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Proceedings of the 1966 Standards Laboratory Conference

United States Department of Commerce
National Bureau of Standards
Miscellaneous Publication 291

THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards[1] provides measurement and technical information services essential to the efficiency and effectiveness of the work of the Nation's scientists and engineers. The Bureau serves also as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To accomplish this mission, the Bureau is organized into three institutes covering broad program areas of research and services:

THE INSTITUTE FOR BASIC STANDARDS . . . provides the central basis within the United States for a complete and consistent system of physical measurements, coordinates that system with the measurement systems of other nations, and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. This Institute comprises a series of divisions, each serving a classical subject matter area:

—Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic Physics—Physical Chemistry—Radiation Physics—Laboratory Astrophysics[2]—Radio Standards Laboratory,[2] which includes Radio Standards Physics and Radio Standards Engineering—Office of Standard Reference Data.

THE INSTITUTE FOR MATERIALS RESEARCH . . . conducts materials research and provides associated materials services including mainly reference materials and data on the properties of materials. Beyond its direct interest to the Nation's scientists and engineers, this Institute yields services which are essential to the advancement of technology in industry and commerce. This Institute is organized primarily by technical fields:

—Analytical Chemistry—Metallurgy—Reactor Radiations—Polymers—Inorganic Materials—Cryogenics[2]—Office of Standard Reference Materials.

THE INSTITUTE FOR APPLIED TECHNOLOGY . . . provides technical services to promote the use of available technology and to facilitate technological innovation in industry and government. The principal elements of this Institute are:

—Building Research—Electronic Instrumentation—Technical Analysis—Center for Computer Sciences and Technology—Textile and Apparel Technology Center—Office of Weights and Measures —Office of Engineering Standards Services—Office of Invention and Innovation—Office of Vehicle Systems Research—Clearinghouse for Federal Scientific and Technical Information[3]—Materials Evaluation Laboratory—NBS/GSA Testing Laboratory.

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[2] Located at Boulder, Colorado, 80302.

[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

UNITED STATES DEPARTMENT OF COMMERCE • Alexander B. Trowbridge, *Acting Secretary*

NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

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NATIONAL CONFERENCE OF STANDARDS LABORATORIES

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STANDARDS LABORATORY CONFERENCE

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FOREWORD

The National Conference of Standards Laboratories provides a means by which the country's standards laboratories may cooperate in generating and disseminating useful information relating to calibration techniques and to the operation of standards laboratories. NBS has therefore encouraged the organization and activities of the Conference, and will continue to provide assistance in mutually useful activities, as valuable supplements to the Bureau's work in disseminating accuracy of measurement throughout science and industry. The publication of the Proceedings of this Conference, containing papers presented at the national meeting, is one example of the Bureau's cooperation.

Most of the papers presented at the meeting are published in this volume. Primary responsibility for their technical content must rest, of course, with the individual authors and their organizations.

A. V. Astin, Director

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PROCEEDINGS OF THE 1966 STANDARDS LABORATORY CONFERENCE

ADDRESS OF WELCOME

Allen V. Astin, *Director*
National Bureau of Standards

It is a real pleasure to me to welcome the National Conference of Standards Laboratories to the new facilities of the National Bureau of Standards at Gaithersburg. As Dr. Huntoon indicated, we look on this meeting as the beginning of a series which will lead up to a formal dedication of the laboratories sometime this fall.

I would like to say a few words about these laboratories in order that you can appreciate a little better the facility in which you are meeting. This site is approximately 20 air miles from the center of Washington, and 25 to 38 road miles, depending upon which route you take. It is located on a tract of 550 acres. The buildings themselves will comprise, when construction now in process is finished, approximately 2,300,000 square feet of floor space, at a total cost of approximately 115 billion dollars. The general design of these facilities provides the central administration and service activities in the center of the site, the general purpose laboratories connected to and surrounding the central service unit, and the special purpose laboratories on the periphery of the site. There are seven of the general purpose laboratories, each of which is approximately 385 feet long and about 105 feet wide. Some have 4 floors, some only 3, depending upon the nature of the site and the nature of the activities that go on in them. These general purpose laboratories are designed for extreme flexibility, with portable partitions and flexible distribution of services, so that almost any type of scientific work can be carried on in them.

The special purpose laboratories which surround the central group are designed around very special types of equipment. There are three of these at the moment. There is an engineering mechanics laboratory designed primarily around a million-pound dead weight machine and a 12-million-pound compression/tension machine. There is a radiation physics laboratory designed primarily around particle accelerators, the major one being a 100-million electron volt linear accelerator with a beam power of 50 kilowatts. The third of these is a reactor building. These three special purpose laboratories were the first ones completed, and the first ones occupied. We're just beginning the construction of a number of other special purpose laboratories—a sound laboratory, a chemical engineering laboratory, and a fluid dynamics laboratory. We are now in the process of moving into the general purpose laboratories at the rate of approximately 100 persons a week at the present time. The latest data I have indicates about 43 percent of our Washington staff are now in these buildings and by the early fall we will have approximately 90 percent of our staff here. The remaining staff will stay at the old location for at least another two years.

The central service facilities contain, in addition to the administrative activities, our library, our meeting facilities, eating facilities and the central instrument shops. We designed this central building to make it possible to hold large meetings here and to provide for the continuing education of our staff. In addition to this auditorium, which seats about 800, there is another seating approximately 300. There are three lecture rooms, each of which seats about 100, and there are smaller conference rooms also. These are all located in the general area between this auditorium and the lobby. We believe that the acquisition of these facilities will make it possible for the Bureau to carry on its research and service activities much more effectively than we were able to carry them on in the old site. We have brought to the design of these laboratories all the modern features that we think will help us in doing the very high precision work which characterizes so much of the scientific activity of the National Bureau of Standards.

I would like next to say a few words about the Bureau's mission and some of our immediate objectives. Since I last spoke to this conference a few years ago out in Boulder, we have had additional responsibilities assigned to us, and we have made major reorganizations in our internal structure in order to facilitate our ability to carry out these additional responsibilities. A little over two years ago, we established four institutes within the National Bureau of Standards, each one dealing with a coherent phase of the Bureau's research and service responsibility.

