For more than half a decade I have listened to the metrology managers' plea for help in satisfying his requirements for technician training. This evergrowing need is the result of the rapid and sophisticated advances in instrument technology, the decreasing availability of technical personnel and the decline of available training from industry, academia and other organizations where training was available in the '60's and early '70's. The current industrial emphasis on employee training goes wanting in the area of instrument maintenance and calibration because of the often acute lack of available training resources.

Additionally, the shortage of personnel resources and the ever increasing equipment inventory, requiring service, allows technician training to take secondary priority. The dynamics of the laboratory manager's daily environment forces him to deal with immediate problems and the training issue is often unwillingly neglected. Remember, the responsibility for employee training rests with his supervisor.

None of us are alone on the training issue. I'm certain each of our laboratories has a training need, and whether it be maintaining current technical competence or training in advanced measurement technologies, the requirement is real. Results of surveys indicate that the NCSL member organization's training needs are diverse, so diverse that a single source of training to satisfy all the requirements is not feasible. The sources of particular training are or will be available from NBS, NCSL, our college and vocational institutions, private consultants and instrument manufacturers.

However, there is one training area that we managers can develop and deliver ourselves — the hands-on training in measurement methodology. The metrology manager knows his unique requirements, has the necessary equipment resources and often has the qualified staff to deliver the training. Many NCSL members are located close by and often have the same requirements for personnel training. There should be little reason why several laboratory managers cannot collectively develop a specific training course, and be able to offer it within one organization's facilities. I'm positive any problems due to security restrictions can be resolved. I strongly feel this may be one of the most appropriate methods for the NCSL community and envision no overbearing restrictions except in the lack of aggressiveness, commitment, and willingness to do part of the job ourselves.

Specialized courses are available from both NBS and some instrument manufacturers. Several measurement seminars are also offered throughout the year from other technical organizations. The NCSL Education and Training Committee is in the process of developing courses having universal or broad application, such as Error Analysis and Thermometry. The committee has been actively pursuing the development of these and additional courses that hopefully can be provided at the regional level. The objective is also to develop the courses under a module concept in order that the user can structure the curriculum for his particular needs. The E & T Committee needs your help in their training needs assessment and active participation on one of the sub-committees.

Reality must be faced and a firm commitment made to assure that the necessary training is conducted. We must become innovative and aggressively seek and utilize all elements that can satisfy a particular need. There is no universal training source for our technical discipline.

In closing may I remind you, that the ability and skills of an employee is often a direct reflection of his management's effectiveness.

James Valentino
President
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WILDHACK AWARD CANDIDATES

Past President Ron Kidd wants to remind everyone that his Wildhack Award Committee is encouraging nominations of people who have contributed to the field of measurement science. Contact Ron at 617-272-3000 X1786. Deadline: May 30.

EDITOR'S MESSAGE

ASSOCIATE SUBSCRIBERS

Last July the Board of Directors approved a trial program to distribute NCSL Newsletters to a list of other laboratories associated with metrology. Generally these were to be labs in organizations that were already NCSL members, but were physically separated from the member labs. The objective, of course, was to give wider visibility to NCSL and encourage increased membership if they see value from the receipt of the Newsletter.

Our first list includes many federal & DOD labs. But remember you can add lab names from your member organization to this list. Just send them to me and mention associate subscriber.

WORKSHOP REPORTS

This issue includes many of the workshop papers from the 1979 conference. The few remaining will appear in June. Papers from Pete England’s workshop had been previously presented so they are included in the comprehensive bibliography Pete submitted.

John Minck
HIGHLIGHTS OF THE NCSL BOARD OF DIRECTOR'S MEETING

January 17 & 18, 1980
Houston, Texas

The NCSL Board of Directors Meeting was called to order at 9:00 a.m., January 17, 1980, by President Jim Valentino. The Board met at the NASA-Johnson Space Center (JSC) on the 17th and met in downtown Houston on the 18th.

Jim thanked Sam Davidson of Schlumberger Well Services and Bill Simmons of Lockheed Electronics Co. for hosting the Houston meeting. Sam handled the overall logistics for the meeting and Bill coordinated the activities at JSC, which included an informative tour of the Space Center and its Metrology Laboratory.

PRESIDENT'S REPORT

Jim Valentino reported that letters of appointment were sent to Committee Chairmen and Regional Coordinators during the past quarter.

He addressed a sympathy letter, on behalf of the NCSL to Brenda O'Brien expressing the organization's feeling on the untimely death of Dave. Jim also arranged to have a terrarium delivered to her.

Regarding the action item to prepare a statement for the Newsletter addressing the financial status of NCSL, Jim reported that it would be inappropriate to issue a statement at this time without the final financial results of the 1979 conference.

Jim Valentino reported that the Executive committee had approved a request by Pete England's Automation Committee to change its name and revise the charter. Name changed to: "AUTOMATIC TEST AND CALIBRATION SYSTEMS."

Charter now reads:

Serve as a forum or information center from which Calibration Laboratory Management may gain knowledge about automated test and calibration systems. Study ATE calibration problems and identify candidate action categories from which recommendations and/or guidelines could be developed, and disseminated to the ATE Design Community.

After a discussion on the change, a motion was made and seconded by the Board to formally approve the change and revision. Motion Passed.

EXEC. VP REPORTS

John Lee reported that he is presently in the process of reviewing the "Long Range Plan." John stated that he is attempting to develop a closer interface between NCSL and the Association for Advancement of Medical Instrumentation (AAMI). He would like to open a communication link and possibly establish a NCSL liaison delegate to the AAMI Board of Directors.

TREASURER'S REPORT

Bob DeLapp submitted two Treasurer's reports, both identified with the heading "NCSL Treasurer's Report Fiscal Year - 1979-80, First Quarter - 1 Oct. 1979 thru 31 Dec. 1979." The first page presents the first Quarter Balances for FY 1980, the second page the Expense to Date. Copies of these reports appear as attachments at the end of these minutes.

With this year's Wildhack Award C4-account balance at zero (award was presented at the '79 Conference which is in FY 80), it became apparent that a special appropriation would have to be made to the FY 80 budget just in case the award should be presented at the 1980 Conference in September. A motion was made and seconded that the current FY 1980 Wildhack Award account be amended to provide an additional $1,000 for the Wildhack Award. Motion passed.

SECRETARY'S REPORT

Since the October Board Meeting, the Secretary has welcomed 16 new NCSL members, all from the domestic area. In accordance with the Secretariat's computer membership report, as of December 20, 1979, the total NCSL membership stands at 405.

REPORT OF VICE PRESIDENT - ADMINISTRATION

Honors and Awards Committee - Chairman Bob Lady reported he had distributed the FY 80 stationery supplied by a local printer resulting in a cost saving of $134.40 as compared to the previous year's cost.

Bob took an action item to investigate methods and sources for the preparation of an appropriate certificate for NBS Boulder's 25th Anniversary.

Bob also took an action item to investigate preparation of a revised version of the Wildhack Award Certificate.

Education and Training Committee - In the absence of Chairman Bryan Werner, John Pipp of Westinghouse reported that the Temperature Course may be changed from a one to a two week course and stated it would probably be held in the Washington D.C. area.
A discussion followed whether existing funds in the committee's budget could be utilized to pay NCSL or non-NCSL instructors. Hugh stated that it would be the committee's responsibility to select the most qualified instructor. The Committee also asked for guidance from the Board on hiring a professional educator to act as a consultant to overview and refine the course outline into a professional program. This Temperature Course will be structured such that any region can present this course by using this same material, course outline and an instructor of their choice. At this time, the Board advised against the procurement of video recording hardware. Hugh Starling stated that based upon the comments from the Board, the Committee would come back with a more detailed report with specifics.

The one-day introductory course (Adjunct Training) for technicians is scheduled for April 8, 1980 and will be video taped.

Brian Belanger reported that NBS is planning a two or three day course in error analysis for NBS personnel and said they could invite some NCSL members to monitor the course to see if the course is what NCSL needs.

Meetings and Programs Committee - In the absence of Chairman Mike Suraci, Hugh Starling asked all Regional Coordinators to provide Mike Suraci with their FY 80 plans for meetings and programs so Mike can properly coordinate the regional programs.

REPORT OF VICE PRESIDENT - MEASUREMENT REQUIREMENTS

Vice President Dennis Gallagher reported on a meeting with Dr. Barry Taylor and Norm Belecki of NBS at Leeds & Northrup on November 7, 1979. Meeting was to inform the Bureau of the need for new and improved primary measurement standards over the next five years as viewed by L & N. Dr. Taylor informed Dennis that other companies who may be interested in such a meeting should contact the Bureau directly.

Laboratory Evaluation Committee - In the absence of Chairman Clem Malot, Dennis Gallagher reported that Clem feels that NVLAP is leaning towards revising their structure to accommodate calibration labs. It is felt that the final resolution of Weinschel's request for microwave accreditation may open the door for other discipline-oriented programs.

Biomedical and Pharmaceutical Metrology Committee - In the absence of Geron Smith, Dennis reported that the committee planned to meet in Chicago in April, 1980 to review the 1979 workshop inputs, plan future actions and discuss any questionnaire coming from that meeting. Dennis related Geron's concern with NBS' non-involvement in the area of electrolytic conductivity. Geron feels this discipline is an essential measurement requirement in the biomedical field, requiring NBS support.

National Measurements Requirements Committee - Chairman Frank Flynn reported he had prepared a questionnaire to accompany NBS prepared measurement capability statements for those areas identified in the 1979 survey as deficient. Purpose of the questionnaire is to determine if the Bureau's services are not adequate or to identify the companies requirements in detail and its source if they are not.

The Committee is in the process of preparing a general form that can be filled out by the membership and mailed to Frank's Committee indicating a measurement problem or a new measurement requirement. This would be used by the NCSL membership on an on-going basis to identify measurement problems in industry or at the Bureau.

Sponsor Delegate's Report

Because of the untimely death of Dave O'Brian, Dr. Ambler asked Bascom Birmingham to inform the Board about the NBS employee assistance program. This is an effective program not unique to NBS, designed to assist troubled employees as soon as difficulties they may be having can be identified. Bascom stated that he had literature available for those members who are interested.

Bascom reported that the Metrology 80 Seminar and Exhibit, planned for Moscow on March 24-28, 1980 was still on, but may be postponed because of the current international situation. Five companies had signed up for the exhibit: Fluke, ESI, Varian, AMETEK and Hunt Instruments.

Regarding the action to determine whether the DoD Video Tape Library at Redstone Arsenal could be used by defense contractors, Brian Belanger reported that Mr. E. P. Williams at Redstone (205-876-2984) informed him that the library is normally intended for government use only. Requests from government contractors will be considered on a case-by-case basis, and exceptions to the government-only policy may be made in special situations. For more information Mr. Williams should be contacted.

Secretariat's Report

Ken Armstrong reported on the normal Secretariat activities since the last Board Meeting.

Ken announced that a number of sets of the NCSL Slide Show are still available for use and distribution by Board Members.

Ken informed the Board of a problem obtaining keypunch help to add the 300 to 400 names identified as Associate Subscriber to the NCSL mailing list. Ken stated John Minck would still like inputs from the Board of names of individuals to be added to the Associate Subscriber list.
Ken again underscored the questionable condition of the NCSL training aids and the continuing problem of managing them. In response to Ken's request for another organization to manage the library, Jim Valentino announced that his company, Sanders Associates, would take full charge of the maintenance and distribution of the NCSL training aids. The 35 mm/audio cassette tape training aids will be checked for quality by Doug Doi and Cliff Koop.

Jim Valentino took an action item to prepare an article for the Newsletter announcing that the Library would be discontinued for an interim period while the training aids material is being checked for quality and updating.

REPORT OF VICE PRESIDENT - COMMUNICATIONS AND MARKETING

Information and Directory Committee - In the absence of Chairman Jim Gilbert, Dean Brungart asked the Board for comments and/or additions to the NCSL capabilities questionnaire which is needed for the next edition of the NCSL Directory. The Board approved the questionnaire for distribution.

Newsletter - In the absence of Newsletter editor John Minck, Dean reported that 250 extra copies of the December 1979 Newsletter were printed for inclusion in membership packets. This issue was the largest so far (72 pages).

John is reapplying for the 2nd class mailing permit with the December issue based upon the October Board action which established the $25 subscription price as a portion of the annual fee.

Recommended Practices Committee - In the absence of Chairman Al Kohler, Dean reported that RP#3 and #5 have been reviewed by the Committee.

REPORT OF VICE PRESIDENT - LAB MANAGEMENT AND OPERATIONS

Calibration Systems Management Committee - Committee Chairman Bob Guibord reported that he had met with George Rice, past Committee Chairman and discussed the previous year's objectives, activities and open items.

Bob outlined the activities planned for this year:
- Continue the wage/salary survey.
- Conduct a survey on calibration intervals and unit time by model/generic type.
- Develop Metrology Guidebook.
- Complete compilation of Government Specifications.

Measurement Assurance Committee - Committee Chairman Gary Davidson reported that the results of the Phase I Southern California (LA Region) Gage Block Group MAP are favorable. However, there has been some concern about the potential cost of the program which will be approximately $3,000/participant. A meeting is scheduled on February 4th to discuss the alternatives.

Voltage MAP Activity - The second Southern California group is scheduled to perform the Phase I experiment for the second time. The anticipated start date is now February 1980. The Northern California Bay Area group stated their Phase I experiment on January 4th. Moe Corrigan is working on geographical problems in forming groups in the Northeast area. Norm Belecki is in contact with a group forming in the Portland, Oregon area.

Gary said he was asked to present a paper at the ASQC 34th Annual Technical Conference in Atlanta, Georgia, on May 20, 22, 1980. His paper is entitled "Regional Measurement Assurance Program, Past and Future."

Product Design and Specification (PDS) Committee - In the absence of Chairman Dexter Franke, Moe Corrigan reported that all Committee records had been transferred to Dexter. Committee members are being lined up and should be firm by the end of January.

Moe stated that one of the Committee's goals will be to address terminology such as "Self-calibrating", as suggested by John Minck.

Automatic Test and Calibration Systems Committee - Committee Chairman Pete England reported that he had prepared and mailed letters of appreciation to members of the 1979 NCSL ATE Workshop in Boulder, Colorado.

Pete distributed a position paper prepared by The Center for Electronic and Electrical Engineering of the National Bureau of Standards entitled "An Approach to Metrology in Support of ATE, Under Consideration at NBS." Barry Bell of Electrosystems Division of NBS is soliciting comments and inputs concerning the paper. It should be understood that the NBS ATE effort, at this time, is in the stage of a feasibility study, and they are primarily gathering and evaluating the technical information. Accordingly, no firm commitments can be made at this time concerning the extent of their involvement.

Pete's Committee is planning to work actively with NBS and other interested organizations in developing a viable technical plan to accomplish some of the objectives and recommendations of the I/JSATP, the aforementioned NBS position paper and the 1979 NCSL ATE Workshop at Boulder.
Board Meeting

Started staffing his Committee for 1980. To date, Barry Bell and Kathy Leedy of the Bureau have agreed to serve. Pete is still looking for one or two more volunteers.

Planned to attend a special ATE workshop at NBS, Gaithersburg during the first week of February. The workshop is a sub-panel of a National Academy of Science evaluation panel.

Liaison Reports

OIML Report - In the absence of Liaison Delegate Don Greg, Bascom Birmingham reported that the Reporting Secretariat 6 of Pilot Secretariat 22 of OIML will be meeting in Paris on March 31 and April 1, 1980. Since Bascom is Chairman of Pilot Secretariat 22, he will be chairing the Paris meeting; and Brian Belanger, Chairman of Reporting Secretariat 6, will be participating as the primary resource specialist from the U.S. It is hoped at the Paris meeting to get agreement from all participants on an international document which can be published by OIML.

GIDEP Report - Liaison Delegate Chuck Corbridge reported that Bill Snell of Tektronix will be the alternate Liaison Delegate.

The last GIDEP Metrology Committee meeting was held on October 21-25, 1979, at Orlando, Florida. The outstanding issue of the workshop centered around calibration intervals and the historical quality data used to establish intervals.

Those interested in obtaining a copy of the GIDEP pamphlet on training courses should contact Bill Fry of the GIDEP Office.

The next GIDEP Metrology Committee meeting will be in Cedar Rapids, Iowa, in April, 1980.

Measurement Science Conference - Liaison Delegate Dean Brungart reported that the conference was held on November 30 and December 1, 1979 at Cal Poly campus in San Luis Obispo, California. There were 293 registered for the conference. Tom Dillon, Deputy Director of NBS gave the keynote address. With the conference attendance growing in size, the MCS Board is considering a commercial establishment for the site of the next conference. This will probably place the conference some time in late January, 1981.

PMA Report - Liaison Delegate George Rice reported that the 1980 PMA Directory will be published this Spring. In order to promote competition among sections, the John Quincy Adams Award has been established to be presented to the section exhibiting the best overall performance.

The Colorado Section of PMA is planning a three day Educational Seminar in the Spring on Flow Measurements in Boulder.

PMA is planning to sponsor an all day technical session on measurement the day preceding the next MSC conference.

ASTM Report - Liaison Delegate Ron Kidd reported that the ASTM E-46 Quality Systems Committee had met in Philadelphia on September 26, 1979 and that Brian Belanger had been appointed to fill the remaining term of Chairman of the Interface Subcommittee E-46.91. Ron then went on to highlight the minutes of that subcommittee (E-46.91). One of the suggested functions of that subcommittee is to provide liaison with outside organizations. Brian's familiarity with NCSL could be useful in involving some of our membership's expertise to accomplish E-46's goals.

ASQC Report - In the absence of Liaison Delegate Max Unis, Dennis Gallagher reported that there is no one NCSL individual or committee who is responsible for keeping the membership informed on Rolf Schumacher's writing committee on ASQC Quality Standards for Calibration Systems and Measurements.

Regional Reports

Region 1 - In the absence of Regional Coordinator Harry Haymes, Director Chuck Corbridge reported on a meeting held on December 11, 1979, at Charles Stark Draper Laboratory hosted by Wes McPhee. The agenda covered the Board of Director's Report, Automated Test Equipment, Standard Cell MAP, and Technical Training. A general consensus of the attendees indicates that they expressed no interest in Matriculation at this time, with requirements being dictated by product sales.

Region 2 - Regional Coordinator Selwyn Smith reported that they have scheduled a meeting at RCA on February 14, 1980. The agenda will include MAP Programs, MIL-C-45622A and Education and Training. An April 3, 1980 meeting is scheduled for the Pittsburg area with the possibility of conducting a one day training course.

Region 3 - In the absence of Regional Coordinator Fred Kern, Director George Rice reported that they are planning three meetings scheduled for February, May and August. Two to be held in the Washington, D.C. area, and the third in the Richmond, Virginia, area.

Region 4 - In the absence of Regional Coordinator John Riley, Director Bob Weber reported that the region has scheduled two meetings for FY 1980. First meeting in Florida at the Kennedy Space Center in late February with the second tentatively set for June in Atlanta. Topics to be discussed at the February meeting
include: MIL-C-45662, Regional MAP, Education and Training, and Metrocification.

Region 5 - Regional Coordinator Joe Katoch reported they are planning three meetings in FY 1980. First meeting at the General Motors Truck and Coach Company, Pontiac, Michigan, on February 21 or 22. Second meeting at Yellow Springs Instrument Company, Yellow Springs, Ohio, on May 21 or 22, with the third at Gaithersburg, Maryland, in September. Regional MAP questionnaires are scheduled to be distributed by the second quarter, with results by the third quarter.

Region 6 - In the absence of Regional Coordinator Paul Groos, Director Cliff Koop reported that the next meeting is tentatively scheduled in the Dallas area in February.

Region 7 - In the absence of Regional Coordinator Harry Doolittle, Director Bob Weber reported they are planning two meetings during FY 1980. First meeting at Hewlett-Packard, Palo Alto, on March 31. Meeting agenda to include: ATE Traceability, Microprocessor Training, Regional MAP's and MIL-C-45662. Second meeting is tentatively scheduled for September at the Tektronix facility in Beaverton, Oregon. Bob also indicated that Chuck Corbridge is starting a grassroots effort in the Portland area, primarily for MAP type programs.

