved. The "TECH-DESCRIPTION" is displayed at the bottom left of the screen and the description field within the data lines are replaced with "SERV-DESCRIPTION" data.

By use of a "marked" data line, all like occurrences of the "MODEL NO" field may be selected. Since the "MFR" and "MODEL NO" field are truncated on each line, the bottom right side of the screen displays the full manufacturer and model number. Input of a "SUB-BY" department adjacent to the "PF10" DEPT produces all like occurrences of the selected department, and the "MFR" column is replaced with the "SUB-BY" dept field. Use of a "marked" data line can directly switch to Service Record View 1 or the Master Record for the "marked" property item. These selections and "view" switches are achieved through use of program function (PF) keys on the terminal.

SCHEDULING - SYSTEM DETAILS SCREEN

This is a display only screen to retrieve service data on equipment that is an assembly of other equipment. This is typified in test consoles and special test equipment benches. To optimize productivity of these systems, the service groups need to identify what components make up the system and to control the service schedule to minimize total system downtime for recalibration.

Input of a "Parent" property number in the "SYS-SERVICED" field will display all components whose Service Record View 1 "CHILD-OF-SYSTEM" field contain the "Parent number. Within each data line is a "Parent indicator ("P"-field) to denote the next system level (see Property number -038). Input of the next level of "Parent" will display all subordinate components, and the "CHILD-OF-SYSTEM" field will note that the "Parent" is subordinate to the next high assembly. There are no restrictions on the number of system levels.

SPEC LIMIT SCREENS (09 AND 10)

These screens allow the service groups to record instrument specifications verified during the calibration or validation process. The specifications may be those advertised by the manufacturer, or special limits may be imposed because of the use or performance of an individual item or because of the historical performance of all models. The screens also record data applicable to a model number (screen 09) or property number (screen 10). The data is then readily available to the service group and the equipment user. Other screen applications include test report forms, recording of standards and accessories required for the calibration process, and unique service hints.

The screens are also used to record maximum service intervals ("MAX S/1") and procedures to be followed during service. Programmed edits on Service Record View 1 prevent service interval assignments greater than the maximum. The average service interval ("AVG S/1") is a display only field and is derived by averaging service interval assignments taken from the last completed service record for all like items within a manufacturer/model class. Use of the proper operating test performed code on Service Record View 1 automatically assigns the average service interval as an initial interval for first-time serviced property. The "STD-CODE" field is for assignment of three position codes as explained on Service Record View 2. The "APPR" field is for supervisory approval and data base update of all entries. The specification field is a 99
data line free form text update for test reports, specifications, etc. Screen 09 generally contain the master record which is readily translatable to screen 10 and modified when required.

Based upon this data the operator can select likely candidates to borrow/reassign to meet inquirers needs. Up to 210 occurrences (30 pages) of property numbers are displayed.

Equipment management functions that have an active crib (equipment pool) utilize the Crib Transaction Screen (05). It is designed to check items in and out of the crib while affording the stockkeeper an opportunity to verify that the entries made are current before the data is updated.

The stockkeeper enters only the employee number of the individual that will be charged with the item, the property number of the equipment, and the new status code. All other elements on the screen are automatically filled for verification. Only two status codes, under the header "STAT," are acceptable to this view, "ACT" (active) or "CRO" (check-out, in route to calibration lab). A message appears at the bottom of the view when an item service due date has expired or when an invalid current status ("F-ST" field) is displayed.

The Equipment Sharing screen (04) was designed to promote the sharing of equipment between users. With the accumulation of performance data and other data furnished by the MES system (Screen 15), anyone may address this screen to select common equipment models to meet their requirements.

The screen is accessed by a catalog code form the "Menu" or from the view itself, an is used for display of information only. The screen identifies the number of items plus the location, service status, utilization, physical status, assigned employee, and planned action for each item selected.
The Catalog Code screen (14) is designed to provide a synchronized interface between the PRESS St. Louis and Long Beach Manufacturer Model and Tables data bases and the EMS system. The screen is used to add new catalog codes, manufacturer, model, and nomenclature descriptors and other relevant data to PRESS.

When maintaining data in a property record, it is sometimes necessary to take all occurrences of specific data in a data element and convert them to new data. The Mass Change screen provides this action. This screen, while available at the on-line terminal, makes mass changes when the data bases are restructured during weekend maintenance. Accessibility to this screen is secured through separate Property Administration, Quality Assurance and Engineering format and password commands limited to groups with need and authority for the specific mass change required. Service related mass change elements include assigned employee, service charge number, catalog code, system service number, and job category code.

CONCLUSION

The PRESS System was developed to maximize the usefulness of test equipment at McDonnell Douglas Corporation, St. Louis. A primary PRESS feature is that the calibration recall system is integral with the overall property record system. This results in satisfying calibration documentation, and accountability requirements, most efficiently while providing the highest degree of management visibility for controlling test equipment usage and productivity. A first year operation was monitored and recorded a million dollar plus cost savings due to PRESS.