First is the Institute for Basic Standards, the organizational unit most directly involved with the objectives of your National Conference of Standards Laboratories. The Institute for Basic Standards, of which Dr. Huntoon is the Director, is concerned with the establishment of the central basis of our measurement system in this country and the coordination of this measurement system with those of other nations throughout the world. It deals, first of all, with maintaining the six standards which comprise the core of the International System of Units, and also with approximately 40 standards derived from the central six. It is the Institute for Basic Standards that is concerned with improving the accuracy with which we can use all of these, and with extending the ranges and the environmental conditions under which we can make measurements. In addition, the Institute for Basic Standards is very much involved in precision data activities—primarily careful measurements on the most important physical constants. We are aware that there is an increasing tendency to use physical constants rather than prototype standards as the basis of our measurement system, and this is a primary reason for our concern with this type of activity. In addition to this central measurement responsibility, IBS operates the National Standard Reference Data System. This program was assigned to the National Bureau of Standards approximately three years ago; it involves the setting up of a central national file for critically evaluated data. In addition to setting up the file, the National Standard Reference Data System seeks to generate inputs to the file in order that its coverage of all important data will be complete. It seeks also to develop more effective means of disseminating what is in the file. This precision data activity is one which we feel goes very well with the Bureau's responsibility for the core of our measurement system.

Our second institute is the Institute for Materials Research which focuses upon increasing our understanding of the relationship between the composition and structure of materials and their performance characteristics. This organization is involved in utilizing measurement capability toward the understanding of chemical structure and toward the development of methods of measuring the bulk properties of materials. In addition, the Institute for Materials Research assists in the dissemination of measurement competence throughout the country through the operation of a Standards Reference Materials program.

Our third institute, the Institute for Applied Technology, is concerned mainly with the development of criteria for the evaluation of technological products and services. It tries to put evaluation of technological products and services on a quantitative basis, to develop test methods and materials data which are essential to the formulation of engineering standards. This type of activity within NBS is one which characterized a large part of our program some forty years ago. It had been deemphasized over the past decade or so, but three years ago the Secretary of Commerce assigned to the National Bureau of Standards the responsibility to serve as the focal point for the application of science and technology to the development of industry and commerce to the United States. It was determined that we had to reactivate, and expand as resources became available, our work on engineering standards. This is because the introduction of new and improved products and services into our economy is critically dependent upon having reliable means of determining the performance characteristics of such products and services. In the Institute of Applied Technology we are also concerned with a number of specialized information services to make more readily available to American industry the results of research and development, particularly government-sponsored research. We operate in Springfield, Virginia, not far from here, a central Clearinghouse for federally generated research and development information. The goal here is to collect information from all generating sources and to organize it, index it, abstract it, and make it readily available to industrial users. In addition, the Institute for Applied Technology serves as the primary focal point within the Department of Commerce to apply science and technology to government operations. Here we have two major activities; one, a central building research program in which we attempt to speed up the introduction of new technology into the government's construction activities. The other is the operation of a central service for the utilization of automatic data processing systems. We were assigned responsibility by the Congress last summer, and by the Bureau of the Budget a short time earlier, to serve as the central resource within the government to improve the government's utilization of the most modern automatic data processing techniques available. In addition, we are concerned with developing performance standards for automatic data processing systems in order to facilitate the interchangeability of such systems in Federal operations.

I mentioned four institutes earlier. The fourth one, no longer a part of the National Bureau of Standards, was the Central Radio Propagation Laboratory located in Boulder, Colorado, where our Radio Standards Laboratory is also located. The Central Radio Propagation Laboratory, as I think most of you know, is primarily concerned with providing a radio weather service to the nation's telecommunications industry. Since this activity involves understanding the electrical characteristics of our environment, describing them and predicting changes in them, it was felt that its work was more closely allied to other activities also concerned with describing and predicting the characteristics of our environment. There was established within the Department of Commerce last summer a new Environmental Science Services Administration (ESSA), which combined the Weather Bureau and the Coast and Geodetic Survey with our Central Radio Propagation Laboratory. The primary role of the total organization is to provide a central place where data on any of the characteristics of our physical environment from the depths of the ocean to the exosphere could be established. Although the loss of the Central Radio Propagation

Laboratory made most of us at NBS feel significantly bereaved, we believe that we made a very important contribution to a most important new national agency.

Now I would like to come back for a few minutes to the mission and objectives of the Institute for Basic Standards, which as I said earlier is the organiation most directly concerned with the National Conference of Standards Laboratories. We have been evaluating our objectives over the past several years and trying to define more clearly the responsibilities of the National Bureau of Standards in order that we could carry out more effectively the job that the Congress has assigned us. This has led us to formalize the concept of a National Measurement System, about which you will hear more later from Dr. Huntoon. Essentially, it lets us put in perspective the total national activities involved with measurement and the critical responsibilities of NBS. It is our concern that there be an effective operating system for compatible, interchangeable, reliable measurements to meet the needs of scientists and engineers throughout our industrial set-up and in our universities. The core of the system is of course the International System of Units and the standards based upon these units. By taking the systems approach to our responsibility here, we think we can simplify greatly the things that really have to be done by the National Bureau of Standards. Our main concern is that this system operate smoothly and effectively, and that all essential activities are provided to bring this about in this country. To this extent we seek to set up standards for the basic units, improve their accuracy, extend them to multiples and submultiples, and make sure that there are adequate services for the dissemination of these values.

As many of you know, we have been seeking to improve measurement competence throughout the country, and have been relinquishing tasks when it appeared that it was no longer necessary for the National Bureau of Standards to do them. This general approach has been interpreted in some quarters as indicating that there are certain types of jobs we don't want to do, and that we take a sort of high-brow approach to the more routine calibration services. Actually, as a Federal agency we should *not* do what can be done adequately by the private economy. To the extent that the private economy has no means of meeting need, and if this need deals with something to make our measurement system operate, then we think it is the job of the National Bureau of Standards to make sure that this task gets done. As a result, we have pushed off some calibration services, and taken on others, and we may have gone a little far in the former direction to the impairment of our own efficiency. We have come to the realization that if we have a calibration set-up in operation, but used only once a year, that this is uneconomic. So even though in general we seek to do only those things that cannot be done adequately elsewhere, it is necessary for our efficient operation to make full utilization of calibration set-ups when we must have them in existence. We think by doing this we can lower the cost of performing these services—lower the cost significantly—and thus provide a much more effective service to the industry dependent upon measurement services.