Region 8 - In the absence of Regional Coordinator Rolf Schueacher, Director Hartwell Keith reported the region is planning two meetings in FY 80. The first meeting will be held on February 27 at Rochelle's Restaurant, Long Beach, California. The agenda will include: ANSI STANDARD - "Quality Standards for Calibration Systems," MIL-C-45662, and Metrocification. The second is planned for the latter part of September. Region 8 has set a goal of 100 paid members for 1980.

International Region 9 - In the absence of Regional Coordinator Graham Cameron, Director George Rice reported on a letter Graham had sent to all International Regional Member delegates and foreign attendees at the 1979 Conference who are not NCSL members. The letter provides a "capsule view" of the '79 Conference, encourages attendance at the 1980 or 1981 Conferences and proposes an International Regional delegate's meeting or workshop at these Conferences.

The Board expressed their concern about whether they were meeting the needs of all the Directors and Regional Coordinators. The Board again reinforced that the grassroots activities in the regions is really the backbone of the NCSL organization. All Regional Coordinators were again reminded to submit the topics of their meetings for FY 1980 to Mike Suraci for coordination. The coordinators were also encouraged to consider inviting people from the Bureau and members of the NCSL Board to their regional meetings.

MAP HANDBOOK

Brian reported that he has received comments from NCSL and inside MDS on the first draft of the MAP handbook. During the next two months, the second iteration of the draft should be completed and will be submitted to the Bureau's Editorial Review Board, and NCSL for review. Brian discussed some of the changes he will be making based upon the comments received. He hoped to have the final printed version available before the 1980 NCSL Conference.

He indicated that the Bureau is intending to develop better documentation for each of the MAP services with a monograph or technote which would provide much more detail of the program.

STATUS OF REVISION OF MIL-C-45662

Jim Valentino reported that a recent draft of MIL-C-45662A, dated 26 October, 1979, which was prepared by DARCOM and released by Del Burchfield, VSD on 15 November 1979 is apparently going to be released. Mr. Burchfield's letter states that only changes considered essential are being made to improve the application of the document and to convert it to a Military Standard in compliance with DOD standardization policy. Since he also thanks industry for their comments and suggestions for the revision of MIL-C-45662A (Draft dated 19 March, 1979, prepared by WIRCOM) and identifies the 26 October 1979 draft as the "final revision," it appears that any objections industry may offer will have little impact on the final draft.

Jim also reported that two industrial associations had voiced strong exceptions to the draft. Strongest exception was to Paragraph 5.6 Out of Tolerance. This paragraph has since been rewritten, coordinated with the DOD agencies--they concur and DARCOM is now awaiting reply from the two associations. The general consensus of the NCSL Board indicates Paragraph 5.6 will have a definite cost impact on Industry.

1980 CONFERENCE STATUS

1980 Conference Co-Chairperson Dennis Gallagher presented an analysis of the 1979 Conference Questionnaire. Dennis discussed the various program and logistical comments submitted by the attendees. The most popular topics for the future in order of ranking:

1. Cal Lab automation and ATE in general.
2. Progress or lack of progress in-train.
3. New devices needing calibration.
4. Update on regulatory or other quality standards.
5. Regional cooperative activities and MAP's.
6. Examples of good working QC systems.

7. Inventory management and cost of ownership.

1980 Conference Co-Chairperson Brian Belanger reported on the logistics of the upcoming conference. Due to the heavy scheduling at NBS Gaithersburg, the NCSL Conference has been moved forward to September 22 to 25 (noon). The Board of Directors Meeting is scheduled for the 25th and 26th of September.

Dennis presented a list of speaker and workshop topics being considered and asked the Board for assistance in making the final selection for either different topics or speaker candidates. All Board members were urged to submit their suggestions and comments to Dennis ASAP. To a round of applause, the board commended the Conference Co-Chairmen for an excellent job in developing conference logistics and selection of potential speaker and workshop topics.

ADDITIONAL NEW BUSINESS

Bob Lady informed the Board about a deep concern by his company regarding the effectiveness of the companies aging workforce to successfully complete existing commitments and be competitive for new programs. He distributed a paper titled "A Study on Continuing Education and Skills Requirements" and asked the Board for inputs on how their companies are dealing with this problem.

Ken Armstrong informed the Board about a letter he had received from Daniela Kruh (Member Delegate) of Israel. She stated that one of the calibration labs' greatest problems in Israel is the unawareness of the people outside the Lab of the importance of their calibration service. They are having a most difficult time trying to get people to cooperate with the calibration lab, and has asked NCSL for documented input (printed reports, slides, etc.) on how this problem was dealt with by the NCSL membership. Ken has requested all inputs be submitted to him.

ATTENDEES:

J. A. Valentino - President - Sanders Assoc. Inc.
J. Lee - Exec. Vice President - U.S. Instrument Rentals
H. C. Starling - Vice President - General Electric Co.
D. A. Brungart - Vice President - Teledyne Syst. Co.
M. J. Corrigan, Jr. - Vice President - Lockheed Electronics Co.
D. H. Gallagher - Vice President - Leeds and Northrup Co.
D. M. Doi - Secretary - Lockheed-California Co.
L. R. DeLapp - Treasurer - SRI International
B. W. Birmingham - Sponsor's Delegate - NBS
H. C. Keith - Director - Ford Aerospace & Commun. Corp.
C. Corbridge - Director - Tektronix Inc.
C. D. Koop - Director - Rockwell - Collins
G. Rice - Director - Rockwell - Autonetics
R. L. Weber - Director - Lockheed Missiles & Space Co.
R. E. Kidd - Past President - Microwave Assoc.
L. K. Armstrong - NCSL Secretariat - NBS
B. Belanger - Liaison from OMS - NBS
R. B. England - Committee Chairman - General Dynamics
G. Davidson - Committee Chairman - TRW/DSSG
R. M. Lady - Committee Chairman - Lockheed Georgia Co.
F. A. Flynn - Committee Chairman - USAF
R. Guibord - Committee Chairman - TRW/DSSG
S. L. Davidson - Member Delegate - Schlumberger Well Services
B. Simmons - Member Delegate - Lockheed Electronics Co.
J. Flipp - Member - Westinghouse Electric Corp.
# NCSL Treasurer's Report

**Fiscal Year 1979-80, First Quarter**

1 Oct 1979 thru 31 Dec 1979

## Account Budget

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## 1st Quarter Balances

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One of the largest costs associated with the life cycle of the majority of the Army's Test, Measurement and Diagnostic Equipment (TMDE) is the cost of its calibration.

The calibration process still falls into the category of a labor intensive process involving relatively expensive labor. Given a fairly constant inventory of TMDE, it is immediately obvious that the less often each item in the inventory is calibrated, the less number of calibrators are required, some less money may need to be spent for calibration equipment and maintenance of that calibration equipment, etc. Consequently, the Army has placed a great deal of emphasis on establishing optimum calibration intervals.

In emphasizing the economy that can be derived from increasing calibration intervals, equal emphasis has been placed on avoiding degradation of end item or weapon system performance. Obviously if no calibration is performed, there is no calibration cost incurred but an even greater cost may be incurred in other forms such as poor quality of material or even weapon system failure which may influence the outcome of a combat situation.

The particular model used in this case is mathematically complex and will not be discussed in detail. The inputs to the model are the identification of the item calibrated, the date of calibration and an indication of the condition of the item when it was received by the calibration activity (i.e., within or outside specified tolerances). A number of data purification techniques are employed and the generalized Weibull distribution of failures is used in estimating the appropriate interval for a given reliability the TMDE is required to meet. (CHART 2) Although the model is quite sophisticated, it must be emphasized that its output only represents a tool to be used in the decision-making process and that the judgment of the decision maker always prevails. (CHART 3)

The information contained in TM 43-180 is used only as a guide in establishing calibration intervals for TMDE used in the R&D, P&S, and T&E environment. Laboratories involved in supporting this TMDE are sometimes referred to as being a part of the Army's industrial calibration program as opposed to the field Army calibration program. Because of the type of work performed in this environment, all the optimum calibration interval are decentralized to the command or installation level. The TMDE user and the installation calibration coordinator are the key decision makers. The user is more familiar than anyone else with the operation of TMDE in his particular project or function. General guidance is provided such as...
items used only as indicating devices require no calibration, items used to provide measurement data which will influence the outcome of a test or a decision must be operating within specified tolerances, etc. The user has the capability to obtain exception to intervals published in TB 43-180 by obtaining the approval of the calibration coordinator.

(Chart 4)

The calibration coordinator evaluates all such requests using historical data gathered through the installation calibration recall system, his own expert opinion, and if necessary, the assistance of local calibration staff or the USAMCC technical staff. All of his decisions which allow exceptions and the rationale for those decisions are documented. This documentation is subjected to review during periodic quality assurance audits conducted by USAMCC. The calibration coordinator conducts his own audits of TMDE users to ensure that they are in conformance with general calibration policies.

Since Army policy provides for exceptions based on good judgment in this type of environment, the calibration intervals used in the recall system at an installation housing R&D, P&P, and T&E type missions are generally longer than those contained in TB 43-180. Equipment specified as requiring calibration in TB 43-180 may not require calibration at one of these installations because of the way in which it is used. Several items may be found in administrative storage marked "Calibrate before use" because they are not required in ongoing tests but are necessary for future tests. Some items may be marked "Limited use" in certain parameters since the capability of the items in this parameter is not required in the use being made of it. These measures result in cost savings with no degradation in the quality of material.

The last system of establishing calibration intervals to be discussed is that used to optimize intervals for standards calibrated at the highest level in the Army hierarchy of calibration capabilities. This capability is found in the Army Standards Laboratory (ASL) which is an organizational element of USAMCC. Detailed performance information is collected at this level in the form of readings at various points in the calibration process. This data has historically been used as a part of the calibration test report in deriving constants and calculating uncertainty statements. It is now being analyzed to optimize calibration intervals for lower order standards.

The information necessary for the analysis is the uncertainty required of the lower order standards and a number of measurement values from previous calibrations. The measurement values are then statistically analyzed and tested for the existence or nonexistence of a significant linear trend. If a trend is present, a set of tolerances is still imposed around the regression line. These tolerances represent bounds in which 95% of the future readings are expected to fall. The tolerance bound is computed for each item for the last year in which a calibration is done and for the next three or four years, depending on what the established calibration interval is. The estimated regression line is also computed for these out years. Suppose for a particular item the 95% tolerance limits remain within the requirement limits for the next two years. This implies that there is a less than 5% chance that the reading taken two years hence will all outside the requirement bounds in either direction. If the item is currently calibrated on a much shorter interval, engineering judgment can be used to extend that interval up to two years with little chance that the item will not meet its requirements during the use period. (Chart 5)

If no significant linear trend exists, the calibration is not time dependent and the regression analysis is discarded. In this case the assumption is made that the distribution of readings follows a normal distribution. The sample means and standard deviations are then computed and used to compute tolerance limits around the population such that there is a 95% confidence that the population 95% of the population falls within these limits. The purpose of this analysis is to determine how these tolerance limits compare with the requirement bounds placed on a given item. It more than 5% of the readings are expected to fall outside the requirement bounds, then no interval extension would be proposed; on the other hand, if no readings are expected to fall outside the requirement bounds, engineering judgment can again be used to extend the interval. (Chart 6)

The TAMMS file of calibration performance data generated within the field Army calibration system is systematically purged of obsolete data. Even so, it currently contains over three million records on the 500,000 individual items. Obviously a large computer is required to store and analyze a file of this size.

The ASL is organized along the parameter lines because of the specialized knowledge required at that level. Performance data which is collected and stored along parameter lines on a relatively small number of high level standards can be organized such that it becomes suitable for storage on cassettes of floppy disks. Analysis for interval adjustment and other purposes can be performed at the workbench or inexpensive micro-computers that are being introduced into the laboratory.

The trend in the immediate future then appears to be directed toward distributed computing within the large mainframe still required for storage and analysis of the massive TAMMS files and smaller, more micro-computer aided for storage and analysis of more accurate but less voluminous laboratory data files. As laboratory scientists and technicians become more computer literate, test reports produced on the micro-computer will progressively provide the calibrated equipment owner with more accurate and useful information. Test reports will provide historical information, graphically display trends, and routinely calculate the data when each individual item should be resubmitted for calibration. When we arrive at this point, the need for calibration will become more meaningful to the equipment user, intervals will be
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optimized on an individual item basis and laboratory calibration personnel will be more directly involved in management of the laboratory workload.

In summary, the Army has recognized the need to tailor its calibration interval adjustment program toward the needs of its field Army, its industrial establishment, and its standards laboratory. In so doing, it has acknowledged the unique requirements of each situation. In the case of the field Army environment, the tremendous volume of data readily lends itself to a rigorous mathematical analysis based on optimally established target reliability criteria and actual instrument performance. On the other hand, the actual use environment for R&D application may vary considerably from activity to activity. In each instance, the user is the most qualified individual to determine calibration requirements based on the specific application of his test equipment. Consequently, a system which provides the necessary degree of flexibility is most appropriate. Finally, in the case of the standards laboratory, still another technique is employed to take advantage of detailed measurement data that is collected as a part of the calibration process. (CHART 7)

Each situation that arises may be different and should be carefully evaluated to determine the most appropriate methodology. Furthermore, the introduction of low cost micro-computers appears to be establishing a trend which will allow the calibrator to become more directly involved in determining optimum calibration intervals on an individual item basis. Thus, the calibration system manager of the future will have available to him an array of alternatives from which to choose thereby insuring the most appropriate methodology for each individual situation.
FEATURES OF THE U.S. ARMY INDUSTRIAL CALIBRATION PROGRAM

- LOCAL INTERVAL DECISION AUTHORITY
- CONSIDERATION OF USER REQUIREMENTS
- DOCUMENTED DECISION RATIONALE
- INTERNAL AND EXTERNAL AUDITS AND INSPECTIONS

SUMMARY

- DIFFERENT SITUATIONS DICTATE DIFFERENT METHODOLOGIES FOR INTERVAL OPTIMIZATION
- DISTRIBUTED DATA PROCESSING WILL ALLOW MORE DIRECT PARTICIPATION BY CALIBRATION TECHNICIANS IN INTERVAL ADJUSTMENT DECISIONS.
RECALL PERIOD PILOT PROGRAM

CHUCK GEBHARDT
Lockheed Missiles & Space Co., Inc.

ABSTRACT

The LMSC Measurement Standards Laboratories (MSL) is responsible for a calibration population of over 50,000 instruments and tools. Recall periods for these devices are determined by the percentage of instruments in-tolerance at the time of submission to the MSL. Evaluation is made of generic groups (power supplies, oscilloscopes, generators) within specific manufacturer/model.

The Recall Period Pilot Program (RP3) was initiated in May 1977 to determine the effects of recall period on instrument quality and reliability. The Program was successfully negotiated with the local regulatory agencies (Air Force, Navy) due to its departure from normal contractual requirements. The following paper describes why and how the study began, why certain instruments were selected over others, and how the program is monitored and controlled.

CALIBRATION - HISTORICALLY

Metrologists maintain the theory that the more frequent a device is calibrated, the better its accuracy and reliability. Supporting this kind of thinking are the influential regulatory documents such as MIL-Q-9858A, MIL-C-45662A, and OD21549B. Similar statements found in each of these documents recommend shortening of recall periods (intervals) to assure continued accuracy. The metrologist should look hard at the basis for these recommendations—were they determined by evaluation of reams of instrument performance data, intuition, or because it just seemed to be the right thing to do?

From a technical standpoint, the frequent calibration of tube-type devices could possible have been the best approach. The contemporary world of measuring and test equipment is predominantly solid state in design, and it is questionable that frequent calibrations are buying better quality or increased reliability. The instrumentation of today has become faster, more accurate, and broader in application, but its sensitivity to catastrophic failure has noticeably declined. Due to improved accuracies and expanded functions, the metrologist is concerned that these features will create a proneness to in-tolerance failures. The LMSC/MSL has found no such correlation in instrument performance data.

Metrologists concerned with instrument reliability must step up to current state of the art conditions along with the instrumentation they service. No longer does the "bathtub curve" appear acceptable in describing an instrument's life cycle. The life cycle of today's devices should be referred to as the "frypan curve" because of the fewer infant mortality failures, shorter period of infant mortality, extensive period of random failures, and longer time to wearout. (Figure 1.)

Advancements in measurement science, component research, and production processes aided instrument manufacturers to bring about this "new" look in reliability. Most influential to new instrument reliability are increased quality awareness and recent studies in Product Liability Common Law.

The "frypan curve" represents a new world for metrologists to explore. The challenge is to review our preconceived ideas concerning instruments and their ability to withstand the test of time. Perhaps a better method of optimizing accuracy and reliability with respect to time will be discovered. Without groundwork studies such as RP3, we might never know.

DEFINING THE INSTRUMENT POPULATION

The LMSC/MSL services approximately 74,000 instruments and tools each year. Our average recall period is 9.6 months which calculates to a yearly calibration frequency of 1.25. There are ten (10) monthly periods in use—1, 2, 3, 4, 6, 9, 12, 18, 24, and 36 months.

The instrument population is defined by a strictly regulated set of four alpha characters referred to as station codes (STACO). The STACO's origin dates back to 1962 when the MSL reorganized its laboratories into stations representing generically similar equipment. This station concept was divided as follows:

- A = Basic Analog
- B = Waveform
- C = Signal Conversion
- D = Receivers/Analyzers
- E = Counters
- F = Digital Equipment
- H = Oscilloscopes
- K = Amplifiers
- L = Power Supplies
- N = Recorders
- T = Special Systems
- V = Primary Electrical
- W = Primary Physical
- Y = Dimensional

Instruments within these groups were assigned an additional three letters to identify specific manufacturer/models. As an example, a Hewlett Packard 3400A voltmeter would be AHPO:

- A = Basic Analog
- H = HP = Manufacturer
- P = Model

or a Fluke Manufacturing Co. 8020A digital voltmeter is FPLG:
The level of discreteness in the assignment of station codes is dictated by the need for meaningful instrument performance data. Low accuracy, one of a kind, or technically obsolete equipment are generally collected into one code since recall period changes to these devices are infrequent.

Further definition of the population is accomplished by a performance code and the use of an IBM card service document. The performance code is a collection of five alpha characters used as attributes data to describe an instrument’s condition upon submittal to the MSL. The servicing technician selects the proper alpha code according to the data coding logic diagram (see Figure 2) and records it on the service document. The service document is preprinted by a computer and carries the following information:

Property tag number
Manufacturer
Model
Owner (custodian)
Charge number
Recall period
Calibration procedure no.
Station code
Lab location

The technician completing the service document records his service hours, alpha code, repair or out-of-tolerance data, date completed, next due date, and then stamps off the document with his Product Assurance stamp. All pertinent performance data are entered into a computer program. The service document is physically filed near the MSL to provide this historic data for a period of two years. Instrument performance data are tabulated by station code on two computer reports generated quarterly. One report lists all servicing data for the previous three months, while the second report indicates 12 months of data (see Figure 3).

These data are used for tracking and evaluating instrument performance for recall period changes, failure analyses, and procurement. Once each year, efforts are directed towards culling "dogs" from the instrument population. Low reliability units are first identified by station code. A special program lists individual instruments within those codes which exhibited three or more failures during the time period of concern. These annual exercises tend to stabilize instrument reliability, improve instrument availability, and reduce overall calibration costs.

By far the greatest level of calibration costs, recall period increases at LMSC/MSL in the past year have been minimal. Although cost savings of over a quarter of a million dollars were reported in 1978 from customer approval, mass recall period increases, we predicted several years ago that these changes would "plateau" out. And so they have. In early 1977, we decided to explore different techniques which ultimately led to the birth of RP3.

SELECTING A SAMPLE POPULATION

Selecting the instruments to be included in the RP3 study required that we first establish a set of criteria. Preliminary negotiations with our regulatory agencies permitted us freedom of choice from any portion of the instrument population. To aid in deciding upon realistic criteria, we grouped the calibratable population into classes and types as follows:

Classes

a. Transmitters - oscillators, generators, power supplies
b. Receivers - meters, counters, oscilloscopes, recorders
c. Passive - inductors, resistors, capacitors
d. Functional - amplifiers, signal conditioners, tools

Types

1. Mechanical - crimpers, micrometers, dial indicators
2. Electromechanical - mechanical drive, electronic circuits
3. Tube Type - vacuum tube circuits
4. Hybrid - combination vacuum tube/solid state
5. Solid State - transistors, IC's, FET's, etc.