PRESS has significantly reduced paperwork flow, enhanced workload management, and improved "all-around" visibility throughout test equipment life cycle for the MDC Engineering Calibration and Standards Laboratories. Highlights of PRESS service related advantages we have experienced are summarized as follows:

- Automated sort/distribution of service alert/overdue notices.
- Elimination of massive paper filing system for pre-service and post-service records.
- Automated sort/distribution of workload with the Calibration and Standard Laboratories.
- Immediate response to equipment user inquiries for both work backlog records and historical records.
- Classification of workload through on-line search modes.
- Improved data integrity through programmed edits and conscientious service group update efforts.
- Improved communication between remote sites and St. Louis.
- "Ad-Hoc" reports on request within 2 hours to 2 days.
- Improved communication between Property Administration, Equipment Management, and the Calibration Laboratory to assure record accuracy.
- Elimination of pre- and post-service keypunch operations.
- Improved equipment turn-around time.
- Access to other IMS data bases (Purchase orders, stores locator, PRESS Data Dictionary, etc.).
The workshop, "Living with Out-of-Tolerance Feedback," considered the topic of out-of-tolerance feedback from three perspectives. The first perspective, presented by Thomas E. Wolf of the Army, was from that of the service which sought to protect itself to the extent possible from the potential damaging effects of using out-of-tolerance instrumentation in the production of hardware. Mr. Wolf used personal examples from his experience in the Army's calibration program to suggest a need for at least some type of feedback program.

The second presenter, Rolf Schumacher of Rockwell Anaheim, considered the risks associated with using out-of-tolerance instrumentation in conducting production measurements. Rolf had performed some statistical analyses to determine the effects on alpha and beta risks as a function of amount of out-of-tolerance and as a function of the accuracy ratio employed. One feature of this analysis was the effect of error compensation in accuracy ratios less than 10 to 1. Questions posed to Rolf concerned the implication of his analysis to the ANSI standards he is working on and the necessity for developing a specific feedback program.

Finally, Carroll Croarkin of the NBS presented information on the necessity in some cases for statistical control of measurement processes to use check fixtures, or other "standards" to maintain knowledge concerning the measurement processes.

The workshop, particularly the last two sessions, developed into a consideration of the statistical quality control techniques which many believe are going to be increasingly more necessary at all levels of production and tests in the future.

George C. Rice
Rockwell International
Herb Barclay of GTE Sylvania was then recognized for his many years as a NCSSL member delegate. Herb is retiring from GTE soon after this meeting. Herb's most recent contribution was that of regional training coordinator. On behalf of all those at NCSSL we would like to thank Herb for his many years of dedication to NCSSL and wish him a multitude of very prosperous and enjoyable years in his retirement. Taking over Herb's training coordinator responsibilities will be Bill Robertson of Raytheon.

Harry announced that an attendance of 12 of the present 16 Region 1 member delegates attended the recent NCSSL Conference in Gaithersburg.

Harry then introduced Ed Nemeroff of Guildline Instrument Company, NCSSL Regional Director who has recently been named Vice President of Communications and Marketing for the 1983 NCSSL Board of Directors.

Ed updated NCSSL activities, including a brief synopsis of the new 1983 NCSSL Board of Directors. The areas of importance which Ed briefed the members of the meeting on are:

- A total of $65K is the present amount of money in the NCSSL budget. Because of the efforts and activities of the Education and Training Committee, it is expected that this committee will receive the biggest share of these funds. A word of appreciation was extended to TRW for it is within their computer the NCSSL budget is housed.

- Robert A. Kamper, NBS Director of the Boulder, Colorado, facility is now NCSSL Sponsor's Delegate. NBS is the only sponsor of NCSSL.

- A very favorable report on the progress of NCSSL Education and Training Committee was presented by Ed. Approximately 25 people working at least six different subcommittees are accomplishing a good deal of meaningful progress. H. Bryan Wener, Westinghouse Electric, heads the Education and Training Committee and to quote Ed, "is doing a super job from that of a practically dormant committee of only a few years ago."

- Work has been completed on a Calibration Laboratory Managers Handbook and the NCSSL member delegates should receive a copy soon.

- It was announced that Harry Haymes will assume Ed Nemeroff's former position as Regional Director for the new NCSSL Board of Directors.

- Ed also reported that present membership within NCSSL is 524 with an estimated 15% per year growth over the next five years. New area of memberships are expected from the biomedical and utilities field.

- An important note to come out of the conference was that Dr. Ambler of NBS requested that his Deputy Director address the member delegates of NCSSL on the possible results of a 11.9% decrease in NBS funding by Congress. This money had previously been funded for the NBS MAP's (Measurement Assurance Program). Congress wants industry to assume funding of future MAP's which would have the effect of increasing the cost of MAP's enormously. For example, a voltage MAP which had cost approximately $3K in the past would now increase to $156K, a factor of 52:1. The decrease in NBS funds is also expected to produce a 4 or 5 to 1 cost increase in NBS Standards Calibrations. A letter from NBS to NCSSL is expected to follow soon.

- The next NCSSL National Conference is scheduled for July 18-21, 1983 in Boulder, Colorado. The reasoning for the scheduling in July as opposed to October is attributed to the fact that housing is easily obtained and less expensive at this time of year. Interesting point for those members who would like to bring their families.

Nilt Towne of Sanders Associates then presented an update of the Education and Training Committee's most recent efforts which are:

- The first change of the year was the introduction of a new committee which is the Metrology Public Relations Committee. One of the first efforts of the new committee was a public relations poster designed and supplied to the Butler County Community College Science Fair.

The Metrology Public Relations Committee has also put together a canned public relations training package. The package includes a canned speech and approximately 30 slides.

- An update of the Metrology Associate Degree program at Butler County Community College shows that of the 12 people starting the program, only 6 remain. Tough course!
Regional Reports

- Adjunct training efforts are moving along quite well with the hopes of coupling available mini-courses together for the purpose of a certificate or even degree program in Metrology.
- Mitt also made a request to the members of the meeting to see him if anyone is interested in helping with any of the Education and Training committee sub-committees.

Harry introduced Mr. Bob Watson of EG&G, a product specialist in Photometry and Radiometry. Bob presented a very thorough and informative talk on Photometry and Radiometry in Metrology.

Bob covered four areas of concern which are:

1. Photometric units of measurement
2. Measurements and Calibrations
3. Standards
4. Standards societies and organizations

A question and answer period followed Bob's talk.