Many people are concerned about the balance we have in our program between research and service. We are an organization that must do both and do them in reasonable balance. The measurement activities of IBS must in their general competence be unexcelled, because if they are excelled then the standards become ineffectual. We must have research activities in all the major frontier areas of science and engineering where precision is important. To have this competence, to be alert to needs for extensions in range and improvements in accuracy, we feel that a very broad and comprehensive research program is necessary and this we seek to carry on. In addition, we must make sure that all of the services which are essential to the smooth working of our measurement system are adequately provided for. So we strive to find a reasonable balance between research and service activities, and essentially the only way we can determine whether the balance is proper is whether or not there are deficiencies in the service program, or whether or not we are missing important bets in extending the science of measurement into new areas. We hope that within our resources we can keep these two programs in reasonable and effective balance. However, both are critically important and we cannot adequately do either without the other.

Finally, I would like to say that I think you have a very interesting program planned for the next few days and I think you would do much better to get ahead with that program than to listen longer to me. So let me say again that I'm very happy to have this opportunity of welcoming you here and I wish you every success in the rest of your meeting.

NCSL 66

WHY DON'T *THEY* DO SOMETHING? LUNCHEON ADDRESS

W. G. Amey
Leeds & Northrup Co.
North Wales, Pa.

There have been a lot of questions about the subject of my talk, but the emphasis *is* in the right place—that is why the *THEY* is *capitalized.* The topic was chosen because I felt that it represented somewhat the situation in which the adherents of this group found themselves at the Boulder Conference six years ago. Many of those here today, along with Bill Amey, were aware of things that needed doing. The standards laboratories of the nation needed collation and coordination of terminology, definitions, procedures, and preferred practices. There were problems of finding, selecting, developing and training people, and of using them effectively. There were problems of improving the available measurement techniques, and of devising techniques to fill "gaps" in our hierarchy of measurements. It was argued that top management didn't seem to recognize either the potential value of proposed standards laboratories, or the benefits of continuing and possibly increasing the support of existing ones. Existing technical societies were said to be uninterested in our plight.

No, most of us recognized that the situation just couldn't possibly be of OUR own making. It was simply that THEY (those fellows out there) the composite of business managements, NBS, technical societies, etc.—hadn't recognized THEIR responsibilities. They had abandoned us to the waves of problems that threatened to engulf us. It was true that the Precision Mesasurments Association had launched a program touching on some of the problem areas, but that lifeboat didn't appear capable of saving all of us at once—particularly from some types of problem waves.

And then, in that Summer of 1960, the calm voice of Harvey Lance was heard above the roar of the surf. He helped us realize that our problems were after all not one big irresistible wave, but really only separate smaller ones which could be identified, and through which the shore could be reached if only WE would decide to coordinate OUR efforts and assist each other.

See what WE have achieved! I include myself in the WE in an editorial fashion—but it is you fellows who have done it. The presence of this audience today, the nature of the program for the meetings this week, the Newsletters from Charley White, speak more eloquently than can I on the accomplishments since 1960. However, a few remarks on my part may help to provide the "mood music" for meeting the future challenges and responsibilities that I'll try to cite later.

As a consequence of Harvey Lance's speech in the Summer of 1960, further discussion ensued at the ISA meeting in New York that Fall, and an Ad Hox Committee was appointed to ponder the matter. Ponder it did. So much so that the initial reaction to its report at the ISA 1961 meeting in Los Angeles was that there was more evidence of ponderousness than of pondering. But that committee went on to plan for the advent of NCSL as manifested by the first Standards Laboratories Conference at Boulder in 1962.

That Ad Hoc Committee and its successor, the General Committee of NCSL, and all of the Officers and the chairmen who have served that group, have had important decisions to make. Was a new organization really needed? What should be its mission and its objectives? Who should be members? Individuals or the laboratories they represented? Should there be dues or fees? What functions could clearly be recognized as being uniquely the responsibility of NCSL? Which functions are best performed by existing outside organizations? How to establish contact with the outsiders? How to persuade, cajole or otherwise "con" them into cooperation? And this above all—how to enlist the aid of individuals and the support of their corporate managements in meeting the tasks that NCSL set for itself?

These men who have been working on your behalf on this committee are modest and objective. If you were to press them, especially after the end of a hard day, they probably would tell you that they wish they had worked smarter rather than harder. They will probably also share with you their fears that some of their decisions might better have been the other way. But I am going to take the liberty today—since I have been somewhat detached from the activities of this group for more than a year—to tell you that you should miss no opportunity to thank those men individually and collectively for what they have achieved on your behalf.

It takes hard work, and the Conference we are now attending is a perfect example. Plans were formulated many months ago and there has been much work on the part of many individuals—evidencing itself in the program that you have. It is a good example of how much lathering it takes to make a good shave.

But OUR tasks are not complete. That's another way of saying: enough of sweetness and light in this talk. If I continue in that vein, those of you who know me best will think I have lost the fire of my youth. Not so. I'm still a pesky gadfly. Besides, the post-luncheon lethargy must be broken. Your blood must be stirred—even if I tempt you to shed mine. So here it comes!

The trouble is—I guess some of you have heard this before—most of us are in favor of reform, but what burns us up is being reformed by somebody no better that we. I'm not going to try to reform anyone here. I am just going to try to encourage you to look in a number of directions for things yet to be done; and, at the same time to ask each of you and the members of the General Committee (or Board of Directors, as you now call them) not to bite off more than you can chew. The same kinds of agonizing decisions that were made four or more years ago have to be made this year—and next year—and the year after that—if NCSL is to be a vital and thriving and important factor in the operations of standards laboratories throughout this country.

NCSL is now of age. It seems to be growing steadily larger, and its professional responsibilities are growing with it. But, as it grows, there will be a temptation to take on more and more projects. The question you must face is this: As the membership grows, is it growing with men who wish to contribute to the work, or is it growing with additional members who want to receive something? I say this quite seriously with no reflection on anyone. It is an important problem that you face.

I was almost inclined to apologize for the use of that word "work." It has only four letters, and it is used in hard-core management-type communications, but no other word will suffice. Work on the part of your dedicated associates brought NCSL to its present state of vital importance in the operations of standards labs. It took work to get underway, it still takes work to maintain the motion against all of the drag effects, and it is going to take even more work to effect any acceleration. Self-motivated work is the characteristic of every professional, and it is the only medium through which directories, recommended practices, standards, definitions, etc. come into being.

I am taking the liberty here—since they gave me the rostrum today—to ask everyone in the audience who is not now active in some facet of NCSL work, "Please contact our Chairman and indicate what you think you can do to assist." Otherwise, we will find ourselves in the situation of just getting things started, with nothing more happening.