Ideally, we wanted to select instruments, tools, or both which would represent a large variety of classes and types. Realizing that most vacuum tube devices and some hybrid circuit devices are being phased out of the population, there would be no contemporary value in including these devices in the RP3 study.

Another look at the classes and types narrowed our selection to three classes and two types. Since passive devices were predominantly primary standards, they were not included. Using electro mechanical instruments in a study involving recall periods of up to four times normal could be catastrophic, so these devices were cancelled out.

The following four groups of calibratable devices met our selection process relative to class, type, age, reliability, and utilization: (see Table 1 for additional data).

Group I is an early solid state model of a function generator with high utilization and good reliability. Group II comprises the latest types of high frequency oscilloscopes.
with state of the art circuitry, excellent utilization, and good reliability. The amplifiers of Group III were selected because of unique circumstances associated with the population. Group III was the largest, single family of intermediate solid state amplifiers used by the organization and calibrated on the Fluke T10 Automatic Calibration Station. The tool group selected was a popular dial indicator family with high utilization, minimum recall period, and marginal reliability.

**CALCULATING TEST RECALL PERIODS AND SAMPLE SIZES**

Having selected four families of devices for use in the recall period study, each of these were assigned a set of four intervals. The intervals began with the currently assigned recall period \( T_1 \) and increased an interval at a time until \( T_4 \), e.g., \( T_1 = 9 \) months, \( T_3 = 12 \) months, and \( T_4 = 18 \) months (see Table 2). It was desirable that each test interval within each group contain a sample population capable of yielding an equal amount of data bits (servicings) per study period to properly balance the judgments made on interval effects (see Table 3).

Sample populations for each group were calculated using simple proportion techniques in a computer program to account for calibration frequency variations among the assigned intervals. The frequency, or number of calibrations per study period, were calculated by dividing each interval, \( T_i \), by the last and longest interval, \( T_4 \). Since shorter intervals result in increased frequency, the sample populations were proportioned to yield an equal number of calibrations over a given time period.

To prove the sample population credibility in providing a balanced data yield for any selected time period, a matrix was constructed to illustrate the data bits available for each interval in each group at year end and at \( T_4 \).

Table 3 proved the sample size selection to be sufficiently balanced \( \pm 1.3\% \) among the intervals and the groups to adequately detect any dramatic shifts in instrument performance. The incremental increases which are a necessary part of this study characteristically result in a larger proportion of units appearing at the longer intervals. This is because a recall period increase brings about a decrease in the frequency of calibration. Since we established sample sizes within intervals at a level which would produce equivalent annual data bits, a greater sample size was necessitated at longer frequencies. To reduce the tremendous clerical effort of records change to assign to new STACO's to the 16 RP3 populations, the currently assigned STACO was used for each group at the \( T_4 \) test recall.

These groups and their corresponding intervals represent 16 distinct instrument populations which are evaluated as separate entities over some period of time. To accomplish this discrete analyses, each of the 16 populations had to bear its own unique identity.

**IDENTIFICATION AND TRACKING OF POPULATIONS**

The use of a four-letter station code to identify manufacturer/model groups for data gathering and analysis has been quite successful in the MSL for 14 years. The four groups of devices dealt with in this pilot study each have their own assigned code as indicated in Table 4. It was necessary to assign different codes to the remaining populations in order to discriminate between blocks of data. The 16 individual populations have codes assigned as indicated in Table 4.

The 16 populations and their respective codes have been entered in the computer-based calibration program records, and the quarterly and annual reports will provide necessary performance data. Tracking of the data is accomplished in two ways: first, the raw data is recorded on a tabulation sheet for each station code (Figure 4) on a quarterly basis and, second, the raw data is graphed as shown in Figure 5 for measurement of in-tolerance reliability. Failure rate, turnaround time, and hours per unit are also recorded as shown in Figure 6 to determine any influence on these areas due to extended periods.

Performance data to be used for evaluating the study population will not be valid until a period of time equal to the old plus the new recall period has elapsed. This is to assure that an absolute purge of old data has taken place, and that only data representing the new assigned recall are collected. To take advantage of this opportunity to study recall period effects, we chose to extend the program of data collection to a point equal to three times the original recall. The start and stop periods for the original interval \( (I_0) \) and the new interval \( (I_n) \) were calculated as follows:

\[
\text{START DATA} = I_0 + I_n \\
\text{STOP DATA} = I_0 + 3(I_n)
\]

The actual start and stop dates for data collection, as shown in Figure 7, also incorporate the computer-generated data report's scheduling. These reports are distributed every third week of February, May, August, and November, so that the data start and stop points reflect a time relative to the issue of these documents. (Figure 7 only shows dates for the increased recall periods.)

Every quarter, the completed tabulations and graphs are presented to the local regulatory agency (NAVPRO) for evaluation and discussion. The MSL or the agency can exercise the authority to disrupt all or a portion of RP3 should one or more of the test populations appear out of control. Out of control is defined as serious deterioration of any measured parameter such that, through engineering evaluation, it is determined to be unrecoverable. All data tabulations and graphs are available for inspection or reproduction at any time by regulatory agency personnel (Air Force, Navy).
The integrity of the RP3 program has been assured by the implementation of several communications methods. Prior to the effective date of the program, all involved laboratory personnel met to discuss the mechanics and objectives of the RP3 program. Each engineer received an explanatory cover letter describing the program in detail, a copy of the report presented to and signed by the regulatory agency, and a set of listings identifying the 16 populations and their respective property tag numbers. On a random basis, these listings are correlated with the service documents to ensure that each of the 16 populations remain as originally assigned. The quarterly reports on instrument performance data also serve as a check on the quantity serviced in a particular time period from each of the distinct populations.

**SUMMARY**

The Recall Period Pilot Program is an extremely visible study in that resultant data are available to internal product assurance and corporate auditors as well as to our regulatory agencies. Built in protection for the credibility of each population is assured since only one individual has the authority to alter the plan.

Details of RP3 have been presented in other formats at other times to metrologists with responses ranging from "So What?" to near violence. These mixed emotions were accompanied by criticism from both ends of the scale--destructive and constructive. In review of these events gone by, we will include here some pertinent questions directed towards RP3 and how LMSC/MSL replied.

**Question #1:**

"How did you manage to sell RP3 to your customer?"

**Answer #1:**

Two basic reasons--rapport and confidence. The current method of adjusting recall periods has been successfully used for 12 years. We talk to our customers frequently and freely to resolve problems of mutual interest and benefit.

**Question #2:**

"How can you maintain the identity of the individual instruments within each group to keep them out of other groups?"

**Answer #2:**

Individual units are uniquely identified by a property tag number. Computer lists used by lab engineers assigning work specify which tag numbers belong in what group. Prior to work assignments on RP3 devices, the service document data are reconciled against the computer listing.

**Question #3:**

"What assurance do you have that differences in data will not occur because one technician makes a center-spec adjustment while another does not?"

**Answer #3:**

Instruments in the RP3 study do not get center-spec adjustments although our organizational procedures do permit center-spec adjustments under certain circumstances relative to repair or system calibration.

**Question #4:**

"How do you keep new instruments of the same manufacturer/model from infiltrating the RP3 populations?"

**Answer #4:**

The last letter of each station code involved is changed to "U" (for example, BWAU, BCAU, KDIU, YBAU).

The most important question yet to be answered is, "What will LMSC do with the RP3 data?" We hope, of course, to be able to make some concrete determinations that recall period increases do or do not have an effect on the quality and reliability of the population tested. Whichever direction the data takes, the intention is to evaluate all parameters contributing to those data and isolate and identify time dependent measurement areas. With this accomplished, the calibration procedures and processes relative to those measurement areas will be reviewed for adequacy, i.e., are we over-calibrating or under-calibrating. Similar reviews will be made of failure rates, turnaround times, and hours per unit to see if effects of recall increases were felt in these areas.

Analysis by formal statistics is not required nor does it seem necessary at this time. Should the data collected warrant a more formal statistical approach in order to reach a decision, then such methods as required will be utilized. Changes to recall periods in our current instrument population are made on the basis of intolerance reliability, and should serve equally well to evaluate the results of the RP3 program. RP3 is operating in a controlled framework whereby each instrument is calibrated at the same station with the same procedure and, usually, by the same technician. The RP3 population is not being sampled since each and every instrument in the program will be looked at at least three times by the end of the study.

It is not the intention of this program to promote the end of calibration recall periods nor to encourage exorbitant recall increases. The possibility does exist, however, that the culmination of the program will indicate the need for more research into how to change recalls and how much change is profitable.
BATH TUB VS. FRY PAN CURVE

Bathtub vs Frypan

Figure 1

DATA CODING LOGIC

Figure 2

MSL MANAGEMENT AND RELIABILITY 3 MONTH SUMMARY

Figure 3

EDITOR'S NOTE: Figures 4 through Figure 8 are not reproduced here because of size. Contact author.
ABSTRACT

In today's economic environment, the question for the Metrology Manager is not whether to automate, but rather how and when. This paper presents some alternatives to the normal choices of manual vs. turn-key automated measurement systems, and discusses the decision criteria applied by the Metrology Division, Naval Avionics Center, Indianapolis, Indiana.

Evaluation of the calibration process elements, and an analysis of the available automation resources are also presented. The interrelationships of hardware, software, quality assurance, and people costs are considered, and the question "How much calibration?" is raised.

This paper discusses one Metrology Laboratory's approach to the questions of how and when to automate. When is easy to determine. Automate as soon as possible after you have properly determined how. Even though this sounds trivial, you probably cannot recall many automation projects that you've seen fail due to insufficient planning. Then remember that most Metrology operations are overhead functions, and are closely controlled with respect to capital expenditures. Your automation project will probably have to be very well planned and presented in order to receive budget approval, and if it's unsuccessful, you may not get a second chance. The prime question then appears to be how to automate. What should you consider during the planning stages? Here are some factors to consider in answering these questions.

Consider the entire calibration process, and strive for systems solutions. All of the

following factors can contribute significantly to the relative efficiency of a new calibration system. And each of them should be rethought in the context of automation and the many new potentials it affords for savings throughout the Metrology Laboratory and the organizations it supports.

What to Measure - defining test parameters and sample sizes.

How to Measure - defining test methods and developing procedures.

Data Acquisition - assembling appropriate test equipment, performing the test and recording the data.

Data Analysis - mathematical, statistical, graphical and tolerance analysis of data.

Decision Making - making accept/reject decisions.

Test Reporting - conveying calibration results to potential users in readily usable formats.

Data Storage - parametric and performance data for calibration history files, recall interval adjustments, and management information and control systems.

Quality Assurance - insuring accuracy and traceability of measurements, completeness and consistency of testing.

Try to look at these factors from a corporate viewpoint. If your automated calibration system saves time for quality assurance, engineering of manufacturing divisions, include that in your planning.

Define your calibration workload requirements. Start with your big workload areas first. If you have a large number of instruments of one general type (for example, oscilloscopes or meters) you may be able to justify a commercial turn-key automated calibration system. While the initial cost of such a system may be high, calibration software is often provided and the system may be highly automated, allowing the use of lower level calibration personnel. Consult the manufacturer and other users for their experience and assistance with cost/benefit analyses. If you're learning this way, however, you should investigate the manufacturer's provisions to allow you to write your own custom software and to update/replace the test hardware in the systems. Your workload will change rapidly in the years ahead and a device with fixed software, measurement ranges and accuracies will soon become obsolete. If you don't have the fixed workload to justify a large commercial system, then a modified approach is in order. In any case, you should strive for flexibility and modularity in planning a system based on optimal use of all available resources.

Define your available automation resources. Take a careful look at all the available resources, and don't forget to consider the following:

Computers - cost halves while capability doubles about every two years (a 1000 times improvement in 16 years). There is much more available now for your money.

Test Equipment - new standards and test equipments often have more capability (sometimes at less cost) through application of microprocessor and digital electronic technologies.

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METROLOGY LABORATORY AUTOMATION - A MANAGEMENT CHALLENGE

THOMAS A. PEARSON
Director, Metrology Division 430
Naval Avionics Center (NAC)
Indianapolis, Indiana
IEEE-488 Interface - this vastly simplified and widely accepted format for interfacing test equipment and computers makes it easy to configure and re-configure modular automated systems.

Personnel - the availability of professional personnel and/or high level technicians can give you the option to do-it-yourself, while the loss of these personnel could dictate turn-key systems in spite of the economics.

Evaluate several of the best alternatives. For example, you may evaluate turn-key automated systems with calibration program software provided against manual calibrations. But you should also consider flexible modular automated stations controlled by calculators or a distributed computer via a standard interface bus. Significant features of this type approach include reduced test times, improved quality and better equipment utilization.

Reduced Test Times

- The first full year's experience at NAC with automation of microwave/RF, AC/DC meters, and function generator calibrations via the IEEE-488 Bus under distributed computer system control, have shown overall savings of better than 50 percent (this includes time to prepare all the calibration software).

- In addition, this system has provided greater flexibility to meet new measurement requirements and has virtually eliminated manual data handling.

Better Equipment Utilization

- IEEE-488 Bus compatible instruments may be used in either manual or automated mode, providing graceful system degradation and easy troubleshooting.

- The flexibility/modularity of the system allows for easy system update if improved hardware or software modules become available.

- By configuring the system with basic, general purpose sources and measurement devices, a wide variety of high accuracy capabilities are available with a reduced equipment inventory.

Better Testing and Quality Control

- Advanced testing technologies such as Digital and Numerical Analysis techniques are readily applied.

- Third generation ATE concepts of software intensive testing and accuracy enhancement can be used.

- Mathematical, statistical and graphic techniques can be applied directly to speed the data analysis and decision making processes.

- More thorough, repeatable calibrations are possible.

If you've done your planning well, winning budget approval will be much easier. Automation of metrology functions is an exciting and rewarding technical challenge that will stimulate your better personnel. But with all the potential rewards come several new management challenges. Knowing about them in advance will give you a better chance of successfully meeting them.

Quality Assurance - software quality assurance is as important as the calibration of your standards in a software intensive automated calibration system. You'll need a plan that provides the necessary levels of QA without eating up all your savings. (NAC has a draft plan and copies are available by contacting the author.)

Cost and Schedule Control - developing calibration software takes time. Determining the proper automated test samples size for each calibration will help keep software development costs and schedules in line.

Recall Intervals - almost without fail, automation leads to a more thorough calibration process (a larger sample of the unit under test's performance). Often this results in a higher probability of finding at least one out-of-tolerance reading. Obviously this does not mean that the unit under test is less reliable than it was when tested with less thorough manual methods. A more sophisticated approach to determining instrument reliability and appropriate recall cycles will be needed.

Training and Staff - selection of computers with mature operating systems and high level languages can greatly reduce the time requirements for programming and systems management. Training requirements are also simplified with this type system. In any case, a good staff of professionals and high level technicians seem to yield the best productivity when your workload is complex and varied. If you have large, repetitive workloads, you may be able to invest more in procuring or writing complete, sophisticated software and then use lower level calibrators. With either type of system, training a good metrologist to write automated calibration programs works well, while training a programmer the required metrology takes years.

In summary, it now appears that almost all calibration processes can be automated cost-effectively. But as with all new, more powerful tools, proper management of automated metrology is essential if the lofty productivity and quality goals are to be reached.
The National Conference of Standards Laboratories (NCSL) Training Committee continues to search for an educational program for calibration technicians that will meet the requirements of calibration laboratory managers. This includes giving due consideration to costs and time, in program preparation as well as presentation. This paper is prepared for the purpose of extracting the essence of your combined thinking rather than to inform you. Therefore, we urge each one of you to contribute your comments. We hope the quiet majority will not be intimidated by the vocal few.

Our topic of discussion today is minimum requirements for calibration technicians. My definition of minimum requirements is those factors that enable an individual to compare an instrument to an appropriate standard and perform whatever maintenance is required to cause it to perform reliably within specifications.

Our topic of discussion today is minimum requirements for calibration technicians. My definition of minimum requirements is those factors that enable an individual to compare an instrument to an appropriate standard and perform whatever maintenance is required to cause it to perform reliably within specifications.

When we attempt to define minimum requirements for calibration technicians, we must be aware that measurements involve every technology known to man and almost every phase of our life. We may wonder if there are enough threads running between the various technologies to form a common set of basic requirements from which each can develop. I think we will find that there are.

We might also wonder why NCSL should be concerned about minimum requirements for an activity that crosses the entire field of science and technology. There is general agreement that a better educational program in measurement science is needed. Most of us are painfully aware of the absence of measurement science curriculum in post high school technical schools and institutes throughout the nation. Defining the minimum requirements is basic to developing a curriculum guide for establishing adequate post high school programs. These minimum requirements must be acceptable to a large segment of the measurement community to provide enough student interest to maintain a curriculum.

We might wonder what minimum requirements will be required of calibration technicians three, five and ten years in the future.

Perhaps those of you who may be in the instrument development and manufacturing business could present some enlightening comments. Surely some things to be considered will be auto calibration systems, microprocessors, throwaway modules, and complete sensing-evaluating-regulating and controlling systems with no visible readout.

What will be the impact upon those who are already classified as calibration technicians but who may lack several of the minimum requirements? This will vary of course. For some there will be no impact because they already meet company and union requirements for the job and it is unlikely that it will change. For others it will provide incentive to company and employees for short courses to meet these requirements.

Minimum requirements may be defined at two levels—the entrance level and the journeyman level. Let's look briefly at these. For the experienced calibration technician I would list knowledge, wisdom, personal integrity, skills, and manual dexterity in order as absolutely essential for satisfactory performance of those who perform calibration and maintenance on instruments of high accuracy and precision.

Why Knowledge?

Obviously because we must know the basic laws of physics, electricity, magnetism, gas flow, fluid flow, and solid-state devices if we are to determine what is wrong and what is required to bring an instrument into calibration. So whatever our field, we need to know the basic information that governs the operation of the sensor, signal amplifier, and readout and the outside influence that may affect them.

Why Wisdom?

Defined as the correct application of knowledge, this also becomes apparent but it is not taught in the classroom. It may be demonstrated, to a degree, in the laboratory, but generally it is acquired through experience. Understanding the parameters that can influence the accuracy of an instrument or system requires not only knowledge of specific laws, but the interrelationship of those laws.

Why Personal Integrity?

The only reason integrity is not at the top of the list is that it is useless in calibration work without knowledge and wisdom, but then neither are they of any value without it. The technician on the bench is the last person, except for spot checks, who has an opportunity to correct a defective instrument before it becomes involved in critical measurements. If he lets those that are erratic, or just a little out of tolerance, or have gus performing performance slip by until next time, he has no business in standards calibration. He should feel confident that the calibration data truly represents the condition of the instrument and barring misuse or competent failure, it will perform within its specifications until the next calibration due date.

Why Skills and Manual Dexterity?

These are by no means synonymous, but for brevity we will consider them together. Manual dexterity is the physical ability to efficiently
perform the tasks necessary to the work at hand, while skills may be defined as the mental ability to efficiently develop shortcuts, better methods, and enhanced accuracies with a given measuring system.

Minimum requirements for the entrance level would be similar. Knowledge, integrity, and manual dexterity are essential, while wisdom would be replaced by ambition and a desire to learn. Skills would be replaced by a willingness to observe and be taught.

Meeting the knowledge requirements may be accomplished in a number of ways including formal classes, short courses, self-study, and a combination of any or all of these methods.

Designing an educational program to meet the minimum requirements of calibration technician requires studies in many fields of technology. Calibrating a given measuring system may require competence in mechanics, electricity, electronics, physics, and chemistry. Today's sensors and measuring devices employ the most advanced technology in every field, often approaching the state of the art. Hence, it becomes obvious that two of the essential educational requirements will be a solid base of physics and mathematics. Since practically all fields of modern measurement employ electronic devices in some form, this becomes the third basic requirement.

Many educators and laboratory managers agree that a technically intensive two-year post high school curriculum provides only the bare essentials for success in measurements. Satisfactory progress in such a course requires two years of math and one year of physics in high school.