Harry then introduced Mr. Henry Hall of Gen Rad who gave a talk on automatic precision measurements. Henry's talk centered around the question, "Why would people want to make automatic precision measurements?" Some very pertinent and interesting points were covered in the talk. One point being automation eases the calibration tasks a great deal due to the fact that there is usually a storage medium available for the storage and analysis of calibration data. Another point of interest is that of reducing the tolerance bands through precision measurements which has the effect of realizing cost savings by not having to test or inspect to such previously wide tolerance bands.

On behalf of the membership of Region 1, I would like to thank Gen Rad and Dr. John Hersh for hosting the meeting. The facilities and lunch were top notch. Also, many thanks go to Tim Driver of Sprague for volunteering to do the minutes.

ATTENDEES:

Andrews, Eric
Ascanio, Ivan
Barclay, Herb
Bean, John D.
Boynton, Tom
Brown, Alan
Bustin, Ralph
Carbonneau, Norm
Carter, George
Conary, William

Analogue Devices
New England Nuclear
GTE Systems Group
Astra Pharmaceutical
New England Nuclear
Hayes Instrument Services
Raytheon Company
MA/COM
Tektronix Corporation

Driver, Tim
Foley, William
Haymes, H. B.
Jackson, Carl
Karns, Fred
Leaney, Jim
Majewski, Joseph
Nemiroff, Ed
Potaro, Larry
Prather, Pat
Quinby, David
Riccitelli, John
Roderick, Ray
Taittrie, David
Towne, Milton
Vogel, Peter
Watson, Robert

Sprague Electric Co.
Raytheon & Sig. Div.
Sanders Associates, Inc.
Northrop Corporation
John Pluke Company
Consultant
Boston Edison Company
Guildline Instruments
Sanders Associates
Paradyne
Bill Brown Instruments Systems
Ittek
Foxboro Company
Foxboro Company
John Pluke Company
Sanders Associates
Guildline Instruments
EG&G, Inc.

November 23, 1982
Sheraton Sunnyvale, CA
Carl Quinn
Region 7 Coordinator

The meeting brought out some new participants who were interested in learning more about NCSL and the subjects on the agenda.

Automatic test systems incorporating self-calibration were described by Dennis Dingman of Lockheed Missiles and Space Company. These second generation systems feature imbedded standards which may be calibrated on site to reduce calibration cost and improve the accuracy of the general purpose programmable equipment. The functions available are AC and DC volts and current, resistance, frequency, time interval and digitized waveform.

An application of measurement assurance was presented by consultant Roger Alcantara. Artifact standards such as resistors lend themselves to a system of data analysis typical of the well-designed measurement assurance quality process. Roger has developed software for SIMCO which performs linear regression and systematic errors prediction on SIMCO’s standard resistors, inductors and capacitors. Roger’s 1982 NCSL Conference paper was handed out.

Jim Marshall, Hewlett Packard, reported on Volt MAP group activity. The last NBS transfer gave the group greater confidence in the ability to isolate and correct problems and was an improvement over the prior year. The group is working with NBS on a design for a reverse Volt MAP which should increase measurement confidence in the field and reduce cost to NBS. Much of the data processing is done by the participants and more frequent intercomparisons are also required in each lab. The Bureau monitors
this activity and performs only on required intercomparison of a selected transfer enclosure. Final NBS test reports are then issued to each laboratory to correct systematic voltage error and assign uncertainty based on each lab's capability.

Test laboratories provide a technical service in much the same way as a calibration laboratory provides calibration service. A great deal of effort is being invested in the accreditation program development for testing laboratories. These testing laboratories must satisfy a list of criteria which includes as a principle element a legitimate quality program. Fred Sieg, Quality Assurance Manager at SIMCO, described such a quality program developed for SIMCO in anticipation of an accreditation program for calibration service companies. Fred supplied a paper prepared for the Regional Meeting.

Director Robert Weber recapped the NCSL workshop in October. Advocacy position guidelines were discussed in a brief review of the evolution process. A most important description of the current status of MIL Standard 45662 was given by Bob. January 1, 1983 is the current estimated date for the final DOD revision. This revision records Paragraph 5.6.2 to clarify responsibility for compliance and leaves less cause for conflict between enforcement agencies and contractors.

**Attendees:**

- Carl Quinn
- Fred Sieg
- Mike Zall
- Jack Milburn
- Tom Freeman
- Richard E. Fisher
- Al Koehler
- Dennis A. Dinkmann
- John Cox
- Craig Zack
- Lee Ashford
- Albert Laung
- D. P. Chaffman
- Bob Weber
- Dean Williams
- Bill Mauster
- Ivan Terry
- Paul Chang
- F. J. Danielin
- Bill Wexford
- Tim Marshall
- John H. McCaig
- Warren W. Wilson
- James McClean
- Joseph Rothleder
- J. W. Ingraham
- Ivo Naher
- Roger Alcantara

**SIMCO Electronics**

- Watkins Johnson
- Dalmo Victor
- Lockheed, Sunnyvale
- Lockheed Missiles & Space
- Lockhead
- LMSC
- Electroc Test, Inc.
- Apple Computer
- Apple Computer
- ESL, Inc.
- ESL Systems
- Hewlett Packard - Santa Clara
- Ross Eng. Corp.
- Fairchild Test Systems
- PG&E Research
- U.S. Instrument Rentals
- Tektron
- Consultant ATK

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Seventy-three representatives from 50 organizations attended the 23rd Region 8 Seminar. NCSL President Dean Brungart opened the meeting.

In his notes from the NCSL Board of Directors, Bob Weber announced that the new NCSL Director will be published soon. The Calibration Laboratory Manager's Guidebook is being distributed. Bob explained how advocacy positions will be handled by NCSL.