Some time back, NCSL initiated activities leading to the formation of the American Standards Association Sectional Committee C–100 about which you'll hear more this week. The purpose of that Sectional Committee is to provide meaningful ways of specifying the performance of electrical laboratory instruments. It will be a help to both supplier and potential buyer if we can all reach a common understanding. NCSL has committees following the progress of this work, but I don't know how many NCSL members are really active in helping—either by direct participation on ASA C–100, or through the NCSL committees. If you are interested, I feel from what I've heard that your services can be used. If the number of people working on this task is indeed large, then Committee C–100 needs a new set of press agents. For the job at hand—the tremendous task of trying to deal with the provision of these specifications—I feel I've seen relatively few names on the roster of task forces. So once again, if you feel you can do anything, please volunteer your services.

There has been much discussion at past NCSL meetings—and at workshops—concerning the problems of locating and/or training laboratory personnel. There is a session this week in your program. I'll have to ask you, and I hope that this session will ponder such questions—Did we *ever* need many people who are broadly trained in the profession of metrology, or have we mostly needed technicians? The answer would appear to be—if the experience of the George Washington University Center for Measurement Science can be used as a criterion—that we really didn't need very many broadly trained professional personnel. The amount of support that the Center has received—from the broad range of organizations represented by adherents here in this meeting—is rather small. So one of the problems—one of the things that has to be decided is—do we have a problem? If so, can this group provide guidance for the universities and the training centers to help them move their programs in a direction to fill the needs which you recognize and identify?

And I might even sneak in one more little plug. As an organization like this grows a bit more successful, it gets bigger, it holds meetings. Somehow or other these meetings are rarely held at a loss, and the treasury of such nonprofit organizations seems to grow. I'll just leave with your Board of Directors the question of whether they might not return some of that money to the people who produced it by providing a scholarship or fellowship sponsored by NCSL. That is one way of putting it to work, and if that graduate work could be directed toward some broad and basic problem of concern to all of NCSL you would be killing two stones with one bird.

Now we all pride ourselves on the quality of the measurements that we think we know how to make. In fact, however, if we are honest, we really know absolutely a lot of things that aren't true at all. Each of us would like our management to appreciate the value of our operations in our respective organizations, but do any of us really know what a given kind of measurement is worth? Not what it costs to make, but what is it worth to the organization for which we are making it.

To date we have been very ready to talk about management problems where higher levels of management always seem to be the problem. But is it THEIR responsibility to understand what we would like them to know? I submit that one of the differences between managers and the people who do the work, is that the people who do the work know *how*, and the manager—if he is any good—knows *why*.

WE as an organization, if we are going to talk about management problems associated with standards laboratories, must face OUR responsibility to find better means of evaluating not only the technological competence of our measurements, but also the value of them.

Jerry Hayes had a Navy film here today called "Why Calibrate?" In the case of the defense applications of metrology, all of us feel intuitively that we understand. When we see it so clearly as was presented in the film, there is no question in our minds. However, most of the funds supporting the Bureau of Standards, other than those that are allocated from DOD, come via the Department of Commerce's budget. What's it worth to the economy of this country to be able to make a given kind of measurement with a given limit of error? If the measurements are worth while, if we as individuals can provide a composite set of data that will help the Department of Commerce and our Congress to recognize the need and the justification for better measurements in support of our economy, then I feel that budgetary problems will take care of themselves. But I find it very hard to be critical of anybody who says—"I'm not going to give you the money until you tell me what it is worth". I ask the same thing of my son; my boss asks me.

Accordingly, I would like to encourage NCSL to consider setting up some kind of a committee structure that would ponder this question: How do we evaluate the value of the measurements that we already know how to make? This is important because Charlie Johnson has a session later this week in which he is going to report some of the measurement needs that have been cited to him. These are needs that will be called to the attention of the Bureau of Standards as *gaps* that desirably should be filled. Some of them are readily justified by the defense effort. Justification of others may not be so obvious and will require our best management judgment. Let's try to produce the evidence.

Of course there is one thing we'll have to face. You know what happens to the turtle when he sticks out his neck—sometimes he makes progress and sometimes he gets it lopped off. If we are going to be professional in our attitude, we have to be prepared to be honest in facing the possibility that some of the measurements we are making really aren't worth making.

And now, one more matter. I don't believe that NCSL can totally duck the question of ethics in the making and reporting of measurements, in the advertising of instrument performance, etc. These are questions that have been raised by other people, but I think they are justified questions in many instances.

How do we provide an answer? We can't, easily. Part of it is related to the work that C–100 is doing. We can't really consider ethics until we first consider the question of having standards against which to make judgments. To illustrate my point, if George Vincent will give me permission. I will steal from him a story that he says originated with Marion Eppley. I enjoyed it, and I hope you will.

It seems there were two partners who ran a small retail business. One afternoon the son of one of the partners came in from high school and said, "Dad, the teacher told us he is going to talk tomorrow about ethics. What are ethics?" The father thought for a moment and replied, "Well, let's see if I can think of an example. Oh, yes, a man comes into the store and buys a carton of cigarettes. I give him the cigarettes, he gives me $5.00, and I give him change. He takes the cigarettes and the change, and starts to walk out. Just as he is about to leave, I notice that the $5.00 bill seems a bit thicker than usual, and as I examine it more carefully, I notice that it is two $5.00 bills stuck together. Here son, arises the question of ethics. *Should I—or should I not—tell my partner?*"

All that I am trying to say here, gentlemen, is that your Board of Directors should not overlook the question of ethical considerations. They also should recognize, however, that inadvertent damage to people, organizations, and reputations can be avoided only by working towards standards of nomenclature, standards of practice, standards of common understanding among all.

NCSL 66

THE MANAGEMENT OF STANDARDS AND CALIBRATION LABORATORIES

BANQUET ADDRESS

E. G. Hill

General Dynamics Corp., San Diego, Calif.

I am honored to be with you tonight, particularly since this is the occasion of a meeting of the National Conference of Standards Laboratories at the new facilities of the National Bureau of Standards. I had the pleasure of seeing those facilities today, and they are indeed impressive. Learning something about this business of measurement is one of the rewards of being here. I have learned, for example, that metrologists can measure to 1/10 of a microgram, and I'm told that this is approximately 1/10 of one-millionth of 1/32 of an ounce. In the face of an achievement like that, I have no business to talk about measurement, so I've discarded that notion and decided to talk about management: the management of measurement and standards laboratories. Section II–A of your Bylaws says: "The National Conference of Standards Laboratories is an organization to promote cooperative action on common problems of management and operation of measurement standards and calibration laboratories".