The two-year course of study should include one year of physics, math, and electronics. The remainder of the courses should cover techniques of measurement in as many fields as time permits. Beyond this two-year course, the calibration technician would concentrate their efforts in their chosen field. A program of study such as this should equip a technician to succeed in the calibration laboratories of today and tomorrow.

We have described a method of meeting one version of minimum requirements. Obviously this is not the only answer. Many good calibration technicians in our laboratories today have had little or no formal education beyond high school. Some individuals possess the drive and ambition to read and study to continue to stay abreast of new technology in their field on their own initiative. Others progress by company incentive, via short courses and on-the-job training. These alternative methods may be the preferred route to increase the competence of established employees. But for the young entrants into the measurement field, I believe the formal training will be far more satisfactory.

I would like to describe briefly a training program being used in the Tennessee Valley Authority. Staffing the generating plants with qualified personnel from established institutions had proven to be unsatisfactory. So, a training center was developed to train crafts- men and operators to fill the specific requirements of TVA. The duties and technical requirements of instrument mechanics are similar to those of calibration technicians. Their duties consist of calibrating, repairing, and maintaining all installed instruments, controls, sensors, and indicators in the generating plants. Senior instrument mechanics receive 27 weeks additional training, mainly oriented toward maintenance of plant control computers and digital equipment. Secondary and working standards are calibrated and maintained in the central laboratories by instrument technicians who are not trained at the center.

A register of applicants is prepared from the results of GATE exams. Predetermined scores are required for entrance into each craft. Selection from the register is done by a committee composed of representatives from the crafts, EEO, and management with due regard given to veteran's preference, the handicapped, and other Federal requirements. A class usually consists of no more than 20 students. The students are on full-time training status for 12 months. They are then transferred to the various plants for two more years' training. The implant training program is prepared and controlled by the plant superintendent and not the training center.

This program provides the minimum educational requirement for entrance into the instrument mechanic program. I believe calibration technicians should be equally well prepared.

Attached is a brief description of the program and the curriculum.

EDITOR'S NOTE: Readers should contact the author for copies of the instrumentation training syllabus for the TVA Power Operations Training Center.
The Constitution provides the Federal government with authority to establish standards of weight and measure and to regulate the use of weighing and measuring instruments in commerce. Article 1, Section 8, empowers Congress "...to fix the standards of weights and measures."

The National Bureau of Standards (NBS) was organized at the turn of the century to fulfill a need for a centralized measurement authority in the United States. Since that time, the Bureau has served as the center of measurement accuracy in the country. However, the Federal government has not exercised its power to regulate commercial weighing and measuring instruments and practices but has, instead, allowed the states to assume this responsibility through the enforcement of state statutes that are designed to meet their needs and unique circumstances.

Thus, the weights and measures system (or as known internationally as legal metrology) in the United States differs from those of other countries throughout the world which have legal metrology as a function of their national government.

The National Bureau of Standards, through its Office of Weights and Measures (OWM), has a responsibility of providing leadership and technical assistance to the states in administration of their weights and measures programs. The purpose of this assistance is to promote uniformity in weights and measures laws, regulations, and methods of test; and to provide a forum for problem solving at the national level. The latter is achieved through the sponsorship of the National Conference on Weights and Measures (NCWM). In effect, NBS serves state and local weights and measures officials much as a trade association serves its membership. This is a unique relationship in government and has long been held as an excellent example of intergovernmental cooperation.

There are over 3,000 officials employed in weights and measures programs throughout the United States. These are divided among some 700 state, county, and city jurisdictions. Under this system, the need for central coordination and guidance is obvious.

The significance of weights and measures enforcement is easily demonstrated. There are five economic activities involving commerce that are subject to regulation under state weights and measures statutes. These are: agriculture, manufacturing, mining, wholesale and retail trade, and services. The total value of commerce subject to regulation is well over $600 billion annually. Weights and measures officials are responsible for assuring equity in all commercial transactions between buyer and seller where quantity is involved. This means surveillance and control of the accuracy of grocery scales, gas pumps, taximeters, fabric measuring devices, motor truck scales, fuel oil truck meters, grain hopper scales, packages of meat, food and all other items and devices where quantity is represented in the transaction.

The Office of Weights and Measures, NBS, is responsible under the Bureau's enabling legislation to cooperate with the states in securing uniformity in weights and measures laws and methods of inspection, OWM's role as a leader in the weights and measures field is primarily focused on its interaction with state and local officials in three areas: (1) The National Conference on Weights and Measures, (2) Laboratory Metrology, and (3) Technical Training. It is through these activities that the majority of personal contact is made with weights and measures officials.

The OWM technical training program has been in existence for many years and its goal is to develop and improve upon the professional skills of those working in the weights and measures field. The program has been structured to be sensitive to the differing educational background of officials, their levels of experience, and the specialization of activities. Instruction is offered in the classroom, laboratory, and field and includes seminars for inspectors, metrologists, supervisors, and administrators. The training has these specific objectives:

1. to provide basics in weights and measures enforcement such as device or package inspection to those new in the program;
2. to explain the newest technologies (such as digital electronic scales) to keep officials abreast of technical developments and test requirements;
3. to provide training to laboratory metrologists in the use, care and maintenance of state standards to ensure traceability to NBS standards, and
4. to explain model laws, regulations and methods of test developed by the National Conference on Weights and Measures for adoption by state and local jurisdictions.

Training for field inspectors usually involves a three-day session in all phases of weights and measures inspection and is conducted at the facility of the requesting jurisdiction. Additionally, there are training sessions each year that specialize in on-site demonstrations and instruction of various types of test equipment and procedures such as for liquid petroleum gas meter provers and road testing of odometers and taximeters.

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In recent efforts to broaden the impact of the program and to spread limited resources further, industry service personnel have been invited to participate in the seminars, both as instructors and students. An effort is also being made to group adjoining states together where possible, to form regional training groups. Four such regional groups exist today in the northeast, southeast, northwest and southwest. Under this plan, a different state in each group hosts the seminar each year with all of their field staff participating and as many officials as possible from the other states in the region. Industry officials with national responsibility have been willing to participate in assigned specific areas as instructors in these regional seminars.

Metrologist's training provides basic, intermediate, and advanced courses for state laboratory metrologists. The basic course, given over a two-week period, devotes one week to the study of mass and one week to length and volume. As many as eight of these sessions may be conducted annually.

The training of metrologists is carried out by OWM through its conduct of the Laboratory Auditing Program (LAP) which is taking on greater significance as the states upgrade and expand their laboratory capabilities. Recent changes in the program have been made that will recognize the differences between laboratories with respect to services and capabilities. As always, basic and regional training of metrologists on laboratory calibration operations and technique represent the main thrust of the LAP program.

A central part of the LAP involves a measurement surveillance program which enables the metrologist, in performing certain measurements, to assure the validity of the measurement and uncertainties, and monitor the standards and the performance of his laboratory equipment.

This is important to OWM's certification of state weights and measures laboratories. The certification is essentially to say the metrologist is capable of performing certain measurements and that those measurements are correct, thus, the state laboratory is capable of providing specific laboratory services. Certification depends upon two factors. First, the state must have adequate facilities and, second, the metrologist must demonstrate the capability to do the work. If a state lacks either of these two factors, the laboratory will not be certified under the LAP program. A state that has a capable metrologist but inadequate facilities that do not provide for adequate protection of the standards and equipment or is not conducive to good measurements will not be certified. A laboratory with inadequate facilities is not able to provide essential support data as to the continual validity of the standards or the measurement process and cannot be certified.

The condition of state reference standards is not a problem for each state has been equipped with a modern set of basic metrological standards and laboratory instruments by NBS. As a prerequisite to receiving the set of standards, the state had to provide a laboratory facility that would meet certain space and environmental control specifications. All in all, the states' weights and measures laboratories across the country are of good design and are being properly maintained.

A state metrologist is required to attend two weeks of the basic metrology seminar at the NBS and then demonstrate measurement capability by successfully completing ten basic LAP problems in mass, length, and volume as assigned by OWM. The laboratory will be certified in other measurement areas as the capability of the metrologist increases. If a laboratory has only one qualified metrologist and the metrologist leaves this position, the laboratory will lose its certification because it does not have a trained metrologist to take over. It is then necessary for the state to send a new metrologist to the NBS for training and to complete the basic LAP problems to recertify the laboratory at the basic level. If a laboratory has two metrologists and one metrologist leaves, the laboratory will only be certified in the areas where the remaining metrologist has demonstrated measurement capability. The laboratory certification may be at a lower level than when both metrologists were present.

In the past a laboratory was asked to demonstrate its ability to perform certain measurements by completing specially assigned projects. This approach is being changed so the metrologists can assure themselves that the measurements they are making are correct and in control. Such an approach is needed to benefit the metrologist more than to aid OWM in certification. The requests for precision calibration are increasing. The sophistication and knowledge of the people requesting the calibrations are increasing. In the case of many industrial companies, improved measurement accuracy and control are being mandated by legislation and regulation. A state metrologist can be called upon to provide documentation that the measurements made on a given date were correct, in other words, within control. This means the metrologist must take sufficient steps to assure himself or herself that the measurements were in control, i.e., the standards were correct, the instruments were performing properly, and the measurements were typical of the measurements made in the past.

In conclusion, I would like to make brief mention of an important breakthrough in the general use of training in industry, the development of an educational program in measurement sciences. We all know the measurement practitioner—whether a scientist, engineer, technician or manager—is facing a technological environment that is progressively getting more complex and interdisciplinary. Several organizations are addressing a perceived need for improved competence and proficiency in the measurement sciences at the professional and technical levels, as applied to research, government and industry.
The National Bureau of Standards has begun to investigate the development and implementation of college programs in measurement science. Mr. A. D. Tholen, Chief, Office of Weights and Measures, is leading the NBS activities. Mr. S. H. Raskin has been retained to provide assistance in planning and coordination with universities and industry. The goal is to increase the skills and knowledge of personnel engaged in research development, manufacture, use and regulation of measurement devices and systems, by providing educational programs at the university level leading to master's degrees, as well as undergraduate courses and continuing education.

A number of universities have been contacted and, without exception, have expressed favorable interest. Texas A&M University representatives are scheduled to visit NBS this month. Professional societies, trade associations and individual industrial firms, plus regulatory offices at the local, state, and federal level are being contacted to generate support for the program. Response to these sectors also has been favorable.
ADJUNCT TRAINING

(AN IDEA WHOSE TIME HAS COME)

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INTRODUCTION

Metrology as a profession is very young. Science from the beginning of time has been concerned with measuring things. But until this century, the field of measurement science has not developed into a field devoted to the creation of uniform measurement systems and the technology for disseminating these systems.

Since the 1950’s, the field of metrology has expanded from one serving primarily scientists to one servicing government, business, industry and the public. Metrologists are now indispensable because they are the custodians of the communications systems which enable all elements of our technological society to converse through measurements. Accurate measurements which mean the same things, no matter where they are made, have been required by the advent of modern military systems, space flight, digital communications, atomic energy, environmental monitoring, medical technology and modern commerce requiring greater accountability for what is sold.

Most of the people currently employed in metrology have been trained in the labs where they work. No one, to my knowledge, has graduated from an educational institution, serving the public, with a degree qualifying them as a metrologist.

Perhaps the single greatest concern that I hear expressed among the NCSL memberships is for professional training in metrology. And our community is faced with an explosion of requirements for engineers and technicians trained and experienced in measurement science. The medical industry in particular, is experiencing this as a result of recent FDA regulations for good manufacturing practices (GMP)

Professional recognition is a need which goes hand-in-hand with training. Ask anyone on the street what a metrologist does and your answer will probably be that he predicts the weather. How can you attract people to a profession when people don’t even know it exists?

And for your measurement systems to work, we need widely disseminated uniform standards of practice. I am sure that many of you have encountered people or labs who appear to be making measurements to the tune of a different drummer. A knowledgeable and widely disseminated educational system for metrology would do much to get everyone dancing to the same drummer.

What is out there? Plenty. Knowledge of measurement science and the science of measurement systems is abundant, however, it is locked in the laboratory in the bodies of the metrologists and technical publications on the laboratory bookshelf. Our profession has been one primarily of practice, not of teaching.

This brings me to the topic of this paper, training for the metrology technician. It is education which will give us the manpower to do our job, the professional recognition to attract and influence people, and a common base of knowledge and practice through which to communicate.

ADJUNCT TRAINING

Adjunct training is a simple concept which may in the near future fulfill a significant portion of our need for training. Its definition is training which is presented at the same place and same time as our region meetings. There is nothing especially magical about this approach, it just seemed like a convenient way to make training in metrology available to the NCSL membership.

When this idea was presented at a meeting of Region II of the NCSL, it was greeted enthusiastically. They asked, “When can we do it?” As a result of this, we held a workshop at the September 1978 meeting and planned our first course for adjunct training. It was an experiment to find out what would really happen if we did it. Well, on September 13, 1979, we presented that first course, titled, “Basic Metrology, An Introduction.”

That day we presented six subjects to twenty-one people, we gave them lunch and sent them home with three valuable reference books for their personal use. We did this at a cost of ten dollars per student. Appendix A is a copy of the announcement that was made prior to the course. It gives the basic outline of the days activities. Appendix B is a sample of the questionnaire filled out by the students following the course. Appendix C shows a copy of the certificate being sent to each participants. Appendix D lists the references handed out.

Of all the things learned from this experience, probably the most valuable ones come from the students through this questionnaire. The student appraisal was very positive. If their ratings are evaluated on a scale of one to five, with one being VERY GOOD and five being POOR, this course got a score of two. That means that we probably turned-on more people than we turned-off, or in other words, we hit the spot.
When asked, "Do you have associates who would benefit from this workshop?" The reply was 17 yes out of 19 responses. There must be at least 17 people from the same places who are potential students.

When asked, "Would you be interested in a one-day workshop, in depth, on a specific subject introduced today?" The reply was 18 yes out of 19 responses. Certainly the students must desire the training, and it appears to be a mandate from those who would benefit most directly from such training.

Fourteen of the written comments on the questionnaires showed specific interest in additional in-depth instruction on several subjects.

From this experience it seems clear, if we can assume that these people are representative of the nation at large, that we must continue to present training. It's time to don our teacher's hats and share that knowledge which we have so abundantly. People are seeking it, and adjunct training appears to be one good way of providing it.

**THE FUTURE**

Where do we go from here? I know that Region II is probably going to schedule two training sessions this coming year. This doesn't help other regions directly, and it doesn't answer the larger questions which arise now when we begin thinking about implementing adjunct training through the NCSL.

What are these questions?

1. **Universal availability:** how do we make the training available to all who are interested?
2. **Quality assurance:** should we implement mechanisms to ensure that course content is accurate, comprehensive, training aids are available and instruction is adequate?
3. **Accreditation:** will the training be recognized by regulatory agencies?
4. **Budget:** what should the investment be in producing this training and where should the money come from?

Adjunct training is a continuing project of the Education and Training Committee and this year will be one of decisions relevant to these questions. The major task will be to develop the machinery which will produce the kind of training we are looking for. It is this workshop which will provide much of the feedback from the NCSL membership that is required to make decisions in agreement with the needs of the conference.

**CONCLUSION**

There is a need for additional training resources in metrology to teach the philosophy and practice of measurements and measurement systems. It is now our responsibility as metrologists to become teachers and open our profession and knowledge to the world.

I am committed to a development of adjunct training so that it can be available to all. I've organized a successful training session and I expect to do more. I now challenge NCSL membership to put action in the place of words. There is no reason why any region must wait for a packaged training session to be sent to them. Anyone who is interested should give me a call and I will give any assistance that I can.

In the coming year, the Education and Training Committee will surely address the questions of

**TODAY**

Today, we have the opportunity to pioneer a system of education in metrology, to define it in terms of the real needs of our profession before training requirements become entrenched in regulations that may not truly reflect the real world. The Education and Training Committee is trying to work on these training problems. Adjunct training is only one of several approaches being developed.

The committee has two major needs. People, a small staff can do only so much. We are looking for people with an interest in training to take on the responsibility for some portion of a project.

The second need is feedback. Ideas and comments obtained during this annual workshop serve as a guide throughout the year. During the discussion session of the workshop, we want to hear your comments. In addition to the four questions given below, the following are questions I have relating to adjunct training:

1. **If you were to present an adjunct training course, what materials would you need supplied?** A canned video tape presentation? A curriculum outline? Lecture notes? Etc.
2. **What is the best way to handle the fee collection and payment of expenses?** I had to write personal checks to cover all bills until the fees were collected.
3. **Should we pay a professional to develop each course segment and package it so that anyone could present it?**
4. **Isn't there another good way to develop a course for distribution?**
5. **Can we induce experts to attend and present one-day training sessions from a prepared curriculum?**
6. **Should the NCSL maintain a library of packaged training sessions for use by members?**
universal availability, quality assurance, accreditation, and budget for adjunct training. And I think we can expect some real action and results if the committee membership increases. The progress report on adjunct training at the next Symposium and Workshop of the NCSSL should be very exciting.

EDITOR'S NOTE: A report on the Training Workshop of Region II including answers to the questionnaire appears on pp. 62-63, in the December, 1979 Newsletter.
INTRODUCTION
Over the past few years, local and national NSCIL meetings have echoed the need for better training and education for metrology personnel. The lack of curricula in this field is obvious to most of us, with the duties of education and training falling to the calibration and standards lab managers. The net result is most often a deficiency in desired training, excessive time demands upon the manager, and a total lack of uniformity in the way people are trained. Sometimes training is left to subordinates who are experienced in metrology but who themselves may be lacking in certain aspects of metrology education. It's not unusual, either, for basic concepts to be overlooked or assumed known as more specific aspects of the work at hand are taught.

Some contracting agencies have recently become concerned over the qualifications of calibration and standards personnel. They're looking for evidence of education and training of the personnel, as well as their experience in the field. Thus, a formal education program in metrology is not only desirable from an operating standpoint, but is looming as a contractual necessity of the future. NSCIL is the logical vehicle for both developing a specialized metrology educational program, and coordinating this with laboratory accreditation requirements.

This paper deals with the development of extended courses which would qualify for continuing education units, and in total could be equivalent to a technical school education in metrology. This is a first pass at such course development, and feedback and suggestions are sought to keep progress in a fruitful direction.

PHILOSOPHY OF OVERALL PROGRAM
There are various ways in which a comprehensive, technical education in metrology could be presented. One would be to establish a full-time two-year technical program leading to an associate degree in metrology. Unfortunately, where this has been tried, interest and attendance has been below a level sufficient to maintain such a program. For NSCIL purposes, there would be the further disadvantage that it probably could only be offered at one location in the country. Secondly, most employers would not subsidize such a leave of absence for their employees. Finally, two years of technician schooling would tend to be inappropriate for engineering and management personnel to attend.

The strength of the proposed plan is that it would be a "distributed" program; distributed both in time and in location. Individual courses compressed into one or two week segments could reasonably be justified by manage-
expertise can be gained first. On the other hand, courses which do not relate to a particular lab's work would not have to be attended at all, although consistency of the overall program would allow simple addition of new expertise at later times. This uniformity of education would reduce the problems of "re-training" personnel that transfer from one lab to another.

One point yet to be resolved is who would develop the individual courses? Should the NCSL Education and Training Committee do it? Should NCSL membership at large do it? Should NCSL hire an academic organization to plan this? Should NBS develop the courses? The answer is not obvious, but it is extremely important—we will gain little if the courses are not of an extremely high quality in technical and educational content. Since the entire program can be developed in a piecemeal fashion, it would be possible to evaluate the quality of initially developed courses and, if necessary, change our course of action before further money and effort is put into developing subsequent courses.

PHILOSOPHY OF COURSE CONTENT

One device reported to have worked well in courses in metrology is to divide the course into two distinct parts, the first half devoted entirely to presenting the theory and physics behind the parameter(s) involved. This would include teaching in detail how the applicable instruments and standards work, and what factors affect their accuracy. The second half of each course would then go into calibration techniques and practices involving those instruments and standards. This progression of thought puts into play the metrology maxim that "if you don't understand what you're doing, you're probably not doing it right." This diversion of each course into two parts could readily be applied to courses which NCSL develops, whether they be one week or two weeks long.

When designing a course, there is always the paradox of trying to be all inclusive, but at the same time emphasizing only items of direct interest to the course. In metrology, we range from very elaborate and expensive international standards, down through process type of instrumentation, to extremely simple instruments such as are used in the home and car. It would be well to avoid diluting what course time is available by including too much information on instrument types such as process and simpler instruments.