Mike Bumm opened the Education and Training session by reviewing the training materials package sent to member delegates. Mike invited all Region 8 member delegates to contact him with training needs which Mike will coordinate. (Mike's phone number is 213/849-6701.) Mike surveyed the attendees for their preference for video tape format; preference covered the range of available formats with some preponderance of 3/4 inch. Training tapes in VHS format may be requested. Tapes may not be reproduced. Butler Community College has 19 new students enrolled in its metrology program. Mike then introduced Bill Gibbs, Chairman of the Region 8 Training Committee, Xerox Electro-Optical Systems.

Bill reported on the changed direction taken by this committee as a result of earlier committee meetings. Another meeting will be held December 9 at Xerox Electro-Optical Systems, Pasadena. Help is needed; anyone interested is urged to contact Bill at (213) 351-2351, Ext. 2121 or 2122. Bill detailed the problems connected with introducing metrology courses into learning institutes. Awareness of the need for metrology training must be enhanced among potential students, educators, and textbook writers. Bill then introduced Dr. Norman Rich, Associate Dean, Golden West College.

Dr. Rich informed the attendees of the metrology program at Golden West College, Huntington Beach, which has just begun its three-year trial period required by the State of California for state support needed to keep the program going. The help of all interested persons and organizations is required to assure the future of this program. Golden West College is ideally located for Region 8 and now needs students, information on job availability, metrologists to teach, and surplus equipment (tax deductible). Dr. Rich invited reviews of the curriculum and comments. The program has been started with a scale technician training course intended for entry level positions. Charlie Wells, OCASPRO-Hughes Fullerton, pointed out that government surplus equipment is available to schools.
Roland Vavenk then began a round-table discussion on productivity in metrology by explaining the productivity measurement methods applied at Rockwell's Metrology Department in Anaheim. Technician jobs are standardized by specification sheets detailing calibration operations. "Calibration technicians are tweakers; they tend to adjust equipment right to the center of the tolerance. Once they do that, they have already changed the program." Detailed standardizing specifications are, therefore, necessary. The cost per instrument has gone down, following the initial portion of the bathtub curve as predicted. Intervals are adjusted for each instrument individually and have become longer. Important for productivity measurements and increases are engineering of instrument tolerances, intervals, preventive maintenance steps, laboratory and work floor layout. In the ensuing discussion, it became clear that all details of calibration laboratory operating procedures and management affect productivity and can be adjusted to increase productivity. The objection that initial intervals may have been too short was answered by the calibration laboratory taking the risk, rather than the customer, until instruments have proven their reliability.

George Rice gave a report on the revision to MIL-STD-45662 and the publication of MIL-HDBK-52. Both have been delayed by opposition to the proposed changes by two service branches. It appears that acceptable new wording has been found and that the documents will have their final wording by the end of November 1982.

Laurel Auxier reported on actions taken or responses furnished by NBS on requests for increased or improved services made at Region 8's January 1982 meeting. George Rice then discussed NBS plans to recover all costs incurred from providing services through changes in the fee structure. By October 1983, charges for NBS-conducted Measurement Assurance Programs (MAPs) are expected to incur massive increases to include research and development costs supporting MAPs and reserve MAPs. The effect may be the elimination of MAPs by NBS as they are provided now, causing shifts of charges to arrangement costs. George reported to organizations to inform NBS of the impact of changed NBS policy on their operations. Dr. Brian Belanger and Norm Belocki of NBS explained the probable impact of changed fee schedules and resulting changes in demand for future NBS services.

John King has accepted to be the San Diego Area Coordinator. We plan to canvas NCSL member delegates and other people on our mailing list to compile names of possibly interested organizations in these areas and arrange "grand opening" meetings inviting all known local organizations. If you have any ideas how to increase our chances for success or wish to volunteer in the organization, please write or call Rolf Schumacher at (714) 632-5981. Target date for the first area meetings is Spring 1983.

ATTENDees:

Abeyta, M. Ford Aerospace & Communications Corp.
Amano, E. TRW-DSSC
Ardagna, Ned Monitor Labs
Auxier, L. M. Beckman Instruments
Barger, J. A. Contel Corp.
Belanger, B. C. NBS
Delegates were informed of the new NCSL Committees.

1. Membership Promotion
2. Publicity
3. National Measurements Requirements. Five committees formed to update and summarize the findings.
   a. DC and Low Frequency
   b. Microwave
   c. Electro Optical
   d. Lasers and Infrared
   e. Temp and Press
   f. Physical Measurement

Volunteers were solicited.

The NBS proposal to recover cost for MAPs was discussed. Advocacy Position Guidelines were read and discussed. MAP handbook was discussed and the need for an automated switch was pointed out to help save money for participants.

Delegates were informed of the changes of the 1983 National Conference to be held in Boulder, Colorado on July 17 to 20th.

Cliff Koop reported in MIL-STD-45662 from information he had gathered from George Rice the morning of the meeting.

Les Huntley of the John Fluke Company gave a paper and slide presentation on "An Application for the Solid State Reference Standards of Voltage."
Regional Reports

Dave Agey gave a paper entitled, "A Preliminary Evaluation of the Accuracy of the 10 Volts as Maintained on the West Coast," describing an experiment designed to determine how well the industry is doing in the measurement of DC voltage at the 10 volt level.

"The Fluke Volt Measurement Program," by Les Huntley of the John Fluke Company, described the hardware and procedures used by the John Fluke Service Centers to maintain the standard cell voltage references.

Lunch was provided by the John Fluke Company in the executive lunch room.