I note that your agenda for this meeting is strongly oriented to management activities. As managers, your primary interest is not measurement per se. Your primary interest is assisting in delivery of satisfactorily high quality products out the door at the least possible cost, so that in combination with all other activities necessary to success, our companies' reputations and profitability are maximized. I think we in this room can agree that measurement to the appropriate degree is necessary, and I know from personal association that a professional engineer with good business acumen can make this possible.

I'd like to approach the subject on the basis of a checklist of the points which make for successful management of the measurement function, other than technical competence. These points are equally applicable to commercial, government contracting, or government operations. Further, they apply to any size or type of business. This is not a complete list, and I'm sure you could add to it. After I've given you my checklist, I'll talk a bit about return on investment, then pose an additional challenge to you, and we'll call it a night.

These are the points I consider to be a major responsibility of the management of a standards and calibration laboratory:

1. Organization

Definition: The responsibility of the standards and calibration laboratory is to provide inspection, test, and measuring equipment in compliance with company and customer specifications to all departments, as required to support current and future contracts.

The total responsibility for the management of this function of the business should be assigned to one group in your plant. If it is splintered, consolidation is the first step to full effectiveness, in my personal opinion.

The concept must be one of service with responsibility—and allow me to emphasize—with particular attention to cost. You have found from experience that this gets tricky, because most technical folks like to have everything they need or may need at their fingertips. *It is the job—the responsibility—of the standards and calibration laboratory to insure that necessary functions are provided at the least possible cost.* We have not yet found a completely satisfactory solution to this problem, have we? There are still some operators who believe that the equipment is theirs, not the company's, and others who don't appreciate the economic facts.

2. Physical Control of Test Equipment

Record keeping is the tool that makes this possible. The laboratory should have a good deal of information at its fingertips. Basic are these things: what kinds of measuring equipment do we have; how many of each kind; where is it located; how is it being used; to what degree is it being used?

These two points deal with physical control; many of the remaining points bear on the total subject of control.

3. Set Calibration Cycles

Set calibration cycles for each piece of test equipment. It should be the longest possible time taking into account all of the risks. Only experimentation and acquisition of facts will get the job done. Take into account the degree of use and environment. Set a median for each model, and deviate as appropriate.

4. Recall Procedure

After setting calibration cycles, establish a procedure for pulling the equipment in for maintenance and recalibration. Study carefully to maximize load levelling for greatest efficiency and best turn-around time.

Maintain careful records of what was required to get information on possible misuse and to acquire data on cost of maintaining. This latter will be of significant assistance in determining who the best manufacturers are. By the way, this is the efficient way to get physical inventory data, which is a subsidiary benefit.

5. Recognize Cost

As stated previously, your job is to get the measuring function performed at the least possible cost to your company. It may be cheaper for you to buy the service than to possess your own capability. If it is, go that way. Never ignore this possibility. You might find a real bargain down the street.

Acquisition cost is only the beginning. Take into account the maintenance cost in your decision-making.

The laboratory must have the responsibility for decision as to whose equipment to buy, as representing the only folks in the business with total analysis capability. As new needs arise, it is important to have qualified personnel search for equipment now on hand that will do the job. You must certainly recognize that this function is a major element of the cost of doing business today.

6. Maintain Only to the Use Required

If a given piece of equipment is being used short of its full capabilities, then maintain it accordingly. An example is a rack of 10 instruments, one of which is a meter with 6 ranges. Suppose this special test equipment set-up uses only one range. Calibrate that range only. Place a decal on the mounting rack so that if the meter is removed, it cannot accidentally be used by someone thinking it is in full calibration.

Decal all equipment which is being used in a limited way. For example, a meter being used only to determine if the power is on need not be accurate as to voltage. We decal these "INFD" (Indicator-Not for Data).

7. Surplus Any Equipment Not Required

If this is a temporary situation, one technique is to establish an inactive storeroom and subsequently calibrate such an item when the need develops, not before. As we discussed in our first point, on organization, this is a most difficult task. You gentlemen need to develop the tenacity of a bulldog on this one. Make it a cardinal rule that an operating department holds only the equipment necessary to perform current tasks.

If it is a permanent situation, dispose of surplus equipment immediately, so that your company can put those dollars to productive use.

8. Recognize the Cost of a Bad Measurement

A. J. Woodington (General Dynamics-Convair Division), has provided me with an illustration of this point, showing that your responsibility is significant indeed. Recently a composite test of a space booster had to be re-run due to the failure of an optical recorder. This resulted in an additional 300 man-hours work in the shop, as compared to the 5 hours required by the laboratory to return the test equipment involved to operating specifications.

9. Measure Performance

Measure performance of both the equipment and the personnel performing the calibration task. Maintain very careful histories on your equipment as a guide for future acquisition decisions. Buy the equipment that is going to do the best job for you.

Constantly appraise the performance of your technicians. You should be able at all times to ascertain their individual performance. I want to emphasize that point: Know the skill and efficiency of your people.

10. Written Procedures

You should have written procedures. Donald De Lauer (IG & C Group, Vandenberg AFB), in his talk this morning made the important point that procedures should provide for doing only what is necessary at calibration.

Procedures should be written in such a way that engineering judgment does not need to be applied anew each time the equipment is presented for re-calibration.

Procedures provide the basis for getting accurate performance information on technicians doing the calibration. They will improve the quality of your maintenance data.

That completes the checklist. Let's turn now to considerations of return on investment, for a few points.

Return on investment is a fundamental and important measure of the use of capital. It is the job of management to maximize return on investment to the share owners. A parallel in a government situation is to provide necessary function at the least possible cost.

Keeping it simple, if you deposit $1,000 in a savings bank and the bank pays you 4 percent interest, your return on investment for a one-year period is 4 percent, or $40.00. In a business situation, capital requirements are provided for from the depreciation provision and from earnings. Testing equipment needs must be appraised along with other capital equipment needs of the business, and must meet the test of offering satisfactory return. The facts count.

The measure to be applied then, when considering a new acquisition, is a comparison of before-and-after cost, equating the cost benefits to the cost of investment. Consider the purchase of service possibilities. This test must be a significant part of the decision-making process. The wisdom of your actions is going to be reflected on the profit and loss statement. Remember the basic point—as managers you're interested in improving your company's performance. Look at all the alternatives.