Pulling in the other direction is the fact that standards and calibration people should be knowledgeable of the full range of measurement technology. This is so they may aid in measurement problems, or orient their calibrations toward actual end uses. For instance, calibrating an infrared pyrometer by standard methods may be of little help to an end user who is going to measure flame temperature with that instrument. Thus, a good basic knowledge of measurement and instrument theory is prerequisite to a valid and measurement.

Most calibration and standards laboratories associated with NCSL have little encounter with process type instruments. The maintenance and calibration of process instruments usually becomes the responsibility of other groups, and ISA and other organizations already offer comprehensive courses and workshops for that level of instrumentation. If a need still exists, though, we might consider a secondary level course for those who need only personnel qualifications limited to that level. This should be relegated to future consideration after the main courses are developed. Note that the adjunct one day courses now being developed by NCSL might fulfill this lower echelon need, as well as serving as preliminary courses for those going on to the one or two week in-depth courses.

DEVELOPING FUNDAMENTAL CONCEPTS

The history of measurements, how we fit into the national and international measurement systems, calibration lab practices, precision and accuracy, the structure and historical development of NBS, and other background subjects are very important for a person to fully grasp what standards and calibrations work is about. One needs to know where he has come from and where he is going if he is to fully grasp his position and function at the present time. Unfortunately, convincing a manager that you or your technicians should attend a course in the "history of measurements" could prove a little difficult. The natural tendency would be to bypass such basic background courses, and send personnel to the few courses that "appear" to be directly linked to their work.

One way of handling this would be to make one or two of these basic courses a prerequisite requirement for subsequent courses. More appropriately naming these something like "The Heritage and Theory of Measurements" and "Precision and Accuracy—Theory and Practice" might aid in management understanding of their importance. Alternatively, short coverages of these subjects could be included in each of the specialized technical courses, but this would be less efficient and would divert time away from other subject matter. One factor that should be included in each course, however, is the care and proper maintenance of instruments and standards for that particular discipline.

COURSE LISTING

The listing that follows is not meant to be comprehensive nor consistent in detail. There is no implication, either, of progression of attendance except that these listed as prerequisite should precede any of the subsequent courses. Some of the courses in the listing are little more than a title. Other have considerably more detail of content, although order of this content within these courses has not yet been worked out. For some courses, the content may be too ambitious, particularly if we decide that they should only be one week long. These courses might be split into two separate courses. In other cases, it might be desirable to combine two or three of the listed courses into one, making use of a more relaxed two week schedule.

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There are omissions to this course listing, particularly in pharmaceutical, biomedical, chemical, and other disciplines now coming into the fold of NCSL. Input is needed from those members so that the listing can be expanded in a direction that will be useful to them.

CONCLUSION

No claims are made that this program is 100 percent complete or 100 percent appropriate in the more conventional fields. You should view this listing as a starting point for a dialog between you and the committee. The aim is to develop the best possible program that will aid the most NCSL members. While you are urged to respond to any questionnaires the committee puts out, the most helpful information sometimes is that which comes in a detailed form from individual members. After reviewing this paper, you may have some ideas you feel would be appropriate. Please don't keep these to yourself! Some members may have course materials which they have already developed and which they would be willing to share with the membership. Such proven instructional material would be welcomed by the committee. A few members have already submitted some material, and in reviewing this material it would appear that some of the NCSL courses might be well on their way to a final form, ready for presentation.

Finally, like all committee activities, an active committee membership is necessary if particular programs are to be developed. If the educational program outlined here would be of great help to you, consider that a contribution of some of your time, effort, and ideas as a committee member or committee associate could speed the program into fruition.

METROLOGY CURRICULUM

BASICS

100: The Heritage and Theory of Management

The history of measurements from ancient times; international agreement of units; metric system and SI units; history of NBS; basic and derived units; national measurement system; calibration hierarchy; NBS "traceability"; lab comparison methods; "assurance" versus accuracy; redundancy techniques; Measurement Assurance Programs (MAP).

102: Standards Lab Practice

Recordkeeping and data taking; quality assurance; MIL 45662A and other specifications; and how to comply; auditing and surviving audits; traceability to NBS and derived units; substitution, interchange, and ratio techniques; use of redundancy, prior data, and trend charts; basic instrument maintenance; environmental controls; in situ calibrations; calibration intervals; instrument trouble shooting; care of standards; housekeep-

110: Precision and Accuracy

Systematic and random errors; precision versus accuracy; errors versus correction factors; common sense in error analysis; introduction to statistical techniques; large number math shortcuts; false "accuracy" from calculators and computers; misinterpreting least squares fit; working with parts per million; mistakes; "eyeballing" versus computers.

120: Digital Meters

Binary and BCD numbers; D/A and A/D conversion techniques; digital control of precision sources and meters; interface testing; microprocessor data manipulation in instruments; matching instruments to peripheral; troubleshooting techniques; introduction to microprocessor architecture; data scanners.

130: Automatic Control

Control of calibration furnaces, uniformity and stability; analog control loops; digital control loops; ringing; transients in source and load.

140: Automatic Calibration And Test Systems

ELECTRICAL

200: Electrical--D.C.

Voltage; resistance; standard cells; ratio dividers; moving coil meters; digital meters; precision sources; bridge designs; current; high voltage devices; thermal and parasitic voltages; ground loops.

210: Electrical--A.C.

Voltage; complex impedance; vectors; wave shape errors; distortion measurement; bridges; ratio transformers; thermal converters; RMS; sources; wattage; metering complex waveforms; three phase; parasitic voltages; ground loops, db scales and math.

220: RF and Microwave

Attenuators; VSWR; distributed impedances; bolometers; db scale.

230: Instrument Noise and Ground Loops

In depth study of parasitic voltages and currents that degrade measurements.
PHYSICAL

300: Temperature--Theory

Thermodynamic scale; heat theory; IPTS; calibration baths; ovens and radiant energy sources; fixed points and their attainment; freezing point apparatus; triple point cells.

301: Temperature--Measuring Devices

Thermometry devices--resistance, thermoelectric, expansion, radiant energy, change of state; calibration techniques; computer enhancement of data; calibrations utilizing sliding reference frames; limits on accuracy; stability of measuring devices.

304: Calorimetry

310: Pressure

Piston gages; liquid columns; buoyancy effects; absolute versus gage pressure; barometric pressure; correction factors; bourdon tube devices; differential pressure; surface tension.

312: Vacuum

McLeod gages; ionization gages; molecular forces.

314: Flow

Effects of temperature and gas composition.

320: Dimensional

Gage blocks; thread gages; micrometers; elasticity; surface effects; wringing gage blocks; surface finish; flatness; laser techniques; errors due to table in-accuracies; optical comparators; corrosion effects; proper handling and cleaning.

330: Mass and Density

Buoyancy effects and corrections; balance design; pivot errors; corrosion and proper handling; electronic balances; force transducers and standards; gravitational effects; torque; density; specific gravity.

350: Frequency and Time

370: Vibration and Acceleration

Interferometry methods; reciprocity theory, db scale.
"Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to get to," said the Cat.

Lewis Carroll—Alice in Wonderland

During the decade of the 1970's, now in its closing months, the trend in the marketplace was for the production of reliable consumer products from automobiles to devices and drugs for health care. There are many government agencies organized to mandate assurances that products are reliable, that claims for products are truthful and are not misleading, and that they are safe for consumer use. The Food and Drug Administration is one such government agency that is having a direct influence on the medical device and pharmaceutical industries. The restraints mandated by the FDA for these industries has been pronounced by regulations to provide for the production of products that are effective for their intended use, and that risks that may be associated with these devices are minimized. In the introductory remarks of the Good Manufacturing Practice Regulation the commissioner states that, in his opinion, a well organized controlled quantity assurance program is essential for the production of medical devices: (1) This same viewpoint is expressed and is also a requirement for the Good Laboratory Practice Regulation (2) as it relates to non-clinical studies. The quality assurance program is designed to be preventive so that only suitable products are produced within the constraints of design criteria for the device, and that they are reliable and minimize risk to patient well being in operation.

Quality Assurance, as used here, is a planned, systematic, and controlled system in the production of medical devices and studies, such that the items designed, produced and tested are faithfully reproduced within desired and adequate limits. Furthermore, an adequate confidence can be placed in these items, with such a QA program, such that they can demonstrate that they are what they were intended to be in configuration and operation. A rational approach thus implemented to solve the dilemma, "There is never enough time to get it right the first time, but there seems to be sufficient time to rework it." A commitment by management to assure that only reliable products are produced, and that the whole organization is structured in cooperation with interlocking fashion is a necessary condition for the assurance of quality.

Most quality organizations generally include (or should include) provisions for the assurance of measurements that are required for the production, verification, and acceptance of produced items. These provisions are variously referred to as standards laboratories, standardizing laboratories, metrology labora-

tories, instrument shops, PME labs, etc. In this presentation the term metrology laboratory or simply metrology is used to denote those activities which are concerned with the assurance that measurements, and measuring equipment, and references for measurement are producing valid and useful measurement data within the total organization. Measurement assurance follows the same general concepts as those suggested for quality assurance, i.e., adequate, valid, and useful data that is essential for medical devices and pharmaceutical products as well as other useful items. The means, concepts, and principles to achieve assurance of quality measurements is an issue of primary importance to the metrology manager for the succeeding decade.

Measurement is quantified information upon which decisions can be made by scientists, engineers, technicians, assemblers, and managers to coordinate and control the processes of production from the inception of ideas through the finished and accepted product. Correct decisions, synchronized with the national measurement system, between producers and consumers can only be made if there exists a high degree of confidence that measurements are correct and intelligible and supported by sound scientific principles. The supporting evidence that measurements are what they are intended to be is one of the primary responsibilities of the metrology laboratory. To achieve the desired levels of measurement assurance, and to comply with the C dietary regulations, the following outline is the function suggested for a small metrology laboratory:

- provide for the traceability for measurements to the national measurement system through NBS, constants of nature, or developed references where necessary.
- maintain the primary, secondary, and working standards referenced to NBS, etc.
- calibration and calibration control of all measuring and test equipment.
- validation of calibration results and design and test specifications.
- consulting service for industrial functions requiring assistance with measurement problems.
- education and training for personnel in measurement science.

The purpose of these suggested responsibilities is to provide the assurance that the right measurement is made at the right time, at the right place, and with the right accuracy and precision necessary for reliable data and devices. Such tasks for measurement reliability and assurance represents a sizable investment in the resources needed for measurement references and control in terms of capital, space,
time, and personnel for a small laboratory, and, if it is to be effective, must be used efficiently to achieve the goals mandated by government regulatory agencies.

The functions and tasks of metrology laboratories is a concept of interrelationships between the national measurement system, industrial metrology standards for practice, government metrology laws, as well as internal cooperative efforts of validation of measurements, processes, and specifications. There are many competing definitions for many of these functions, such as traceability, which have evolved over the years to assure industries that their measurement systems are in control. The choice of definition depends a good deal on the regulation or specification that a particular industry is obliged to be in compliance with. This workshop is to consider the concepts of measurement assurance as they relate to the Good Manufacturing Practice and Good Laboratory Practice regulations. How these two requirements imposed on industry relates to other regulations, past, present, and future is of primary concern to the metrology manager over the next decade.

REFERENCES


2. "Nonclinical Laboratory Studies, Good Laboratory Practice Regulations", Federal Register, Vol. 43, No. 245--Friday, December 22, 1978 pp. 59986 to 60025.


TRACEABILITY OF MEASUREMENTS ON PRODUCTS TO THE NATIONAL PRIMARY AND LEGAL STANDARDS OF MEASUREMENTS

THE NATIONAL BUREAU OF STANDARDS
Maintains the national primary and legal standards of measurement

(verify measurement standards)

Metrology Laboratory

verifies production standards of measurement to the NBS verifications

PRODUCTION OF WORKING STANDARDS OF MEASUREMENT

PRODUCTS are designed to measure or use measurements of something

PRODUCTS are adjusted to measure or use measurements correctly

PRODUCTS are proven to conform to these measurements traceable to the national primary and legal standards
ABSTRACT

The impact of the Food and Drug Administration’s Good Manufacturing Practice (GMP) and Good Laboratory Practice (GLP) regulations, on the medical products industry relative to instrumentation and calibration requirements is discussed. The basic concepts involved in developing an Instrumentation and Calibration Program are addressed. The requirements include scope, National Bureau of Standards (NBS) traceability routing, equipment requirements for a standards laboratory and plant calibration program, calibration procedures, personnel requirements, and measurement assurance program in relation to NBS traceability are discussed. The importance of equipment validation to assure that measurement of process variables is accurate and valid is emphasized. A discussion of the responsibilities of the equipment user and the Food and Drug Administration for equipment and standards specified in the Good Manufacturing Practice regulations are addressed.

Program Purpose and Scope

An Instrumentation and Calibration Program is established for the purpose of:

1. Developing a Standards Laboratory or responsibility that can provide calibration certification of measurement standards used by manufacturing plants, research and development divisions, Quality Control, and other users who have a need for measurement standards with calibration certified as traceable to the National Standards at the National Bureau of Standards. If National Standards for the discipline(s) being measured are not available, an independent reproducible standard derived from the natural laws of physics may be used.

2. Selection and validation of instrumentation and standards to be used in process measurement and control systems relating to critical systems.

3. Development of calibration procedures that will assure uniformity between pro-
duction plants with sufficient instruction and information to enable qualified personnel to perform the calibrations required, in such a manner as to comply with the FDA GMP regulations and other regulatory requirements.

4. Implementation and maintenance of a measurement assurance program that demonstrates that the total measurement uncertainty of the Standards Laboratory and Plant Calibrations relative to National or other designed standards is quantified and sufficiently small to meet the requirements defined for the measurement discipline.

5. Developing and implementing a training program to maintain Technicians and Engineers proficient in current instrumentation technology, calibration procedures, and regulatory requirements.

6. Development of specialized measurement techniques.

7. Interface with the National Bureau of Standards and regulatory agencies on instrumentation, calibration, and measurement concerns.

Before an effective Instrumentation and Calibration Program can be developed the requirements must first be determined. Of fundamental importance is that the program capability must be structured to meet the current and future needs of the medical products firm. Important areas of consideration that must first be studied are:

- Calibration requirements for critical and non-critical systems.
- The number of different facilities that will be participating in the program.
- Accuracy and precision requirements for each measurement discipline required.
- Equipment standards, procedures, and personnel capability currently available at each plant.
- Current and proposed government regulatory rules.
- Equipment, standards, procedures, and personnel capabilities needed to equip and staff the program.

Measurement and control requirements for critical process systems should be developed first. Usually measurement disciplines associated with critical process systems will include a large percent of the total disciplines required by the corporation.

Examples of measurement requirements relating to process control technology and dimensional metrology that may be associated with critical process systems are:

- Temperature
- Radiation dosimetry
- Heat Flux
- Gas analysis
- Pressure (including vacuum)
- Flow/velocity (gas and liquids)
- Humidity (% RH), Volume
- Absolute humidity, dew point), pH
- Mass (weight)
- Conductivity of liquids
- Resistance
- Viscosity
- Voltage and current (A.C. and D.C.)
- Photometry
- Torque
- Tensiometry
- Dimensional measurements
- Time and frequency
- Topography
- Hardness

The Instrument and Calibration Program should be capable of supporting all manufacturing, corporate support, and development units in terms of providing calibration standards that are traceable to the National Standards at the National Bureau of Standards.

Traceability routing of measurement standards and calibration is shown in Figure 1. Calibrations at each production plant are traceable to the National Bureau of Standards by way of the Corporate Instrumentation Standards Laboratory.

![Figure 1: Traceability Routing of Instrumentation Laboratories Measurement Standards](image-url)
EQUIPMENT REQUIREMENTS

Selection of calibration equipment for the Corporate Standards Laboratory and the plant calibration program should not be one of buying only the best or most accurate. It should be to provide the greatest return on the investment by the selection of equipment to satisfy only the need. In some cases, calibration equipment far in excess of the actual needs has been purchased. The result is a system that will not be used to its fullest, and may result in elaborate and unnecessary operational procedures to be followed. Either of these conditions result in unnecessary increased calibration costs. Thus, an Instrumentation and Calibration capability should always be focused on the current and future need of the operation that is to be supported.

In the case of medical product firms, the needs for each measurement discipline is based on:

1. Levels of accuracy required for various process measurement systems.
2. Procedures used to transfer the accuracy of the measurement discipline from the primary standard to the final process equipment.
3. Government regulatory requirements.

The overall accuracy of the calibration system should be at least four to ten times more accurate than the system being calibrated. An accuracy ratio of 10:1 is preferred, but frequently this is impractical because of complex procedures and high cost.

It may be that the required accuracy of a process measurement discipline is of the same order of magnitude as the NBS Calibration accuracy of the standards used to calibrate the process measurement equipment. When this happens, one may have to be satisfied with the accuracy ratio of 1:1 and take special steps in calibrating and documenting the transfer procedures.

Procurement of equipment for a Standards Laboratory and plant calibration program constitutes a sizable capital investment. With proper care, high quality standards and calibration equipment will last for many years. Therefore, one should thoroughly investigate the availability of equipment from several equipment manufacturers who have a proven track record in supplying quality calibration equipment and standards.

CALIBRATION PROCEDURES

The FDA regulations covering Good Manufacturing Practices and Good Laboratory Practices require that equipment calibrations will be performed in compliance with procedures that contain specific directions and information regarding limits for accuracy and precision. Information contained in the procedures must be adequate to enable qualified personnel to properly perform the calibrations.

CORPORATE INSTRUMENTATION
STANDARDS LABORATORY

When repeated calibrations are to be performed in the Instrument Standards Laboratory, a written procedure should be developed for calibration of each type standard being calibrated. The procedure outline should include: Purpose, Scope, Frequency of Calibration (where applicable), Equipment and Standards Used, Preliminary Examination Required, Calibration Protocol, Documentation Requirements, and Report of Calibration to be issued.

When equipment or standards are calibrated in the Standards Laboratory without the aid of a written procedure, details of the calibration protocol, and standards and equipment used should be documented in the Report of Calibration and in the Laboratory Log Book.

CALIBRATION PROCEDURE SPECIFICATIONS
USED BY PRODUCTION PLANTS

Where applicable, Corporate Procedure Specifications should be issued to standardize calibration procedures at each production plant. The procedure outline should include: Purpose, Scope, Frequency of Calibration, Equipment and Standards Used, Preliminary Examination and Operations, Calibration Process, Remedial Action for Out-of-Tolerance conditions, and Documentation Requirements (including traceability documentation).

PERSONNEL REQUIREMENTS

The FDA regulations covering GMP and GLP require that calibrations shall be performed by personnel having the necessary education, training, background, and experience.

The personnel performing calibrations of instrumentation and devices must have knowledge of the following areas:

1. Measurement equipment--How it operates, what are its limitations, how it must be maintained, how to check it for accuracy, and how to perform routine equipment repairs.
2. Devices being calibrated--How should they be powered, what is their operating range, what are their limitations, what is the output signal(s), and what is the range of the output signal.
3. Must have a good understanding of the disciplines measured by equipment; they are required to calibrate, what is the time response of the standard(s) and the unknown being calibrated, how to determine response time of the process and measurement equipment and how it affects the process measurement.
4. Must have a good understanding and appreciation for the calibration procedures used.
to calibrate instrumentation and devices as well as the FDA regulations that apply to calibration and maintenance of equipment, including documentation requirements.

Accurate and reproducible calibrations will require extensive training. Depending on complexity and procedures, weeks to months of training may be required for a Calibration Technician to become proficient in calibration techniques required to achieve the necessary accuracy.

The training of calibration personnel can be achieved through equipment manufacturers' training programs, technical training on-site, NCSL or ISA training programs, and seminars given by NBS and private training organizations. The selection and training of competent calibration personnel is equally important to the selection of equipment. In fact, it may precede the equipment selection.

The selection of competent Calibration Technicians is an important consideration in establishing an effective Instrumentation and Calibration Program. The technician should be a technical school graduate or have the equivalent experience, with training in instrumentation technology, engineering technology or physical science. For the program to be effective, it is important that corporate goals be in the direction of procuring and maintaining key technical personnel at each plant whose training, experience, and career objectives coincide with the program.