Rich Hatten and Gale Culbertson of the J.M. Perry Institute described the process by which they plan to approach the Metrology curriculum at the J.M. Perry Institute.

David Daellenbach of the John Fluke Company took the delegates and guests on a very comprehensive tour of the new facility.

ATTENDEES:

Cliff Koop Rockwell
L. C. Hammans Boeing
Norm Goobie Sundstrand
David Daellenbach Tekh
Warren Collier John Fluke Co.
Del Knapp Tektronix
Tom Short B.P.A.
Howard Johnson Hewlett-Packard
Les Huntley John Fluke Co.
D. L. Bintliff Westinghouse Hanford
Richard Hatten J.M. Perry Institute
Gale Culbertson J.M. Perry Institute
Keith Cable N.W. Calibration Systems

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December 1, 1982
Canadian Marconi Co.
Montreal, Quebec
Graham Cameron
Region 10 Coordinator

Forty-two interested persons came to the Canadian sector meeting held at Canadian Marconi Co. Ltd., Montreal, Quebec, on December 1st. Topics of primary interest were:

"Movement of battery powered or shock sensitive standards/instruments by commercial air lines,"

"Customs clearance of standards and measuring/test equipment," and

"National accreditation of testing organizations."

Designated members will pursue these topics with the appropriate authorities and bring about clarification of procedures and develop communication between NCCL and customs/excise, the principle Canadian airline, the National Research Council and the Standards Council of Canada.

I suspect we will have additional applications for NCCL membership from Canada to go beyond our current dozen.

The International Regional Meeting held in the senior luncheon club NBS Gaithersburg had 40 attendees.

* * * * * * * * *
NEW STATEMENT OF NBS FY 1984 BUDGET REQUEST

A total of $98.7 million is included for the Commerce Department's National Bureau of Standards (NBS) in the fiscal 1984 budget proposal sent to Congress by President Reagan.

The budget request represents a net decrease of $19.2 million from the bureau's current appropriation of $117.9 million. Program decreases totaling $25.1 million and cost of living increases and built-in changes of $5.9 million are proposed for FY 1984.

Several of the proposed reductions reflect the Reagan Administration's policy of encouraging the private sector and state and local governments to play a greater role in certain programs now conducted by the federal government. These include:

- Building Research ($3.17 million). The NBS Center for Building Technology would be eliminated.
- Fire Research ($5.89 million). The NBS Center for Fire Research would be eliminated.
- Computer Science and Technology ($7 million). The Bureau would no longer develop AOP standards, shifting its emphasis to support the voluntary standards process.

Budget reductions for three other programs reflect the administration's policy that user charges should replace appropriate funds wherever direct beneficiaries can be identified. Services from these programs would continue to the extent that users are willing to bear the full cost of the activities. These include:

- Measurement Technology Transfer ($1.93 million). Fees would be increased for measurement assurance programs.
- Voluntary Laboratory Accreditation ($5.7 million). NBS establishment of new laboratory accreditation programs, maintenance of existing programs, and international representation of U.S. accredited laboratories would depend on the interest of the beneficiaries and their ability to bear the full cost of these services.
- Standard Reference Materials ($4.43 million). User fees would be increased to offset higher material costs.

Other proposed reductions include:

- Computing Support ($2 million). This one-time reduction is associated with delays in purchase of the NBS replacement computer.
- Automated Manufacturing Research ($1.65 million). In FY 1983 these funds provided the capital needed to equip and operate the Automated Manufacturing Research Facility at NBS.
- Recycled Oil Measurement Methods ($1 million). This work has progressed to the point where it is appropriate for the private sector to continue further efforts.

Also proposed for reductions are: central planning ($5.2 million), non-metallic materials ($5.2 million), and training services related to fundamental physical measurements and standards ($5.06 million).

A breakdown of the FY 1984 budget request follows:

<table>
<thead>
<tr>
<th>Estimated NBS Operating Funds</th>
<th>Congressional Appropriation* (In Million of Dollars)</th>
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<tr>
<td></td>
<td>FY 1982 (Actual)</td>
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<tr>
<td>Measurement and engineering research and standards:</td>
<td></td>
</tr>
<tr>
<td>Measurement research standards</td>
<td>$47.4</td>
</tr>
<tr>
<td>Engineering measurements and standards</td>
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<td>Computer sciences and technology</td>
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<td>Core measurement research for new technologies</td>
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<tr>
<td>Fire research</td>
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</tr>
<tr>
<td>Subtotal</td>
<td>$94.9</td>
</tr>
<tr>
<td>Competence and central technical support:</td>
<td></td>
</tr>
<tr>
<td>Technical competence fund</td>
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</tr>
<tr>
<td>Central technical support</td>
<td>17.8</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$25.4</td>
</tr>
<tr>
<td>TOTAL APPROPRIATION</td>
<td>$120.3</td>
</tr>
</tbody>
</table>

*NBS receives additional funding from other federal agencies and the private sector for research and services provided.
IMPROVED MEASUREMENT SYSTEMS FOR INDUSTRIAL TRANSDUCERS

An inexpensive calibration system that greatly improves the accuracy of a wide variety of commonly used industrial transducers has been developed at NBS. The new NBS technique, built into a small microprocessor-based device, uses a mathematical analysis technique to improve the linearity of transducers—the degree to which the transducer responds in a smooth, predictable way to changes in the condition measured. The system is substantially easier to use than previous methods of solving this problem. NBS engineers have already applied the technique to the design of a new-automated tool-setting station in the bureau's machine shops. Traditionally, tool-setting is done by hand, a process which takes about two minutes. The NBS tool-setting station does it automatically, at 10 times the accuracy, in about 15 seconds. The U.S. Air Force, which provided partial funding for the development of the system, estimates that the automated tool-setting station would cost about $10,000 per machine tool. Annual savings in time alone would amount to about $28,000 per machine tool, according to Air Force estimates. CONTACT: Michael Baum, 301/921-3181.