The last thing I want to cover with you is a challenge for the future. The formation of this organization is a step in the right direction, as are meetings of the type you are having here this week.

It occurs to me that there is a need to work out sharing arrangements at the local level, not only among plants within the same company, but among several different companies. I believe that several companies exploring this idea might gain very real competitive advantages in the market place.

One angle to consider is for each of several companies to specialize in one field of measurement, and then exchange services with the others.

Devise a means of getting data on the costs of calibration to your operating organization. This may be the real answer to insuring that only needed equipment will be found in the operating areas.

To summarize, gentlemen, we've talked over some points which I think bear in an important way on proper management of the standards and calibration function. I hope you have found this useful. We've examined in a fundamental way the matter of return on investment. Now, managers—go manage!

256-114 O-67—2

SESSION 1: MEASUREMENT COMPARISON

Status Report of the NCSL 1965–66 Measurement Comparison

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1. Introduction

The purpose of this presentation is to bring to you a status report of the present NCSL Measurement Agreement Comparison. This comparison actually originated in the response to the presentation of the first experimental comparison at the Standards Laboratories and Measurement Standards Symposium during the ISA Conference in October 1964 [Richardson, 1965]. That response left no doubt as to the general widespread interest in such measurement comparisons. The Measurement Agreement Comparison (M.A.C.) Committee decided that every NCSL member should be invited to participate in a full scale comparison and that several comparison routes would be established.

2. The Survey Questionnaire

The M.A.C. Committee prepared a membership survey questionnaire to more specifically determine the comparison interests of the NCSL members. The questionnaire was sent out to all member delegates in late February 1965. It so happened that an additional list of new members was received on March 19 and so the same questionnaire with a postscripted cover letter was sent to them a few days later. To the best of our knowledge every NCSL member as of that March 1965 date was invited to participate.

The questionnaire surveyed five specific areas of interest to the Committee. The first was the number of participants and specifically who they were and their mailing address. The second was on the comparison areas of interest; this was divided into three measurement areas on the questionnaire: d.c.—low frequency electrical, high frequency electrical and a physical package including mass, dimension and angle. The third survey item was the participant preference regarding the above areas and also his interest in multi-route participation. The fourth item surveyed was the participant's specific interest and suggestions for "comparison package" contents. The fifth surveyed item was the solicitation of package items for loan to the comparison for its duration, and the availability of such items in pairs.

3. The Survey Results

The results of the survey provided the information the Committee needed to proceed. Forty-nine members desired to participate. The participating members are listed in alphabetical order below. Their geographic location by State is also given, to indicate the nationwide scope of the comparison. The participating laboratories are located in 21 different States and the District of Columbia.

NCSL COMPARISON PARTICIPANTS

PARTICIPANT	*STATE*
Aerojet-General Corporation	California
Wm. Ainsworth & Sons Inc.	Colorado
Airesearch Mfg. Co. of Arizona	Arizona
Autonetics—Div. of NA Aviation	California
AVCO Corporation	Massachusetts
Battelle Memorial Institute	Ohio
Bendix Corp.—Scintilla Div.	New York
Bendix Corporation	Missouri
The Boeing Company	Washington
Collins Radio Company	Iowa
Douglas Aircraft Company	California
Edgerton, Germeshausen & Grier	Nevada
Electrical Testing Labs.	New York
Electro Instruments Inc.	California
G.E. Re-entry Systems Dept.	Pennsylvania
G.E. Ordnance Department	Massachusetts
G.E. Electronics Laboratory	New York
G.E. Research & Development Center	New York
General Radio Company	Massachusetts
W & LE Gurley	New York
Holt Instrument Labs.	Wisconsin
Honeywell, Inc.	Pennsylvania
Honeywell, Inc. Aeronautics	Minnesota
IBM Corporation, Dept. 311	California

PARTICIPANT	STATE
Julie Research Labs. Inc.	New York
Keithley Instruments	Ohio
Leeds & Northrup Company	Pennsylvania
Lockheed-California Company	California
Lockheed Electronics Company	New Jersey
Lockheed-Georgia Company	Georgia
Lockheed Missiles & Space Company	California
Lear Siegler, Inc.	Michigan
Martin Co.—Aerospace Division	Florida
Melpar, Inc.	Virginia
Metrolonics Associates	California
RCA–PMEL/E	Florida
Radio Corporation of America	New Jersey
Sperry Gyroscope Company	New York
SSCO Standards Lab. Inc.	Michigan
TRW/STL	California
Turner, Edward H. P. E.	New York
Union Carbide Corp. Nuclear Div.	Tennessee
U.S. Army Missile Support Command	Alabama
U.S. Navy Pacific Missile Range	California
U.S. Navy Eastern Stds. Lab.	D.C.
Veritek Corporation	California
Vitro Laboratories	Maryland
Weinschel Engineering Company	Maryland

The dc—low frequency comparison package was the preferred one and consequently two separate routes were established. They were divided into approximate eastern and western routes and designated as such. One route was established for the high frequency package and one also for the mass-dimension package. Every participant was included in the route of his first choice. Where multi-route choices were made, all second choices were also accommodated. This accommodation quite well balanced the routes and it was decided not to provide for third choices. Such additional scheduling would have made the routes prohibitively long. The routes and number of participants are shown in the following table.

ROUTE SUMMARY

ROUTE	CHOICE FIRST	CHOICE SECOND	TOTAL
L.F.—East	16	3	19
L.F.—West	14	4	18
High Frequency	7	9	16
Physical	11	9	20
			73

4. The Comparison Packages

The items in each of the comparison packages was largely determined by the suggestions made by the participants. Lists of suggested items were made for each of the types of comparison routes. The lists were quite extensive and preference was given to those specific items or measurement areas of greatest interest. The other main consideration was the stability of the prospective items. Other selection factors were size, weight, availability and availability in pairs. The list was culled and reculled with these factors in mind until a package of appropriate size (about three man-days of measuring effort) was obtained.

The items were accumulated primarily from the offers of the participants and the Institute for Basic Standards of the NBS. There were only a few items desired that were not offered on the questionnaire response. In each such case a manufacturer was solicited and in all three cases the requested items were readily loaned to NCSL. The contents of each of the comparison packages are shown in the following lists.