MEASUREMENT ASSURANCE PROGRAM

The GMP and GLP regulations specify that calibration standards shall be traceable to the National Standards at the National Bureau of Standards (NBS). The term "traceable to NBS" often carries an undue aura of authority that assumes maximum accuracy. The National Bureau of Standards maintains very accurate standards. However, after the NBS Calibrated Standards leaves their laboratories, they have no control over the transfer procedures used. Unless great care is taken in developing and controlling calibration procedures, uncertainties can enter into the calibrations which render the term "NBS traceable" meaningless.

Even though the primary standards used by the Corporate Instrumentation Standards Laboratory are traceable to the National Bureau of Standards by the NBS Reports of Calibration, it is important that a measurement assurance program be developed to allow the Standards Laboratory to demonstrate that the total measurement uncertainty arising from both random and systematic error, relative to the National Standards, is validated and sufficiently small to meet the requirements for the measurement process.

Toward this end, the Standards Laboratory should become involved in a measurement assurance program with the National Bureau of Standards, on many of the measurement disciplines available in the laboratory.

Likewise, the Instrumentation and Calibration Program should include a measurement assurance program between the Corporate Instrumentation Standards Laboratory and each production plant to demonstrate the uncertainty associated with plant calibrations on certain measurement disciplines.

Figure 2 depicts a typical flow diagram for a Measurement Assurance Program (MAP) between the National Bureau of Standards, the Corporate Instrumentation Laboratory, and production plants.

Figure 2: Typical Measurement Assurance Program Flow Diagram

The Measurement Assurance Program is an effective method to validate and demonstrate total measurement accuracy of the entire measurement process for each discipline.

EQUIPMENT VALIDATION

The GMP regulations for medical devices states, "All production and Quality Assurance Measurement equipment, such as mechanical, automated, or electronic equipment, shall be capable of producing valid results."

Most standard equipment will produce valid results when properly calibrated and used. However, there are measurement applications in the medical products industry where conventional calibration techniques and procedures do not allow the instrumentation to produce valid results. For these measurement applications it is very important and necessary to prove that the selected instrumentation, measurement technique, and data interpretation provide accurate, reproducible, and valid measurement of the process variable.
SUMMARY

An effective calibration program is basically an extension of a preventive maintenance program that assures proper performance, accuracy, and reproducible results of electronic, pneumatic, and mechanical instrumentation.

The basic requirement for effective equipment calibration is good equipment and standards, detailed procedure specifications, personnel having necessary education and training, and an effective measurement assurance program.

For a medical products firm, it is desirable to develop a calibration system specification that identifies the minimum essential requirements of a calibration program for control of measurement equipment and standards. The outline of the system specification should include at least the following subjects: Purpose and scope, system description, calibration intervals and adjustment technique, traceability, audit requirements, subcontractor control, records, recall systems, labeling practice, calibration procedures, calibration quality, and environmental controls.

When a medical products firm elects to use outside contract maintenance and calibration firms to service their measurement and process instrumentation, it is important that a program be established to assure that the outside contract service firm:

1. Understand and abides by the GMP requirements.
2. Provides their clients with procedures outlining methodology used in maintaining and calibrating the client's instrumentation.
3. Provides a complete system calibration and is willing to give a certified report of calibration complete with all necessary supporting documentation.
4. Is willing to be periodically audited by their client and/or authorized representative.

An effective instrumentation validation program is basically a program that assures when an instrument is being used to measure a process variable; that the measurement technique, instrumentation, and data interpretation provides accurate and valid results. The ultimate responsibility for assuring that measurement instrumentation used in a production process provides accurate and valid results, lies with the user of the equipment.

The FDA stated intent of the GMP regulations is to assure highest possible standards for the finished product. Therefore, it is reasonable to expect the medical products industry to work with the FDA to assure that GMP regulations are written in a manner that would not prohibit the use of advanced technology in measurement and control of process variables.

REFERENCES

7. NCSL Tentative Recommended Practice RP #1. Establishment and Adjustment of Calibration Intervals.
LIQUID-IN-GLASS THERMOMETERS AND THE GMP/GLP

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ABSTRACT

This paper describes the method used by Abbott Laboratories, Corporate Plant Engineering to calibrate liquid-in-glass thermometers. The method of insuring compliance with Corporate quality standards and the Food and Drug Administration’s Good Manufacturing Practices (GMP) and Good Laboratory Practices (GLP) for large numbers of thermometers will be addressed.

INTRODUCTION

In order to meet corporate quality and GMP/GLP requirements for liquid-in-glass thermometers, a policy was needed that would meet the following objectives:

- GMP/GLP compliance
- Cost effective calibration
- Identification
- Acceptance by using departments
- Tolerance definition
- Thermometer quality

To meet these objectives, a policy was established where all thermometers were classified into three categories for the purpose of défining use and tolerance. Also rigid requirements and procedures were established to assure only high quality thermometers are accepted into the calibration program. Calibration markings were established to identify due date and category.

THERMOMETER REQUIREMENTS

All thermometers accepted for calibration must meet the following requirements:

- be of liquid-in-glass type with permanent markings.
- be plainly and permanently marked with manufacturer’s name and unique serial number.
- ASTM thermometers must comply with ASTM Designation El-75.

This assures that all thermometers accepted into the calibration program can be identified and are of appropriate quality.

THERMOMETER CLASSES

All thermometers within the calibration program are classified into three classes.

Class I - High precision and ASTM thermometers only. This class is reserved for thermometers of the highest quality. These thermometers must meet all specifications of appropriate ASTM or applicable standards.

Class II - General laboratory grade thermometers. These are good quality thermometers whose use does not require the thorough testing needed to meet ASTM requirements.

Class III - Limited calibration. Thermometers meeting the construction requirements for Class I and II, but whose use is limited to specific user requirements.

Classifying the thermometers in this way has allowed uniformity throughout the plant, making it easy for the user to know the accuracy of the thermometer and greatly simplifying the calibration process.

THERMOMETER TOLERANCES

The method of determining the tolerance of thermometers is as follows:

Class I - Calibrated for accuracy in accordance with the requirements of ASTM Standards El-75. (Example 1)

Class II - Calibrated to insure they meet the accuracy requirements of NBS Monograph 156 “Liquid-in-Glass Thermometers”. (Example 2)

Class III - Determined by user to meet specific product or engineering requirements and must be approved by quality assurance.

CALIBRATION MARKINGS

Each thermometer upon successfully being calibrated is marked with the next calibration due date. The markings consist of the month and year in which the thermometer will next be calibrated. The appropriate calibration class is indicated by the marking.

Class I - Yellow band with the inscription “CAL ASTM ACCE”

Class II - White band with the inscription “II CAL GEN ACCE”

Class III - Blue band with the inscription “III LIMITED CAL”

CALIBRATION INTERVALS

Calibration intervals are set to insure continued measurement accuracy with due regard to calibration cost. The historical data is statistically analyzed to maximize the intervals. The intervals can be lengthened or shortened in accordance with this data. The due date is determined by assuming the thermometer is calibrated on the last day of the month. The interval for all classes of thermometers is initially established at 12 months.
Unlike other instruments on the calibration program, the calibration laboratory is not held responsible for delinquent thermometers. The user is required to insure his thermometers are in good condition and the calibration is not past due. This responsibility was transferred to the user because thermometers are easily broken or lost, making it difficult to locate for calibration.

CALIBRATION

Calibration of thermometers is performed by corporate metrology approved calibration procedures at predetermined test points depending on the class of thermometers (Refer to Examples 1 and 3).

Initial calibration is performed at all test points indicated. Subsequent (periodic) calibration is accomplished at a single point. This point will be at ice-point or the closest appropriate test point to zero degrees Celsius if the thermometer does not include an ice-point.

This single point calibration was established after a study of thermometer performance was performed at Abbott Laboratories and correlated with findings by the NBS and industry. The findings indicated that the ice or reference point reading will reflect a similar change in reading at other points along the scale. This implementation has resulted in reduced calibration costs.

CONCLUSION

The technique outlined has been in operation for approximately one year and has been received well by thermometer users and calibration personnel. A cost reduction of approximately 50% has been realized in the calibration of thermometers. Also the quality level of thermometers used throughout the plant has been greatly improved.
COMPLYING WITH GMP AND GLP:
THE THIRD-PARTY ALTERNATIVE

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The Food and drug Administration has recently made effective two regulations which have had dramatic impact on the medical device and pharmaceutical industries. The first, Good Manufacturing Practices (GMP) Regulations promulgated as a result of the Medical Device Amendment Act of 1976, was effective on December 17, 1978, and covers those industries involved in the manufacture, packing, storage and installation of medical devices. The second, Good Laboratory Practice (GLP) Regulations authorized under the Food, Drug and Cosmetic Act, became effective on June 20, 1979, and pertains to those non-clinical laboratories which are involved in studies to support applications for research or marketing permits for FDA-regulated products.

Both of these laws have resulted in placing significant requirements on the owners and operators of equipment used in manufacturing, quality assurance and non-clinical testing laboratories. Perhaps the best way to determine the nature of these requirements is to review the GMP and GLP Regulations as they pertain to equipment. The portions of the regulations relating to equipment basically break down into three areas: maintenance, procedures and documentation.

Maintenance: Both the GMP and GLP require that equipment be adequately inspected, cleaned and maintained. This requirement also includes routine testing, calibration and/or standardization on a periodic basis. Schedules of such testing and maintenance must be established for each piece of equipment.

Standard Operating Procedures: Written standard operating procedures must be maintained for equipment. These procedures must establish in detail the methods, materials and schedules to be used in routine inspection, cleaning, maintenance, testing, calibration and/or standardization of equipment. Calibration procedures must include specific directions, as well as limits for accuracy and precision. The written procedures must also specify the remedial action to be taken in the event of failure of equipment or where accuracy and precision limits are not met. Calibration must be performed by personnel having the necessary education, training, background and experience.

Documentation: Both the GMP and GLP Regulations require that written records be maintained of all inspection, maintenance, testing, cleaning, calibration and/or standardization operations. This documentation must include the date of operation, the calibration or inspection date, as well as designating the individual performing each calibration. Additionally, written records must be kept of non-routine repairs performed on equipment as a result of failure or malfunction.

Based on the equipment requirements outlined in GMP and GLP Regulations, medical device and pharmaceutical laboratories are faced with three alternatives for compliance. They are: 1) establishment of in-house metrology service groups, 2) reliance on the manufacturer of the equipment being used, and 3) reliance on a third party capable of providing services to fulfill the requirements of the regulations. In actuality, a combination of the above is also possible, and may be desirable in some cases. Let's examine each of the three discrete alternatives.

Establishment of In-House Metrology Service

Many of the medical device and pharmaceutical laboratories, when faced with the dilemma, set about to establish in-house metrology groups. The advantages of this type of operation have been amply described by other speakers at this conference. However, to reiterate one of the major advantages is that of control—of scheduling, of service quality and of procedural follow-through.

While it is advantageous in many cases to establish in-house calibration facilities, the costs associated with this alternative should be carefully examined. The capital investments in laboratory facilities and equipment, as well as the ongoing operating expenses and manpower requirements must be carefully calculated.

Reliance on Equipment Manufacturers

Reliance on equipment manufacturers for calibration services has one big “plus.” the major advantage is that the manufacturer probably has the experience, training and background to provide expert calibration and repair services. There are, however, many negatives associated with this alternative. Some of those negatives are:

1. Lessened control over maintenance services by the user of the equipment. Having to coordinate the efforts and quality standards for many different manufacturers can be both frustrating and ineffective.

2. Response times by the manufacturer's representative may not satisfy your needs. It can be very difficult to follow the prescribed schedule for equipment maintenance due to potentially inadequate response time by the manufacturer.
3. In many cases, the manufacturer's representative may have a biased opinion as to the quality and integrity of their equipment.

4. With many equipment manufacturers, means of service is available. This may require the user to send the equipment to the factory or other designated location for calibration or repair. This situation, of course, results in increased downtime of the equipment as well as increased difficulty in scheduling of maintenance.

Reliance on Third-Party Service Organizations

The alternative of utilizing a third-party service organization for calibration and repair service has many advantages. These organizations can be utilized to augment in-house capabilities to the extent desired by you. Depending on the organization used, the experience and training of the representatives of the third-party organization can equal or exceed that of the manufacturer of the equipment. Since most third-party service groups handle a broad range of equipment, it is easiest to consolidate purchased services. Whenever the number of different service agencies is minimized, greater control over scheduling, quality of service performed and documentation can be realized.

One point to keep in mind is that utilizing equipment manufacturers or third-party service organizations does not relieve you of the compliance responsibilities outlined in both the GMP and GLP Regulations. Therefore, it is vital that you seek out an organization which is dependable, experienced and adaptable to your specific requirements.

What to Look for in Third-Party Service Organizations

The service organization you use should satisfy your specific needs. Some of the areas which should be investigated are:

1. CALIBRATION PROCEDURES: The service organization should be prepared to work with you in establishing calibration procedures for equipment. A combination of the experience of the service organization, equipment specifications, recommendations from the manufacturer and your own application requirements should result in the optimum calibration procedure.

2. ASSISTANCE IN DETERMINING CALIBRATION SCHEDULE: The service organization should be able to provide you with information based on its industry-wide experience and manufacturer guidelines in order to assist in establishing the calibration intervals for equipment. Analyzing history records of equipment over a period of time can then result in adjustment in the maintenance schedules for optimum efficiency and cost-effectiveness.

3. SERVICE PERFORMANCE: Strict adherence to your established procedures is a "must." In addition to verifying actual instrument performance and performing calibrations as required, the service organization should be capable of handling most non-routine maintenance, including failures or malfunctions of the equipment as well.

4. EXPERTISE OF PERSONNEL: Are the representatives of the service organization factory trained? What is the experience level of the representative? These are questions which should be answered to your total satisfaction prior to assisting you in selecting an outside service organization.

5. DOCUMENTATION: The service organization should be prepared to provide you with a complete documentation package which will satisfy your requirements. Such a package should include history records for each piece of equipment, calibration data sheets which reflect testing results, instrument control/identification labels and calibration stickers.

6. TEST EQUIPMENT AND STANDARDS: The test equipment and standards utilized by the service organization during the testing and calibration of your equipment must be of sufficient accuracy for the applications, NBS traceable and available in sufficient quantities. The service organization should be prepared to provide you, for your records, copies of the calibration certificates for all test equipment and standards being utilized. These test equipment and standards must be routinely re-calibrated or re-certified with updated documentation provided to you.

7. RESPONSE TIME: The service organization should have sufficient time which will ease your burden of scheduling maintenance. There should be backup personnel available in the event of unavailability of the regular representative due to illness, vacation, etc. Keep in mind that it is much more effective to have the same representative performing service on your equipment on each occasion. By adhering to this policy, a closer working relationship will develop between your personnel and the service organization.

By carefully investigating each of these areas with potential third-party service organizations, a very cost-effective alternative or augmentation to in-house service can develop.

In summary, the medical device and pharmaceutical industries have three alternatives, or a combination thereof, for complying with GMP and GLP Regulations. Those alternatives are to establish in-house metrology service capabilities, rely on equipment or utilization of a third-party service organization. There is no one correct alternative which will apply universally. A careful examination of your actual needs must first be made. The next step is to determine which alternative or combination of alternatives will best satisfy those needs from a practical standpoint.

If it is determined that either equipment manufacturers or a third-party service organization should be utilized, discuss in detail those areas previously outlined. The purpose of this discussion is to ensure that the outside service organization can satisfy your needs to the maximum extent, and thereby make it easier and more cost-effective for you to comply with GMP and GLP Regulations.
PHARMACEUTICAL METROLOGY

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TAKING a quote from another metrologist in pharmaceuticals, "Now that aerospace metrology has passed its golden age, the next decade—the 80's—will be concerned with analytical metrology." Today, with the advent of closer government scrutiny and regulatory power, the metrologist with his Q.A. brothers and sisters, has the challenge of orientating the pharmaceutical industry into a more controlled measurement environment.

The alchemists' dream was to turn base metal into gold, it being noted that the metrologist will have to achieve the desired result with very little of the precious metal. Along the same path, in the middle ages the chemist was often considered to be in league with Satan. Today, certain government agencies armed with regulatory sanction, are on a crusade to ensure compliance in many industries, possibly to ensure that the Satan syndrome is not so. This encompasses such areas as environment pollution, energy conservation and pharmaceuticals.

This brings us to reality with respect to measurements in pharmaceuticals. The metrologist does not have to reinvent the wheel, though his understanding of some of the supporting spokes will help, such as chemical technical terms, adjustment to specific measurement needs, and to enlighten the chemical practitioners in how uncertain is the certainty of a measure, will be definitely required. The original wheel can be turned again.

There are several salient facts that can be given. The first are:

- Pharmaceuticals is a large industry, at present with a small metrology awareness.
- Complex equipment and apparatus is used, largely by a non-electro mechanical oriented group of people.
- Government regulations are not necessarily written in pharmaceuticals terms, also being an initial exposure to much of the industry.
- Many measurement processes are in a permanent position, and cannot be brought to the laboratory for calibration/service.

Second, the aerospace-military measurement and metrology services have long been exposed to such parameters as:

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<tr>
<th>Parameter</th>
<th>Unit</th>
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<tr>
<td>Frequency/Time</td>
<td>Mass</td>
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<td>Light/Luminous</td>
<td>Pressure/Vacuum</td>
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<td>Intensity</td>
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To shed some further light on a sleeping giant—metaphorically speaking, of course—we will address some of the factors that have been mentioned.

Size of Industry: Approximately 300 pharmaceutical and 200 medical device manufacturers, as well as several hundred test laboratories, diagnostic clinics and hospitals. (How does this compare with respect to NCSL membership representation?)

Special Equipment: Here we range from sophisticated spectrophotometry, viscosity to electron microscopes, as examples. These and many other special instruments are in everyday use in the production and analytical areas of many plants and laboratories. The users are chemists, biochemists and associates trained in their specific field.

Government Regulations: To cite just a few that have come into legal being in the last year or so: Good manufacturing practices for medical devices (PMA); current good manufacturing practices for human and veterinary drugs (PDA); good laboratory practices (PDA); and do not forget to include the OSHA, FTC and other federal or state agency publications.

Measurement Processes: A large number of the instruments are used to measure, monitor or control complex solutions and processes, and are housed permanently in sterile clean rooms, being embedded in the walls of the rooms in vats or pipes. Many other instruments are permanently mounted in place on equipment, making it difficult or impossible to take such instruments to the calibration laboratory for work. Result is a large in-place or field calibration service workload. This can result in inefficient manpower, and can only be offset by maximum use of:

- Pre-planned area calibrations
- Use of calibration consoles or carts
- Development/use of suitable portable instruments

Some of the problems that become apparent in the calibration process are:

Temperature: The use of many different types and methods in temperature measurement, control and indication. Operating ranges are from
at least -60 to +1500°C., with demand for working accuracy of typically within 0.5° though on occasion, it can be to a few millidegrees uncertainty. It is a large volume workload for the calibration service.

Mass: Another large workload item, I can vouch that one company has over 600 scales and balances and at least 150 weight sets in a single plant, with accuracy requirements from Commercial Handbook 44 to ±1 weight tolerance, as used on microgram precision balances.

Light: Given as a generalized parameter, this covers the spectrum with measurement control needs from white through colorimetric measurement devices, including ultraviolet, infrared and some microwave and laser techniques.

General: Some areas of special measurement concern include: Humidity; hardness and dissolution, all being related to tablet manufacturing. Here the metrologist is being asked to verify the instrumentation used in the quality/analytical laboratory.

To close this short discourse, one other basic need is always very apparent, whether it be in this or in any other measurement orientated industry.

COMMUNICATIONS

We will be conversing with people disciplined and schooled in the sphere of chemical reactions. As an example, the indicators or measuring instruments used in their work, they often believe will provide a true or "absolute" reading; e.g. whether it be a liquid in glass or a platinum resistance thermometer. The trust is placed in the fact that the reading is what it says, with little comprehension of accuracy restriction or uncertainties involved in its use.