COMPUTER PROGRAM FOR GAGE BLOCK CALIBRATIONS

The NBS Center for Applied Mathematics has written computer software to provide a measurement assurance procedure for calibrating gage blocks. The program assumes a standard measurement procedure in which a test set of gage blocks is measured against two standard laboratory calibrating sets with control on the difference between the standards. The program handles the statistical techniques to initialize the process parameters, maintain process control (using a check standard), and periodically update the process parameters. The code was developed in FORTRAN 77 for a UNIVAC 1100/11 system, and runs to approximately 4050 lines. All machine-dependent parameters are defined in two subprograms to facilitate the transfer of the code to other systems. A description of the program is contained in Computer Software for Measurement Assurance of Gage Blocks (TN 1168), available from the U.S. Government Printing Office, Washington, D.C. 20402; stock no. 004-000-0245-1. Printed copies of the program or a recording of the program on magnetic tape are available from NBS. CONTACT: Mrs. Ruth Varner, A314 Physics, National Bureau of Standards, Washington, D.C. 20234, or call 301/921-2806. CONTACT: Michael Baum, 301/921-3181.

HIGHLY SENSITIVE LINK DEVELOPED FOR BROAD-BAND ANTENNAS

NBS has developed a highly sensitive electro-optical link for use between broad-band antennas and receiver electronics. The link replaces conventional metallic cables which can act as antennas themselves and can directly interfere with the electromagnetic field near the antenna. In the NBS system, an electro-optical crystal, which is mounted on the antenna, is used to modulate a laser beam as a function of the voltage at the antenna. The laser beam is then focused onto an optical detector which feeds the receiver electronics. The NBS system is about 100 times more sensitive than previous crystal-based systems and 20 times more sensitive than alternate integrated-optics systems. A summary of the work is available from Jerry C. Wyss, Division 723.03, National Bureau of Standards, Boulder, Colorado 80303. CONTACT: Fred McGehan, 303/497-3246.
government changes to improve that inventiveness—is provided in the final report of the Experimental Technology Incentives Program (ETIP).

The lessons learned from this 10-year program and the primary accomplishments of the effort are summarized in the new publication entitled, Government and Innovation: Experimenting with Change (NBS GCR-ETIP-82-100).

ETIP adopted a strategy of experimentation with incremental changes in administrative policies and procedures in federal agencies. Major components of the strategy included:

- Selection of agencies already inclined toward change where it was hypothesized the change, if properly planned and implemented, would result in an improved environment for private-sector innovation;

- Collaborative problem-solving by involving all stakeholders in the planning, implementing, and evaluating of the experiment;

- ETIP's role of neutral third-party facilitator;

- Continuing feedback of data on the experiment's private-sector impacts for use in evaluating results and planning successive modifications and incremental changes; and

- Emphasis on transferring ETIP's skills, perceptions, and methods to line agencies and institutionalizing those changes which are found beneficial.

ETIP applied the strategy to four areas of federal policy and activity: regulation, procurement, economic assistance, and research and development. Marketplace and government agency changes that resulted from ETIP studies and experiments are described in the 156-page report.

Government and Innovation: Experimenting with Change (NBS GCR-ETIP-82-100) will be available in several weeks from the National Technical Information Service, Springfield, Virginia 22161. Review copies are available to the media by contacting the Media Liaison Office, Administration A903, National Bureau of Standards, Washington, D.C. 20234, or telephone: 301/921-3181.

ULTRA-PAST SUPERCONDUCTING ANALOG SAMPLER DEVELOPED

Using a novel superconducting time-delay circuit, NBS and IBM scientists have developed the fastest known analog sampling device in an integrated circuit. The circuit is able to resolve on 0.5 picosecond rise-time (10 to 90%). The on-chip analog delay permits the results to be displayed on a conventional oscilloscope. The sampler will be useful in measuring performance parameters of ultra-high-speed digital and analog systems. During a one-year project at the IBM Zurich Research Laboratories, Richard Harris of the NBS Center for Electronics and Electrical Engineering and IBM researchers Peter Wolf and David Moore jointly designed, fabricated, and tested the circuit. High critical-current-density edge junctions pioneered for superconducting circuits by IBM Zurich are key to the success of the sampler. Future versions of the device are expected to resolve 2-3 ps rise-times. The results of this project are published in IEEE Electron Device Letters, Vol. EDL-3 No. 9, pp. 261-3, Sept. 1982. CONTACT: Ken Armstrong, 302/497-3767.

NEW BIBLIOGRAPHY OF ELECTROMAGNETIC PUBLICATIONS

Electronics and electrical engineers will be interested in a new bibliography that lists the publications of the NBS Electromagnetic Fields Division for 1980-81. The division develops measurement methods and standards, and provides metrological support for: antenna systems, noise measurement equipment, EM interference, EM environmental characterization equipment, EM interference, EM environmental characterization equipment, EM emission and immunity testing equipment, and equipment for measuring dielectric or loss characterization of materials. Bibliography of the NBS Electromagnetic Fields Division Publications (NBSIR 82-1573), $6 prepaid from the National Technical Information Service, Springfield, Virginia 22161. Order by PB 83-119776. CONTACT: Fred McGehan, 303/497-3246.

BRITISH, GERMAN, AND ITALIAN CALIBRATION SYSTEMS NOW ACCEPT CALIBRATION FROM EACH OTHER

National Physical Laboratories—Declaration of the Equivalence of Deutsche Kalibrierdienst and British Calibration Service Certificates—In 1985 the National Calibration Services of Western Europe began a program of collaboration having the objective of creating and maintaining a mutual confidence in each others' services. The activities in which the calibration services
have been participating to achieve this mutual confidence are described in the Appendix.