DC–LF COMPARISON PACKAGE

ITEM	QUANTITY	RATING
Resistor, Thomas type	1	1.0 ohm
Resistor, NBS type	2	10 kilohms
Resistor, NBS type	2	10 kilohms ±5%
Resistor, NBS type	2	1 megohm
Capacitor, 3 term-air type	2	1,000 picofarads
Std. cell, saturated	2	Transportable type
Voltbox	1	7.5 to 750 volts
Zener reference	1	1.0 & 1.01830 volts
Thermometer, platinum resistance	1	25 ohms at OC (500 C max)

HF COMPARISON PACKAGE

ITEM	QUANTITY	RATING
Attenuator, coax	2	10 dB
Attenuator, coax	2	50 dB
Attenuator, X-band	2	20 dB
Std. mismatch, WR62	1	12.4–18 GHz
Wavemeter, X-band	1	8.2–11.5 GHz
Wavemeter, WR90	1	50–75 GHz
Q-Standards	2	0.5–1.5MHz
Thermistor Mount, coax	1	10 MHz-10 GHz

PHYSICAL COMPARISON PACKAGE

ITEM	QUANTITY	RATING
Gage block, steel	2	0.650 inch
Gage block, steel	2	3.0 inches
Gage block, Croblox	2	2.0 inches
Angle block	1	30 degrees
Angle block	1	45 degrees
Ring gage	2	1.8502 in. I.D.

PHYSICAL COMPARISON PACKAGE—Continued

ITEM	*QUANTITY*	*RATING*
Weight	2	1 milligram
Weight	2	100 milligrams
Weight	2	1 gram
Weight	2	100 grams
Weight	2	200 grams
Weight	2	2 kilograms
SS weight	2	Approx. 97 grams
Optical pyrometer	1	1400–3200 F

Our previous experimental comparison had established the general type of container needed for the packages. We did, however, need several containers, and preferably of less bulk and weight than the plywood box used in the experimental comparison. Consequently, the expenditure of $500 was authorized and several thermoplastic shipping containers with polyester urethane foam permanent packing material were purchased from a commercial supplier. These have proved to be quite satisfactory and to date the damage to any components due to transportation has been superficial. Because of the time schedule established, two weeks per participant including transportation, all shipments other than local have been by air freight.

5. The Comparison Results

For the purpose of the orally presented status report, the comparison results were presented only in graphical form in terms of deviation from the reference. Measured tests values and coded identification were purposely omitted. All four routes have essentially been completed since then and all available measurement values have now been tabulated and plotted. No reference is made to the tables or graphs by number but each one is clearly titled and identified. The tabulated data shows the actual measured test values obtained by each of the participants, as identified by code number only, and also the NBS reference values for each of the comparison items.

Tabulated data is also given in terms of the deviation from the reference versus each of the coded participants for each of the comparison items, as an aid to the assimilation of these extensive data. In some instances the first NBS set of values is used as the deviation reference and in other cases the average NBS test value is used. All NBS values have been plotted in all cases to aid in reference-time identification and to present graphical information on test item stability.

Information is also given showing the relation between the participant's expected accuracy and the deviation from the reference value. In some cases this is presented on the individual test items. In other cases it is presented only for groups of items in a given measurement technology.

6. Acknowledgements

A measurement agreement comparison of this magnitude required the cooperative effort of every member of the M.A.C. committee and their help is specifically acknowledged. The route supervisors directed all the comparison effort once the accumulated comparison packages were delivered to them. They also prepared all the tabular data and graphical presentations. The eastern low frequency route was supervised by Robert P. Heckelmann of the Sperry Gyroscope Company, Great Neck, New York. The western low frequency route was supervised by Herbert S. Ingraham, Jr., of the Radio Corporation of America, Camden, New Jersey. The high frequency route was supervised by Herbert D. Barnhart of the General Electric Company, Syracuse, New York. The mass-dimension route was supervised by William B. McCallum of the General Electric Company, Pittsfield, Massachusetts originally, but who has since transferred to Daytona Beach, Florida.

All the committee members from the National Bureau of Standards activity participated and their help is specifically acknowledged; Forrest K. Harris for his consulting assistance in the design of the comparison packages, Joseph M. Cameron for his recommendations on the presentation of the comparison results, John S. Beers for his service as coordinator of the NBS Washington-Gaithersburg reference activity and as the coding and clearinghouse agent for test results, and to Wilbert F. Snyder for his service as the coordinator of the NBS Boulder reference activity and as the clearinghouse agent for related test results.

7. References

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NCSL 66
LOW FREQUENCY COMPARISON–EASTERN ROUTE

R. P. Heckelmann

Sperry Gyroscope Company, Great Neck, N.Y.