Many times, only a relative reading is needed, but the trap door can suddenly swing open and all is in jeopardy, especially when an unrealistic or tight tolerance for a process is written into a specification, (Rx card) or when in comes the audit inspector, requiring proof of control and measurement integrity.

It will take time in training, discussion and experience to get the pharmaceutical industry to be appreciative of these and other problems, and to get them to challenge the validity and capability of the instrument(s) making the measure. This is part of the metrologists' work in conjunction with our work relatives—quality.
The direction that a metrology program will take can be based on many considerations. These can include the type of support and general philosophy of management, the availability of in-house personnel capable of implementing a metrology program, and the types and numbers of instruments or systems that are involved.

There are three approaches that can be taken in setting up a program. These are:

1. All calibrations done by in-house personnel
2. All calibrations done through contracted services
3. Combination of in-house and contracted services

Each approach offers advantages and disadvantages. The type of approach taken will depend on the considerations just mentioned.

The first step in setting up any metrology program is to conduct an inventory of all instruments and systems involved. This does two things: it dimensions the calibration and maintenance workload, and it is basic information needed when a selection of standards instrumentation or service contracts is to be made.

If a large number of instruments are involved, the availability of a computer for the storage and manipulation of this inventory data is very helpful. There are various manual systems for inventory management but the versatility of the computer for generating schedules, reports, instrument status for a user, or the storage and retrieval of historical calibration data should not be underestimated.

Assuming that a combination of in-house personnel and contracted services will be used, the next step is the selection of primary and secondary standards and specific contracted services for classes of instruments where in-house expertise is lacking or where the number of instruments does not justify the purchase of expensive standards. This hybrid approach offers a flexible and cost effective way of supporting all types of instruments.

The selection of a contracted service is equally important since the responsibility for final calibration rests with the user not the contracted service. Help in this selection process can be obtained from local metrology labs, seminars, and the literature.

Writing procedures, generating record forms, and determining the frequency of calibration and maintenance of each type of equipment is the next step in process. Some contracted services will supply procedures or work with the user in writing procedures. Other sources of procedures and methods are available from the instrument manufacturer or through organizations such as GIDEP or monographs available from the NBS.

Initially, the manufacturers recommended frequency of calibration is followed. This is modified somewhat when the instrument is operated in a hostile environment or the user needs are critical. A more relevant schedule can be generated when sufficient calibration history data is accumulated and analyzed.

Concurrent with this whole process should have been the training of a staff. This can be accomplished through NBS seminars, educational programs offered by NCSL, PMA, GIDEP and others, instrument manufacturer seminars, or the hiring or trained metrologists with military or aerospace experience who can then conduct in house training programs.

The implementation of the calibration and maintenance program is the last step in the process. Plan a flexible schedule since if something can go wrong, it probably will. Accidents happen, people get sick and go on vacations, and in the case of a new program there is a big learning curve, especially when large numbers of different types of instruments and standards are involved.
EDITOR'S NOTE:
Chairman R. B. "Pete" England noted that most of the papers presented in his workshop were published at the San Diego ATE Symposium in April, 1979. They are all listed in the Comprehensive Bibliography which follows. In addition, Pete asked that his letter and the NBS paper be published.

EDITOR:
The Calibration Laboratory Automation Committee has recently changed its name to "Automatic Test and Calibration Systems" and has expanded the Charter to also include the following:

"Study ATE calibration problems and identify candidate action categories from which recommendations and/or guidelines could be developed and disseminated to the ATE Design Community."

The name change and expanded functions are in response to an issue raised at this year's annual conference in Boulder, Colorado. Namely, a recognized need to improve the calibration and metrology support functions for Automatic Test Equipment (ATE). This issue was also explored and discussed at the Industry/Join Services Automatic Test Project (I/JSATP) in San Diego, California, during April 1978. As a result of that conference, several draft recommendations were made by the I/JSATP task groups proposing additional studies be conducted on this subject.

The Center for Electronic and Electrical Engineering of the National Bureau of Standards has recently responded to those recommendations by preparing a position paper entitled "An Approach to Metrology in Support of ATE Under Consideration at NBS." Copies of this paper have been sent to all attendees of I/JSATP suggesting that their comments could be useful to NBS.

AN APPROACH TO METROLOGY IN SUPPORT OF ATE UNDER CONSIDERATION AT NBS

INTRODUCTION

Modern society is now completely dependent upon proper functioning of electronic systems. For productivity enhancement, many businesses (from electronics to the mechanical, manufacturing, transportation, and chemical industries), use electronic-based automatic test equipment (ATE). Advanced manufacturing process control and product performance testing require ATE to provide speed and reproducibility that is beyond the capability of human beings using traditional manual tests. This automated test and process control equipment must perform with:

High Speed - for economy of time in measurement or because of the fast transient nature of the test phenomenon

Precision - for uniformity and high product quality

Reliability - to avoid excessive downtime, particularly on a production line

Accuracy - for marketplace equity, product interchangeability, and traceability to national standards

With the increased level of complexity of modern electronic components, instrumentation, and systems, and requirements for their high performance and reliability, comes the increased need to be able to rapidly test these
items both functionally and operationally in a meaningful manner. The traditional measurements of electrical parameters, such as current and voltage, on an individual basis are excessively time consuming (and not practical in many cases) and do not provide satisfactory indicators of system performance or function. Automatic test equipment systems have been developed that rely on microcomputers, programmable testing sequences, internal stimulus sources, references, and sensors, and internal digital data acquisition and processing systems to rapidly test complex electronic systems. Sophisticated algorithms are employed for the execution of measurements, operation of the entire system, its self-checking features, and other functions. ATE systems are themselves large and complex, systems costing about $1M are in use. To increase operating speed, new approaches in precision metrology must be used in order to capture all the information contained in an electrical signal rapidly varying with time. As a result, ATE systems have often outgrown the metrology needed to support them. Complete calibration of a complex system may not be feasible. Strategies must be developed and optimized for partial checking which would yield the desired level of confidence regarding the overall accuracy of ATE. The field of ATE is relative new. Hence, performance standards, terminology, and criteria for specifications are yet to be developed and agreed upon.

The major problem with ATE, therefore, concerns the process of assuring the accuracy and reliability of these complex electronic systems. Better means are needed for verifying the performance specifications of ATE systems and for assessing the performance state of an ATE. Related to these problems is the issue of testability. ATE systems should be designed so that testing them for the purpose of verifying their performance is less difficult. The concepts of design-for-testability and built-in-test must be explored further with better metrology aspects incorporated.

Because ATE is used in most every high technology industry, the impact of ATE on the productivity of these industries is immense. Most electronic products manufactured in the U.S. (as well as Japan and Western Europe) are supported by ATE on the production line. The worldwide sales of all electronic equipment products during 1978 will exceed $100 billion dollars, with an annual growth rate of 12%. The worldwide sales of test instruments alone is estimated at $2.4 billion in 1978 and expected to reach $5.0 billion by 1983. The prediction for test equipment sales in the industrial/commercial, medical, consumer, automotive, and government electronics categories for 1981 is approximately $87 billion. NBS efforts to provide improved support for ATE will have impact not only on the test equipment itself, but also on the equipment and components serviced by ATE. The prime weapons systems in the DoD having electronic packages supported by ATE are conservatively valued in the billions of dollars.

Eighty percent of the $10 billion of current test equipment inventory in the Air Force alone is ATE. The DoD is spending about $2 billion per year in the acquisition of additional ATE. To summarize, then, the technological barriers that will be addressed by this program are:

- Lack of appropriate electrical standards and a more viable strategy for verifying the performance of multifunction test systems.
- Lack of traceability to national standards and satisfactory methods for assessing and quantifying the overall performance of ATE is a cost effective manner.
- Lack of adequate test strategies.
- Lack of adequate calibration software standards.
- Lack of communication between ATE manufacturers and ATE users.

NBS ROLE

The NBS role is to provide the metrology as needed for verifying the performance requirements of ATE relative to national standards. Some entirely new approaches are required to develop such support. It is important to emphasize that this program is directed toward the metrology for ATE, not toward the development of prototypes of the equipment commercially identified as ATE. It is directed toward the provision of measurement methods, standards, and associated technology used for calibration and for assuring accurate and reliable performance of ATE. It is also important to emphasize that this proposal is responsive to a problem that has challenged the manufacturers and users of ATE for many years (the latter in both government and industry), and it is responsive to strong and specific requests from these manufacturers and users for NBS aid.

In particular, the objectives proposed for this program are related to the draft recommendations made by an Industry/Joint Services Automatic Test Project (I/JSATP) Conference and Workshop held in April, 1978. The I/JSATP was organized to coordinate the efforts of all the military services in supporting the use and maintenance of ATE, and is sponsored by five industry trade associations (AIA, EIA, NSIA, SC/A, and AEA). Recommendations were made that NBS take a greater involvement in the ATE field and play a leadership role.

The current base effort supports a small program aimed at developing measurement technology, calibration and performance standards, and associated data to enhance the calibration, evaluation, utilization and further development of modern electronic instrumentation.

2Dataquest Research Newsletter, June 7, 1979.
Program thrusts in three main areas (precision waveform sources, precision data acquisition components, and measurement processing applications) will be applicable to some ATE problems in the low and audio frequency ranges. Base metrology programs are also underway which address similar problems and needs in the RF/microwave, time domain, cryoelectronics, and optoelectronics areas of the high frequency electromagnetic spectrum. However, the current level of these base programs is inadequate to deal with current government and industry concerns regarding the burgeoning applications of ATE. Most of these applications require knowledge of problems faced in using sophisticated automatic test systems in operating field environments beyond the walls of an environmentally controlled laboratory. Nevertheless, because of the metrology-related and interdisciplinary engineering challenges surrounding the use of ATE, NBS is being asked to act as a central resource which has expertise to contribute towards solving performance verification and testability problems. This kind of resource activity, then, means that to be effective, NBS must mount a program whereby its laboratory reference standards and rigorous test techniques can be readily translated and transferred to the on-site testing terminals of an ATE.

OBJECTIVE

To develop the physical and performance standards and associated test methods unique to the metrology needs of automatic test equipment (ATE) in cooperation with industry and other government agencies. Prototype dynamic transport standards will be configured which cover key measurement and stimulus parameters essential for characterizing ATE. The complexity of ATE systems also necessitates that analytical models and/or statistical methods be determined for assessing the overall performance state of such systems.

RESEARCH PLAN

The plan for implementing a program in metrology support for ATE is aimed at helping to remove the specific barriers mentioned previously. The major efforts presented below follow from these barriers:

- A technical barrier to achieving greater measurement assurance for ATE and, hence, better productivity is the lack of appropriate electrical standards and systems. The need for high throughput, completing many tests in a short period of time, is the compelling motivation for utilizing ATE. Consequently, this need is pushing the state-of-the-art in the performance tradeoffs (e.g., accuracy vs. speed) inherent to key hardware and software elements found in ATE. Work will be conducted on developing national standards and associated methods used for testing and calibrating components generic to ATE systems (e.g., data converters, sample/hold amplifiers, analog comparators, microwave couplers, etc.). This effort will build on experience and competence developed in the base program on high-speed electrical measurements.

- User experience with ATE, as documented in the Proceedings of the Industry/Joint Services Automatic Test Conference and Workshop of April, 1979, has disclosed the lack of satisfactory methods for assessing and quantifying the overall performance of ATE in a consistent manner. NBS stimulus and measurement standards and associated test and calibration systems will be developed to provide standards directly traceable to NBS which can be used in ATE system calibration verification. By working with industry and other government agencies to identify the most useful and critical parameters essential to characterizing ATE, NBS will configure prototype dynamic transport standards (DTS) which would cover the key parameters over the most important ranges of values. An initial subdivision for this purpose, based on generic functional capabilities found in many ATE’s is:
  1. Audio and Low Frequency DTS
  2. Pulse and Digital Logic DTS
  3. Radio and Microwave Frequency DTS

It is anticipated that these DTS’s will be developed with guidance from industry and other government agencies and that, based on these prototypes, appropriate DTS’s will become commercially available at several levels of accuracy. A working system is visualized in which NBS verifies the performance of the highest accuracy DTS’s for a relatively small number of key standards laboratories in industry and government. Such organizations would utilize these high accuracy DTS’s through and intermediate step to verify ATE in the field. The capability for handling the calibration of the high accuracy DTS’s at NBS will require the development and establishment at NBS of the necessary test methods and special automatic test equipment, which utilizes the national standards as references.

- A distinguishing feature of modern ATE is the complexity of these systems in terms of their functional capabilities and the large number of test points available. The advent of these sophisticated testers introduces new complexity to the concept of “traceability” to national standards. Conventional procedures for testing and calibrating the complete functional capabilities of “3rd generation” ATE have been found to be unduly time consuming. Another task under this program will be to develop improving analytical models and appropriate statistical methods which can be applied to the problem of conveniently assessing the overall performance state of an ATE system. Greater interactions with ATE manufacturers regarding test strategies could lead to the development of guidelines for ATE design which permit increased testability.
This approach to metrology in support of ATE has several objectives based on the draft recommendations described earlier as a result of the 1978 I/JSATP Workshop. These include the recommendations of the Task Groups on Metrology and Calibration, New Technology, Advanced ATE Technology, Microprocessors, and Design for Testability.

OUTPUTS, IMPACTS, AND BENEFITS

Several beneficial outputs are expected to accrue as a result of achieving the objectives outlined in the above plan for this program. The primary technical output will be the development of a more systematic approach throughout the national measurement system of addressing the question of how NBS ultimately supports the quality of the data acquired by and delivered from ATE systems. This approach consists of (1) establishing a liaison and coordination activity with industrial and other agency groups concerned with ATE, (2) developing dynamic transport standards (traceable to NBS laboratory standards) for use in verifying the calibrated performance of ATE at the unit-under-test (UUT) interface, and (2) providing guidelines and practices for achieving improved testability and characterization of complex ATE systems.

The program being proposed on ATE is aimed at developing the measurement science to support present and future generations of ATE in both a microscopic and macroscopic sense. The basic hardware elements or components used in the stimulus and measurement channels of ATE (data converters, comparators, multiplexers, etc.) will have their counterparts here at NBS as national standards, together with test methods and facilities for calibration purposes. The
dynamic transport standards to be developed (at the highest accuracy levels) will provide a more direct measure of ATE system performance at the external UUT terminals.

The issue of testability surrounding ATE is, perhaps, the most scientifically challenging aspect of this field. This challenge is because there are questions of optimum test strategies and methods, valid analytical models, and real-time and off-line monitoring and built-in-test (BIT) concepts of both the UUT, as well as the ATE system itself. Complicating this issue is whether such concepts as "Self-Test" and "Automatic Calibration" of the multifunctional capability of both UUT's and the ATE's that test them can ever be completely divorced from the needs for external verification testing and calibration.

The impact of these efforts on the electronics, defense, semiconductor, aerospace, automotive, and medical industries is by virtue of the need for high throughput, completing many tests in a short period of time, the need for making a large number of tests, and the transient nature of properties under test which make annual tests difficult or impossible. The beneficial impacts of this ATE program will be to realize increased productivity in terms of more reliable test data and greater quality control on the products tested. Without this effort, the industries will continue to experience difficulty in assuring ATE performance and increasing downtime taken to determine ATE calibration.
SELECTED ATE CALIBRATION BIBLIOGRAPHY

R. B. ENGLAND, Chairperson
NCSL Cal Lab Automation Committee

This is a bibliography of recent papers on the subject of ATE calibration and was prepared by the Calibration Laboratory Automation Committee of the National Conference of Standards Laboratories (NCSL) for distribution at the 1979 NCSL Workshop and Symposium. It should be recognized that no author or organization listed has agreed to make copies available upon request. Some of the organizations listed are not members of NCSL. Further, approval or disapproval by NCSL or the Committee is not to be implied for any paper listed or omitted from this bibliography.

DESIGN FOR SYSTEM CALIBRATION

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Support Equipment SPO,
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This paper addresses the four present ATE calibration approaches and leads into the new ATE system requirements necessary to ensure confidence that the system is meeting design specifications without excessive down time for calibration.

PATEC - AN AIR FORCE APPROACH TO ATE CALIBRATION

Joseph C. Santo
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Newark Air Force Station,
Newark, Ohio

A general overview of Automatic Test Equipment (ATE) systems and their use in the Air Force is presented. ATE calibration is defined and various techniques which have been employed are discussed. The Portable Automatic Test Equipment Calibrator (PATEC) concept is defined and details of applying this concept are presented. These details include ATE system specifications, selection of the proper calibration point, determination of the "core" instruments, analysis of the self test features and the assembly of a complete PATEC system. A description of some successful PATEC applications and some current efforts is presented.

CALIBRATION DIALECT, COMMUNICATION AND ORGANIZATION

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The mission of "calibration," definitions, fundamentals, as well as the associations and requirements, for application of measurement discipline through the prime and support equipment life cycles are addressed. The various DoD guidelines which impact the effectiveness of calibration planning and support are identified and discussed.

THE ROLE OF NBS IN TRACEABILITY TO NATIONAL STANDARDS FOR ADVANCED MEASUREMENT SYSTEMS

Brian C. Belanger
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This paper discusses the role of NBS in traceability to National Standards; its implications for NBS; the Federal Government's coordination of Precision Measurement activities; Laboratory Accreditation; and ATE Development work at NBS.

NAVY METROLOGY AND CALIBRATION PROGRAM AND TEST EQUIPMENT CALIBRATION

Delbert H. Caldwell
Navy Metrology Engineering Center
Pomona, California

The requirements for assuring the quality of Automatic Test Equipment (ATE) test and measurement capabilities are discussed. The Navy Metrology and Calibration program objectives and methods for supporting Test, Measurement, and Diagnostic Equipment as well as ATE are given. Key improvement areas for ATE calibration are identified along with the status of current improvement actions.

AUTOMATIC TEST EQUIPMENT CALIBRATION IN THE UNITED STATES AIR FORCE

Maynard D. Lay
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Aerospace Guidance and Metrology Center
Air Force Logistics Command

This paper discusses some of the different types of ATE within the Air Force inventory, some of the support problems encountered, different calibration approaches/methodologies and some of the training requirements for support personnel.

ATE CALIBRATION - SUMMARY OF INTRODUCTORY REMARKS

F. B. Seeley
U.S. Army Metrology and Calibration Center
Redstone Arsenal, Al.
The major technical problem in ATE calibration is suggested; deciding how extensively to internally test and validate the measurements and stimuli in ATE. Other problems in ATE calibration include in-situ and dynamic calibration.

STATE OF INDUSTRY ATE CALIBRATION

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Sophisticated automatic test equipment (ATE) has been in use in the industry for over ten (10) years and most companies have learned to operate it economically in a production or maintenance environment. However, advances in the state-of-the-art are continuously pushing the accuracy specifications for measurement equipment closer to the certified accuracy of primary standards. This has created the need for more accurate calibration standards, particularly transfer standards, and reduced certification periods. Documentation records must provide an accurate history of the equipment under certification that starts from the beginning, with initial delivery and acceptance of ATE and leaves a clear history of events that have occurred throughout the useful life of the equipment. The general philosophy of calibration and certification of ATE in one of various industries, the airlines industry, is also discussed.

ATE CALIBRATION - WHERE WE NEED TO GO

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Abstract - Factors relative to the acquisition of ATE and the build versus buy decision are enumerated. A present day ATE systems' calibration procedure, its advantages and disadvantages are discussed. Several proposals as to the direction that ATE calibration should go are presented.

HOW ATE SPECIFICATIONS AFFECT CALIBRATION COSTS AND INTEGRITY

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When a new or extensively modified Automatic Test Equipment (ATE) system is required, the customer should request a trade study by the contractor which shows optimization of three interdependent factors: operational requirements, support alternatives and life cycle costs. Calibration considerations are part of such a study. Since calibration is a supporting function for ATE, minimal but adequate calibration requirements should be reflected in ATE specifications. Optimization of two key parameters, calibration integrity and the calibration support system, provides the best cooperative customer/contractor opportunity for reducing calibration costs. Application of statistical tolerancing and budgeted accuracy ratios reduce calibration requirements while maintaining needed integrity. It also increases opportunities for attractive calibration support alternatives such as ATE in-place calibration by a compact carry-up standard.