On the basis of this program of work, the Deputy Director of the National Physical Laboratory responsible for the British Calibration Service (BCS) declares that there are no significant differences between the Deutsche Kalibrierdienst (DKD) and the BCS which would require a different confidence to be placed by the user on the calibration certificates of the two services: they are equivalent and may be treated as such by the recipients of certificates.

This declaration of equivalence covers all certificates issued by DKD, that is to say, it also includes certificates relating to measurements in fields where there may be no approved BCS laboratory. A reciprocal declaration to this asserting the equivalence of BCS certificates with those of DKD has been signed on behalf of DKD.

This declaration will be in force for an unlimited period, but may be withdrawn at any time. While asserting the equivalence of the calibration service certificates, the BCS accepts no legal responsibility for the correctness of the measurement reported on DKD certificates.

This declaration and any subsequent amendments will be published in the "NPL News."

Dr. P. J. Campion
National Physical Laboratory - 7 Sept. 1981

National Physical Laboratory--Declaration Of the Equivalence of Servizio Di Taratura in Italia and British Calibration Certificates - In 1985 the National Calibration Services of Western Europe began a program of collaboration having the objective of creating and maintaining a mutual confidence in each others' services. The activities in which the calibration services have been participating to achieve this mutual confidence are described in the Appendix.

On the basis of this program of work, the Deputy Director of the National Physical Laboratory responsible for the British Calibration Services (BCS) declares that there are no significant differences between the Servizio Di Taratura in Italia (SIT) and the BCS which would require a different confidence to be placed by a user on the calibration certificates of the two services: they are equivalent and may be treated as such by the recipients of certificates.

This declaration will be in force for an unlimited period, but may be withdrawn at any time. While asserting the equivalence of the calibration service certificates, the BCS accepts no legal responsibility for the correctness of the measurement reported on SIT certificates.

This declaration and any subsequent amendments will be published in the "NPL News" and elsewhere as appropriate.

Dr. P. J. Campion
Deputy Director
National Physical Laboratory - 1 June 1982

NATA AND NVLAP REACH AGREEMENT

John W. Locke, Manager, Laboratory Accreditation

A memorandum of understanding (MOU) signed by Dr. Ernest Ambler, Director of NBS, and Mr. E. E. Bond, Chairman of NATA (Australian National Association of Testing Authorities) was recently completed to provide mutual recognition of testing laboratories of these national systems. The MOU commits each system to:

1. recognize the accreditation of a testing laboratory by NATA or NVLAP as being equivalent to an accreditation by the other
2. recognize endorsed test reports issued by a laboratory accredited by NATA or NVLAP on the same basis as NATA or NBS recognizes endorsed test reports from its own accredited laboratories
3. recommend to other persons and organizations in their respective nations that such persons and organization should recognize the accreditation granted to laboratories by the parties to this MOU as being equivalent to each other's accreditation
4. recommend to other persons and organizations in their respective nations that such persons and organizations should accept endorsed test reports issued under the laboratory accreditation systems administered by each of the parties to this MOU as being equivalent to endorsed test reports issued by laboratories accredited by the other party
5. maintain records of the terms of accreditation of laboratories accredited by each of the parties to this MOU and make this information generally available
6. publish criteria to accredit the laboratories in their own country, maintain on file criteria for the other's country
7. agree to reassess their own laboratories on a regularly scheduled basis and collaborate in the development and adoption of revised criteria for accreditation of testing laboratories to increase harmony between the two accreditation systems.

8. cooperate in promoting the development and adoption of laboratory accreditation principles internationally and in the development of international standards relating to laboratory accreditation.

An appendix to the MOU describes specific differences between laboratory evaluation criteria for each system.

In spite of these differences in criteria, each party to the agreement agrees that: (1) the resulting accreditation programs to laboratories are comparable; (2) work will continue forward eliminating or minimizing differences; and (3) any complaints about laboratories the other party has accredited will be resolved through joint cooperation. From NVLAP News.

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GRAVITY METER PASSES FIELD TESTS OF PORTABILITY, DURABILITY

A new instrument developed by scientists at the Joint Institute for Laboratory Astrophysics (JILA) to measure the absolute acceleration of gravity has been used successfully in field tests at 12 sites across the country. The instrument was driven by van a total of 20,000 km to sites in California, New Mexico, Colorado, Wyoming, Maryland, and Massachusetts. Usually it took one day for the measurement at each location including set up and takedown time. The typical achieved accuracy was one part in 10^8 of g (10^-7 ms^-2 or 10 gal). "The success of this survey with the JILA absolute gravity meter demonstrates that the accuracy needed to detect small changes in gravity resulting from tectonic motions is now available in an easily portable and durable type of apparatus," the scientists concluded. A paper describing the field tests is available from Fred McGehan, Division 360.2, National Bureau of Standards, Boulder, Colorado 80303. CONTACT: Fred McGehan, 303/497-3246.

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HIGH DYNAMIC RANGE, TUNABLE ANTENNA SYSTEM DEVELOPED

NBS recently delivered the first of two high dynamic range, tunable EMI antenna systems to the U.S. Army at Ft. Huachuca, Arizona. The systems were developed specifically for that Agency because, in making measurements of background noise or weak interfering signals in the 10 kHz to 10 MHz range, the limitations imposed by high antenna factors are often a problem. NBS combined an active monopole antenna using high dynamic range MOS field effect transistors with varactors to provide a tuned antenna. This permits enhanced field intensity measurements in both automatic and manually-tuned modes over a frequency range from 250 kHz to 32 MHz. While the antennas were designed for Army-owned field intensity meters, they may also be used with similar commercial receivers or spectrum analyzers via remote control over the general-purpose interface bus. CONTACT: Fred McGehan, 303/497-3246.