ASSURING CONTINUED MEASUREMENT INTEGRITY

John Henderson
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Newport Beach, CA

The performance specifications which describe ATE "Systems" capabilities must be defined to a consistent point or location to be meaningful and assure measurement integrity. The several approaches being used or abused are described and results will be discussed. The cause, effects, and benefits of definition at the UUT interface will lead into the next issue of capability enhancement through software.

ATE "SYSTEM" CAPABILITY IMPROVEMENTS VIA SOFTWARE

David H. Russell
National Bureau of Standards
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The accuracy and efficiency of any ATE system can usually be improved by application of software corrections derived through calibration measurements accounting for system losses or variations. Software enhancement of parameters that can and do change creates special problems for the calibration and user community regarding validity, proper application, and verification. As an alternative to using "gold-plated" measurement standards for overall system calibration, methods of internal system intercomparisons (self-calibration), partial calibration, UUT fail/pass data, etc., will be discussed.

DID YOU GET WHAT YOU PAID FOR?

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TRW Space Systems
Redondo Beach, CA

The acceptance test planning and evaluation of ATE must start before purchase and not after it is paid for. Metrology and calibration criteria must be considered before design and monitored through acquisition, implementation, operation, and support phases of the ATE. Detailed metrology criteria of evaluation, documentation, timing, technical capability,
specificat ion interpretation, calibration inter­
val establishment, etc., is discussed. Cali­
bration reaction mode versus early investment
and action opportunities is presented.

ASSURING CONTINUED MEASUREMENT INTEGRITY

Robert J. Ott
Lockheed Missiles & Space Co.
P.O. Box 987
Silverdale, WA 98370

After the ATE has been proven and document­
ed by the customer to meet all applicable perfor­
mance specifications, safeguards must be imple­
mented to maintain control of the integrity of both
hardware and software. ATE presents new un­
conventional control problems to the calibration
quality organization because of the new measure­
ment contributions of software. Construc­
tion specifications are discussed resulting from ad­
dition of new or modified UUT requirements, sys­
TEM reconfiguration, new measurement tech­
teques, repair/replacement of system compone­
ts, as well as calibration interval adjust­
m ent and data retention. Organizational capa­
bilities and responsibilities required to
achieve measurement integrity are presented.

CALIBRATION, REPAIR, SOFTWARE SUPPORT; RESPON­
SIBILITIES

R. B. England
Senior Quality Assurance Specialist
General Dynamics, Pomona Division
Pomona, California 91766

The DoD community is concerned with logistic
cost and operational readiness of its weapon
system. Today, many of these systems are tested
on Automatic Test Equipment (ATE) at various
depots and field installations. Periodic cali­
bration, repair and support methods and pro­
cedures are established and performed on these
ATE’s in order to ensure that their operating
functions are within acceptable limits and that
the basic system integrity is maintainable over
pre-set intervals. This paper discusses some
basic problems and questions concerning these
methods, procedures and responsibilities. It
will be the function of the workshop to further
identify and examine these methods and respon­
sibilities in order to arrive at some recom­
mendations or common solutions. The remainder
of the paper discusses what the author believes
is the primary problem concerning the support
of military ATE, namely: "The increasingly
difficult task DoD personnel have in repairing
complex field ATE."

DYNA MI C VS STATI C CALI BR AT I ON

Say Kobayashi, Supervisor
Metrology Systems Engineering,
Lockheed Missiles & Space Co., Inc.
Sunnyvale, California 94086

Traditional techniques of static calibration
where time considerations are neglected cannot
be tolerated for a comprehensive calibration of
ATE. Specific areas where dynamic measure­
ments and consequential calibration methods and pro­
cedures must be considered because of critical
time-dependent applications are discussed. The
effect of software algorithms on calibration
integrity is explored. The status of a program
for developing dynamic electrical measurement
standards at the National Bureau of Standards
is summarized.

CALIBRATION PROCEDURES: CONTROL AND REVI S I ON

William H. Kraper
Program Manager
AAI Corporation
P.O. Box 6767
Baltimore, Maryland 21204

This paper discusses some problems with current
ATE calibration methodologies for DoD systems
and proposes some new approaches which the
author believes would increase Test System OR.

DoD uses more than one method of calibrating
ATE. The classical approaches prevalent are
compared to the opportunities, requirements,
and effectiveness of a "systems" or composite
process of calibration. Industry trends, pro­
ductivity improvement potential, calibration
interval adjustment schemes, possible versus tradi­
tional, UUT interface versus external
calibration of individual instruments, etc., is
presented, as well as the prerequisite for
"systems" calibration.
Harry Haymes welcomed the members on behalf of NCSL and the host company Charles Stark Draper Lab.

The meeting opened with a slide presentation sponsored by the National Conference of Standards Laboratories. It described the purpose and charter of NCSL which began in 1961.

Jim Valentino, the new President, gave the report of the Board of Directors after expressing great regret at the death of Dave O'Brien.

The membership has risen to 380. The treasury balance is $32,000 down 5,000 from last year. The annual directory will be published every two years as a method to save the $5,000 publication costs. A dues increase has been considered to offset the cost of the NCSL Fellowship Program. Unfortunately, no Fellow was nominated by any member organization and therefore, the dues increase was not implemented.

The NBS sponsorship for NCSL is stronger than ever before. Jim challenged the NBS management with at least one yearly goal to accomplish.

Pete England is setting-up a new committee to investigate ATE within the calibration environment. Hopefully this will be a goal for NBS to support.

The Measurement Assurance Program brochure has been completed and will be distributed shortly.

Annual meeting workshops were highly successful and stimulated much interest and discussion. Mil Spec 45662A will be released as a MIL-STD in the very near future. The basic change is the out of tolerance data feedback requirement (5.6).

NCSL believes training is necessary to achieve technical competence for new metrologists and experienced metrologists. The NBS does not train at the technician level. Texas A&M is considering a degree in Metrology Science. Jim feels that we are responsible to motivate technical schools to offer a two-year vocational/technical school in Metrology Science for technicians. He also feels that company laboratories should be the training ground.

Harry Haymes followed the training discussion with an introduction of Moe Corrigan from Region #2. He explained a training session that had been initiated in that region. A summary of this training venture is attached. The first training session was held in September, 1979.

A discussion evolved to determine which type of training is required, i.e. specific technical training in a basic instrument, or a general basic training in philosophy. It then drifted to ATE equipment training. A consensus formed that we should contact the local manufacturers for individualized training.

The training philosophy was resolved from the following vote results:

<table>
<thead>
<tr>
<th>Votes</th>
<th>Type of Training</th>
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<tbody>
<tr>
<td>12</td>
<td>Specific repair and troubleshooting for Cal. Labs.</td>
</tr>
<tr>
<td>4</td>
<td>Microprocessor (ATE) and HP9825A repair</td>
</tr>
<tr>
<td>3</td>
<td>Basic standards Lab training</td>
</tr>
</tbody>
</table>

It was suggested that the first hour of training could be basic Metrology with the rest to be specific to an individual subject.

The workshop subject was resolved from the following vote:

<table>
<thead>
<tr>
<th>Votes</th>
<th>Workshop Subject</th>
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</thead>
<tbody>
<tr>
<td>12</td>
<td>Troubleshooting with logic analyzers</td>
</tr>
<tr>
<td>8</td>
<td>Methods and techniques for alignment of new spectrum analyzers</td>
</tr>
<tr>
<td>6</td>
<td>Methods and techniques for alignment of multichannel high frequency oscilloscopes</td>
</tr>
<tr>
<td>6</td>
<td>Troubleshooting with Signature Analysis</td>
</tr>
<tr>
<td>6</td>
<td>HP 9825A programming</td>
</tr>
<tr>
<td>4</td>
<td>Methods and techniques for the alignment of new storage oscilloscopes</td>
</tr>
</tbody>
</table>

Harry Haymes will organize the first training seminar. He will call upon individual Region 1 members to assist in the program.

Milt Towne discussed the present and future plans in the area of automatic calibrations at Sanders Associates.
A general ATE discussion ensued concerning the Fluke 5101B/8502A DVM calibrator, the Tektronix scope calibrator, the Ballantine scope calibrator and the Fluke MECCA system.

The Standard Cell Measurement Assurance Program was discussed to determine if there was interest by approximately five companies to keep program costs at around $500.00. The tangible benefits were questioned by the members. The only benefit would actually be to determine each lab’s measurement capability. The general consensus was to explore the labs’ measurement capabilities to see if there is a problem, before entering the NBS program.

Wes McPhee explained that CSDL had some 7,000 spare equipment manuals. The members were invited to request any of these spares for their use.

The last agenda item was the question of Metroization in the region. All members expressed no interest at this time. It was felt that it would be required only where product sales dictated its use.

Jim Valentino closed the meeting with a plea for Region 1 members to become more involved with NCSL activity and promotion. This can be accomplished only if members are willing to serve and devote time towards making regional meetings successful and participate on NCSL committees.

A resounding thanks was given to Wes McPhee and Charles Stark Draper Laboratories for the use of their facilities for this meeting.

ATTENDEES:
Herb Barclay
Koe Corrigan
John Brano
Ed Plantac
Frank Germani
C. Gustafson
Harold D. Hale
Dan Hayes
H. B. Haynes
C. Jacobson
Richard Lohoski
T. Majewski
Vincent Mattuck
Wes McPhee
J. Bicchellone
Terry Skrypek
Wildred Spring Jr.
J. Valentino
GTE Sylvania
Lockheed Elect. Co.
Northrup Corp.
Continental Resources
Raytheon S.S.D.
Portsmouth Naval Shipyard
Naval Underwater Sys. Center
Hayes Inst. Service
Sanders Associates
Stone & Webster
Draper Lab.
Avco Systems Div.
Digital
Draper Lab.
Perkin Elmer
Poshboro Company
Digital
 Sanders Associates

The workshop was held on April 25, 1979 at the Breckinridge Hotel, St. Petersburg Beach, Florida from 9:00 a.m. to 4:00 p.m. Twenty-eight participants represented 16 corporate laboratories, five U.S. Government agencies and one Canadian Government agency.

NCSL President, Ron Kidd, opened the workshop with an overview of a series of meetings between NCSL officers and NBS directors to discuss areas of mutual concern. Training of metrologists, increased use of standard reference material services and expansion of Measurement Assurance Program (MAP) activities were major subjects of the discussion.

Norm Belecki, NBS, gave a presentation on MAP’s. Norm pointed out the NBS offers MAP services, it is the participant laboratories that accomplish the measurement assurance. MAP’s identify measurement requirements, develop models of measurement processes, monitor measurement process performance, sample periodically to determine offsets and provide program documentation. The sequence of events leading to the establishment of a successful regional MAP was explained. Volt Transfer Program Instructions, observation sheets, and notes on construction of a standard cell comparator were provided and have been reproduced for attendees who requested copies.

Gary Davidson (TSN) and Laurel Auvier (Beckman) participated with Norm Belecki in an informal discussion of the Southern Cal Regional EMF MAP which dealt with need to assure adequacy of pivot lab measurement precision, rotation of pivot laboratory to share workload (NBS now provides a selector switch pivot lab to facilitate tests). This program now maintains the

Region 4 Meeting
A group discussion on the establishment of a Regional EMF MAP in central Florida followed. The prospects for such a program are good since four laboratories participate in EMF MAP's on an individual basis. The chief obstacles to establishing a regional MAP are lack of transfer standards, and the variety of sources used by the laboratories to establish their unit of EMF. As a first step in assessing the capability of potential participants for an EMF MAP, Norm Belecki offered to provide data reduction services on a set of standard cell intercomparison data for interested laboratories. The data were to be submitted to NBS on the observation sheets provided. Norm also provided a cassette tape for standard cell test data reduction on a HP 9830. This effort should be completed before the next regional meeting. Participants were requested to supply a block diagram of the measurement/comparison systems for standard cells and standard resistors. These have been duplicated and copies are attached. (Regional Members and N. Belecki only.)

Jim Valentino (NCSL Executive V.P.) addressed attendees on the impact of advanced technology on calibration laboratory operations, with emphasis on the impact of ATE validation requirements and strategies for optimizing utilization of resources in calibration and maintenance of complex equipment for which annual calibration and maintenance costs may run as high as 60% of acquisition cost. NBS is involved in studies of ATE hardware and software validation techniques and solicits inputs from NCSL member organizations.

Copies of "Traceability an Evolving Concept" (Belanger, NBS), "Regional Measurement Assurance Program for Physical Measurements" (Belanger & Kieffer, NBS), and "Information on Computer Program Availability for NBS MAP's" were provided by NBS Office of Measurement Services for distribution at the workshop (the Regional Coordinator still has some copies available). The first mentioned paper has special significance since it presents an NBS statement on the definition of traceability.

Participants were requested to complete two questionnaires, one dealing with time and site preferences for regional workshops, the other with topics and format. The results were tabulated on the following page and will be used as guidelines for future regional programs.

ATTENDEES:

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
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<tbody>
<tr>
<td>R. Addleton</td>
<td>WRAPB</td>
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<td>L. Auxier</td>
<td>Beckman</td>
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<td>N. Belecki</td>
<td>NBS</td>
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<td>B. Birmingham</td>
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<td>R. Bowen</td>
<td>Harris</td>
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<td>G. Cameron</td>
<td>Qete, Canada</td>
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<tr>
<td>G. Davidson</td>
<td>TRW</td>
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<tr>
<td>L. Dennison</td>
<td>Honeywell</td>
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<tr>
<td>D. Doi</td>
<td>Lockheed, California</td>
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<tr>
<td>D. Gallagher</td>
<td>L&amp;N</td>
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<tr>
<td>W. Gray</td>
<td>Pan American Airways</td>
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<tr>
<td>J. George</td>
<td>Microwave Associates</td>
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<tr>
<td>R. Kidd</td>
<td>Rockwell-Collins</td>
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<tr>
<td>C. Koop</td>
<td>Ford Aerospace</td>
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<tr>
<td>H. Keith</td>
<td>Bionetics</td>
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<tr>
<td>R. Kotsowski</td>
<td>Lockheed, Marietta</td>
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<tr>
<td>R. Lady</td>
<td>Martin, Orlando</td>
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<td>L. Lapanne</td>
<td>Honeywell</td>
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<td>J. Lee</td>
<td>RCA</td>
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<td>R. Mecheid</td>
<td>U.S. Army</td>
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<tr>
<td>J. Mckinney, J. Riley</td>
<td>RCA</td>
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<tr>
<td>C. Sammet</td>
<td>RCA</td>
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<tr>
<td>R. Schnepf</td>
<td>General Electric</td>
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<tr>
<td>S. Smith</td>
<td>RCA</td>
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<tr>
<td>H. Starling</td>
<td>Bionetics</td>
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<tr>
<td>H. Taff</td>
<td>Sanders</td>
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<tr>
<td>W. Tramel</td>
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<tr>
<td>J. Valentino</td>
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</table>
George Washington University Announces Short Course

OPERATING TECHNIQUES FOR STANDARDS AND CALIBRATION LABORATORIES

April 14-18, 1980

DESCRIPTION

This course is designed to present state-of-the-art measurement techniques and laboratory operation to personnel engaged in the technical operation of standards and calibration laboratories. Emphasis will be on organization and management of the laboratory, statistical techniques for improved data analysis, measurement assurance, laboratory automation, routine calibration, and maintenance of the standards. The course will include information concerning the automation of the laboratory and the impact of automation on the quality and quantity of the output of the laboratories. Measurement assurance programs will be discussed as they related to various levels of operation of the standards laboratories. In addition, traditional metrology topics will be covered.

OUTLINE

- Standards Laboratory Organization and Management
- Measurement Assurance
- Statistical Treatment of Data
- Automated Measurements
- Mass and Force Measurement
- Length Measurement
- Electrical Measurement
- Microwave Measurements
- Pressure Standards and Measurement

INSTRUCTORS


FEE

The fee for the course is $610. This includes lecture notes and supplies. Make checks and purchase orders payable to GWU, Continuing Education Engineering Education. Participants may delay payment until arrival. Parking is provided.

LETTER TO THE EDITOR

Dear Editor:

Daniela Kruh from the Armament Development Authority in Israel, whom many of you met at the 1979 Workshop and Symposium in Boulder, has written to the Secretariat as follows: "Our calibration and standards laboratory is relatively a new one. It was set up only five years ago and it is still in development. The subjects we are dealing with in our laboratory are: a) Dimensional metrology (length and angle); b) Physical calibration laboratory consisting of temperature, pressure, weight, torque, force, humidity and acceleration measurements.

"One of our greatest problems in all the calibration areas we are dealing with is the unawareness of people outside the laboratory, about the calibration importance...

"I suppose you have available a lot of documents related to this subject (printed reports, slides, tapes, etc.)."

Though Daniela's problem is a common one, the materials (reports, slides, tapes, etc.) do not seem to be readily available. If you have information about available materials that would help her, please advise the NCSL Secretariat, National Bureau of Standards, Radio Bldg., Room 4001, Boulder, CO 80303. We will be happy to pass your suggestions on to Daniela.

L. KENNETH ARMSTRONG
NCSL Secretariat

TRAINING TAPE LIBRARY CLOSED FOR REPAIRS

Milt Toine of Sanders Associates has taken on the project to review all of the NCSL training tape inventory for quality. He estimates it will take about 4 months and the re-opening announcement will be made at that time.

Meantime, if you have questions or comments, you can call Milt at (603) 885-2672.

SOME VOLUMES OF NBS SP-300 AVAILABLE FREE TO NCSL MEMBERS

While the supply lasts, NCSL Members can receive the following volumes of NBS Special Publication 300, "Precision Measurement and Calibration", at no charge on a first come-first served basis. Special Publication 300 is an update and expansion of NBS Handbook...
SECOND INTERNATIONAL CONFERENCE ON PRECISION MEASUREMENT AND FUNDAMENTAL CONSTANTS SET FOR JUNE, 1981

The National Bureau of Standards (NBS) will host the Second International Conference on Precision Measurement and Fundamental Constants at its headquarters in Gaithersburg, Maryland, from June 9 to 12, 1981.

Conference organizers hope to provide an international forum for scientists actively engaged in experimental and theoretical research on precision measurements relating to the fundamental physical constants and to the testing of related theory. The last such comprehensive international meeting was held at NBS in August of 1970.

One goal of the 1981 Conference will be to gather additional data for the 1981 adjustment of the values of the fundamental constants recommended for international use. This adjustment (using the least-squares method) is being carried out by the Task Group on Fundamental Constants of the Committee on Data for Science and Technology (CODATA).

Proposals for papers for the conference are now being solicited. Topics of interest include the absolute realization of basic measurement units; measurements of fundamental atomic constants such as the Rydberg, the fine-structure, and the gravitational constants; and high-precision tests of quantum electrodynamics and similar fundamental theories. Emphasis is placed on assessment of the present state of precision measurement, basic limitations, and possible future avenues for advances.

Those interested in attending the 1981 Conference or who need more information should contact Dr. B. N. Taylor, Building 220, Room B258, National Bureau of Standards, Washington, D.C. 20234.
HOW TO JOIN NCSL

NCSL is a nonprofit association of laboratories or organizations that maintain or have an interest related to measurement standards and calibration facilities. Each member organization appoints a "member delegate" who has the responsibility of representing the member company or organization in NCSL. Member delegates, working within authority limits agreed upon with their appointing officers, coordinate members' involvement in NCSL's diverse activities.

Make checks payable to the National Conference of Standards Laboratories and mail with application for membership to:

Secretariat
National Conference of Standards Laboratories
c/o National Bureau of Standards
Boulder, CO 80303

<table>
<thead>
<tr>
<th><strong>APPLICATION FOR MEMBERSHIP</strong></th>
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<tbody>
<tr>
<td><strong>NATIONAL CONFERENCE OF STANDARDS LABORATORIES</strong></td>
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</table>

Member Co. or Organization  
Address  
City  
State  
Zip Code  
hereby applies for membership in the National Conference of Standards Laboratories and appoints as its member delegate  
Delegate's Name  
Title  
Delegate's Business Address  
City  
State  
Zip Code  
Telephone Area Code  
Number  
Extension  
who will serve until further notice. The sum of fifty dollars ($50) is enclosed for membership dues for the current calendar year. Membership fee includes $25 for subscription to the NCSL quarterly newsletter.  
Appointing Officer:  
Official of Member-Applicant Organization  
Title  
Mailing Address  
City  
State  
Zip Code  
Date