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U.S. AND CHINA LABS COOPERATING ON MEASUREMENT TECHNOLOGY MODERNIZATION

A team of engineers from the Peoples Republic of China (PRC) arrived yesterday at the Commerce Department’s National Bureau of Standards (NBS), the first stop on a three-week tour of U.S. laboratories and instrument companies that specialize in chemical measurement technology.

The PRC is establishing a Service Center for Testing Technology to serve East China, and has invested $15 million in planning and constructing a new laboratory in Shanghai.

The Chinese group will study chemical analysis and material characterization technology in the United States. The visit was funded by a United Nations Development Program (UNDP) $500,000 grant. The Shanghai Municipal Commission of Science and Technology is responsible for overseeing activities under the grant.

The grant also supports fellowships for PRC scientists and engineers to study at NBS and other U.S. laboratories for periods of up to one year. Scientists from NBS and other U.S. Laboratories will be invited to lecture in China, with expenses funded by the UN grant.

The new service center has asked NBS for technical assistance including the certification of standard reference materials (SRMs). These are standard samples that manufacturers, scientists, and laboratory technicians use to check the accuracy of...
their instruments—instruments that measure
the precise chemical composition of raw
materials like steel, detect toxic pollu-
tants in food or fuels, or establish the
coloration levels of therapeutic drugs
in a patient's bloodstream, for instance.

NBS conducts a large SRM program, selling
more than 900 different kinds of samples to
industrial, university, and other users.
Each year about 40,000 SRM units are sold
by NBS to over 10,000 customers. These
sales cover the cost of research, produc-
tion, certification, and distribution of
the samples.

The PRC study team of five engineers will
spend one week touring NBS laboratories in
Gaithersburg, Maryland. They then will
visit industrial, university, and govern-
ment facilities in the District of
Columbia, Massachusetts, Texas and
California.

This cooperative program expands the sci-
centific communications that have already
taken place between NBS and various insti-
tutions in the PRC. Over the past two years
17 NBS researchers have lectured in the PRC
and 321 PRC scientists and engineers have
visited NBS.
## WELCOME TO OUR NEW MEMBERS

<table>
<thead>
<tr>
<th>Company / Institution</th>
<th>Address</th>
<th>Delegate</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tylin Corp.</td>
<td>23301 S. Wilmington Ave.</td>
<td>Michael R. Paine</td>
<td>Quality Control Supr.</td>
</tr>
<tr>
<td></td>
<td>Carson, CA 90745</td>
<td></td>
<td></td>
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<tr>
<td>Hewlett Packard Co.</td>
<td>Route 41, Avondale, PA 19311</td>
<td>Rom Wood</td>
<td>Electrical Maintenance Supr.</td>
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<tr>
<td>Lockheed Austin Division</td>
<td>2124 E. St. Elmo Rd.</td>
<td>William H. Pederson</td>
<td>Research Specialist</td>
</tr>
<tr>
<td></td>
<td>Austin, TX 78744</td>
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<tr>
<td>Mansour-General Dynamics Co. Ltd.</td>
<td>P.O. Box 725, Dhahran Airport</td>
<td>William J. Frederick</td>
<td>Project Director</td>
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<td>Garden Grove, CA</td>
<td>Mack Ishida</td>
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<td>Frank A. Urbina</td>
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<td>Steven H. Bills</td>
<td>Program Director</td>
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<td>San Antonio, TX</td>
<td>Harold Spoonemore</td>
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<td>Roger L. Hickey</td>
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MEETINGS AND PROGRAMS ANNOUNCEMENTS

April 11, 1983
Region 3 meeting at Naval Ship Weapons Center, White Oak, Maryland. Host: T. K. Hinders.

April 27-29, 1983
Board of Directors Meeting at Williamsburg, Virginia. (Hospitality House Motel).

May 2-5, 1983
Test and Measurement World Expo, San Jose Convention Center, for information call 617-254-1445.

July 18-21, 1983

July 19, 1983
Region 10 plans to hold their Annual Dinner Meeting at the 1983 Conference at Boulder, Colorado.

July 21-22, 1983
Board of Directors Meeting at Boulder, Colorado.

August 8, 1983
Region 3 meeting at Applied Physics Laboratory, Laurel, Maryland. Host: George Skaggs.

October 3-6, 1983
Electrical/Electronics Insulation Conference, Hyatt Regency Chicago, Chicago, Illinois, for information write P.O. Box 159, Libertyville, Illinois 60048.

October 6-8, 1983
Quality "Keystone" of progress Western Regional Conference 1983, Salt Lake City, Utah. Host: ASQC Salt Lake Section.

October 10-13, 1983
ISA, Conferences and Exhibits, Houston, Texas.

October 18-20, 1983

October 18-20, 1983
Quality Expo Time-West, Los Angeles Convention Center.

October 19-21, 1983
Quality Expo Time-International, Chicago O'Hare Expo Center.

1984
CPEM will be held in Delft, Netherlands, Conference Chairman will be Dr. Robert Kaars, National Service of Metrology, Box 654, Delft, Netherlands 2600 AR.

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(613) 997-3411

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1110 W. Dorothy Drive
Brea, CA 92621
(714) 685-0052

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(213) 886-2311, Ext. 2601

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(301) 921-2805

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Litton Data Systems Div.
8000 Woodley Ave., MS 41-01
Van Nuys, CA 91409
(213) 902-4267

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South Avenue
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(617) 272-3000, Ext. 1402

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