1965–66 MEASUREMENT AGREEMENT COMPARISON, DC–LOW FREQUENCY PACKAGE–EASTERN ROUTE

Participant	Thomas resistor		10 kiloohm Rosa resistors			10.5 and 9.6 kiloohm Rosa resistors			1 megohm Rosa resistors			Air dielectric capacitors		
	#1664132 RDG, ohms DEV.*	E.A.*	#1666858 RDG, ohms DEV.*	#1666856 RDG, ohms DEV.*	E.A.*	#1666862 RDG, ohms DEV.*	#1666866 RDG, ohms DEV.*	E.A.*	#1654408 RDG, ohms DEV.*	#1655436 RDG, ohms DEV.*	E.A.*	#138 RDG, pF DEV.*	#567 RDG, pF DEV.*	E.A.*
NBS #1 (Sep. 1965)	1.0000004 00	1	9999.82 0	9999.90 −2	7	10462.18 +6	9582.29 +2	10	1000031 +1	1000043 −2	15	999.973 0	999.998 0	20
NBS #2 (Jan. 1966)	1.0000001 −0.3	1	9999.82 0	9999.93 +1	7	10462.10 −2	9582.26 −1	10	1000031 +1	1000051 +6	15	999.974 +1	999.998 0	20
NBS #3 (Sep. 1966)	1.0000007 +0.3	1	9999.83 +1	9999.94 +2	7	10462.09 −3	9582.25 −2	10	1000029 −1	1000040 −5	15	999.972 −1	999.998 0	20
12K	1.0000002 −0.2	1	9999.81 −1	9999.88 −4	7	10463.81 +169	9581.70 −57	30	1000024 −6	1000033 −12	20	999.977 +4	999.999 +1	5
13B	1.000004 +3.6	5	9999.85 +3	9999.97 −5	7	10462.18 +6	9582.31 +4	7	1000040 +10	1000054 +9	15	....	....	....
16E	.9999998 −0.6	6	9999.80 −2	9999.91 −1	20	10462.05 −7	9582.16 −11	50	1000029 −1	1000040 −5	25	999.981 +8	1000.004 +6	50
17E	1.0000019 +1.5	5	9999.86 +4	9999.98 +6	10	10462.12 0	9582.29 +2	20	1000036 +6	1000052 +7	15	999.973 0	999.999 +1	20
19K	.99774 −2260	100	10000.08 +26	10000.02 +10	100	10462.18 +6	9582.25 −2	100	1000020 −10	1000020 −25	100	999.990 +17	999.990 −8	2000
20E	1.0000014 +1	5	9999.85 +3	9999.96 +4	10	10462.14 +2	9582.27 0	20	1000045 +15	1000056 +11	10	999.975 +2	1000.001 +3	20
28K	1.0000007 +0.3	1	9999.86 +4	9999.98 +6	10	10462.20 +8	9582.29 +2	20	1000032 +2	1000056 +11	20	1000.040 +67	1000.060 +62	200
31K	1.0000006 +0.2	2	10000.017 +19	10000.137 +21	10	10464.180 +205.7	9582.070 −19.7	10	1000032.3 +2.0	1000054.0 +9.4	20	999.979 +6	1000.002 +4	2
35B	1.000000 −0.4	3	9999.83 +1	9999.94 +2	9	10462.17 +5	9582.28 +1	10	1000026 −4	1000045 0	17	999.977 +4	1000.000 +2	25
40B	1.0000004 +0	2	9999.85 +3	9999.95 +3	20	10462.20 +8	9582.30 +3	20	1000010 −20	1000074 +29	50	999.990 +17	1000.014 +16	25
44B	1.000001 +0.6	3	9999.76 −6	9999.87 −5	9	10462.1 −2	9582.20 −7	9	999855 −175	999846 −199	15	999.977 +4	999.999 +1	24
46B	....	....	9999.835 +1	9999.973 +5	10	10462.096 −2.7	9582.286 +1.9	20	1000027.1 −3.2	1000037.2 −7.4	50	....	....	....
47B	1.00001 +9.6	20	9999.75 −7	9999.9 −2	10	10462.1 −2	9582.20 −7	10	1000001 −29	1000018 −27	10	999.9795 +6.5	1000.0015 +3.5	20
50B	.999987 −13.4	3	9999.81 −1	9999.91 −1	10	10461.95 −17	9582.04 −23	30	1000131.8 +101.5	1000158.8 +114.1	50	999.976 +3	1000.001 +3	20
51E	.9999993 −1.1	3	9999.817 −0.6	9999.932 +0.9	5	10462.231 +10.8	9583.524 +125.7	15	1000027.1 −3.2	1000048.8 +4.2	5	999.980 +7	1000.000 +2	10
53B	1.000004 +3.6	20	9999.81 −1	9999.95 +3	20	10462.14 +2	9582.27 0	30	1000013 −17	1000015 −30	50	999.9760 +3	999.9994 +1.4	70
54B	1.000004 +3.6	10	9999.85 +3	9999.94 +2	10	10462.15 +3	9582.28 +1	25	1000044 +14	1000057 +13	30	9999.979 +6	1000.0034 +5.4	40
58E	1.000023 +22.6	20	10000.01 +19	10000.15 +23	20	10462.34 +22	9582.48 +21	20	1000020 −10	1000020 −25	200	999.978 +5	999.998 0	30
59C	.999999 −1.4	10	9999.82 0	9999.94 +2	10	10462.23 +11	9582.35 +8	10	1000040 +10	1000054 +9	10	999.973 0	999.999 +1	5

*DEV. = Deviation from median of all NBS and participants' readings, ppm.
E.A. = Participant's Estimate of Accuracy, ± ppm.

Table 1, Heckelmann 1–12–67

Participant	Saturated standard cells			No. 3489 Zener reference				Volt Box No. 1679746							
	#24209 RDG, volts DEV.*	#24210 RDG, volts DEV.*	E.A.*	1.0000 V RDG, volts DEV.*	E.A.*	1.0183 V RDG, volts DEV.*	E.A.*	50X 1.00000 RDG, ratios DEV.*	E.A.*	200X 1.00000 RDG, ratios DEV.*	E.A.*	1000X 1.00000 RDG, ratios DEV.*	E.A.*	5000X 1.00000 RDG, ratios DEV.*	E.A.*
NBS #1 (Sep. 1965)	1.0182522 +1.6	1.0182510 +2.1	1	.999983 +3	5	1.0182950 +3.3	5	.999920 +10	20	.999930 +10	20	.999960 +10	20	.999970 0	20
NBS #2 (Jan. 1966)	1.0182505 −0.1	1.0182489 0	1	.999984 +4	5	1.0182945 +2.8	5	.999910 0	20	.999920 0	20	.999950 0	20	.999970 0	20
NBS #3 (Sep. 1966)	1.0182492 −1.4	1.0182468 −2.1	1	.999973 −7	5	1.0182856 −6.1	5	.999900 −10	20	.999910 −10	20	.999950 0	20	.999950 −20	20
12K	1.0182516 +1.0	1.0182517 +2.8	2	.999980 0	20	1.018290 −2	20	.999940 +30	30	.999980 +60	30	.999960 +10	30	1.000000 +30	30
13B	1.0182470 −3.6	1.0182465 −2.4	7	.999985 +5	2	1.018298 +6	2	.999928 +18	2	.999935 +15	2	1.000006 +56	2	1.000015 +45	2
16E	1.0182500 −0.6	1.0182480 −0.9	2	.9999836 +3.6	8	1.0182936 +1.9	5	.999908 −2	30	.999903 −17	30	.999898 −52	30	.999944 −26	30
17E	1.0182522 +1.6	1.0182515 +2.6	5	.999984 +4	5	1.018293 +1	5	.999870 −40	20	.999890 −30	20	.999920 −30	20	.999943 −27	20
19K	1.018286 +35	1.018285 +36	50	1.0000015 +22	50	1.0182919 +0.2	50	.980016 −19894	100	.99567 −3530	100	1.003811 +3861	100	1.033390 +33420	100
20E	1.018247 −3	1.018244 −5	2	1.000025 +45	15	1.018289 −3	5	.999926 +16	40	.999930 +10	40	.999921 −29	40	.999992 +22	40
28K	1.0182493 −1.3	1.0182467 −2.2	2	.999983 +3	3	1.018293 +1	3	.999890 −20	100	.999890 −30	100	.999890 −60	100	.999940 −30	100
31K	1.0182487 −1.9	1.0182468 −2.1	5	1.0000002 +20	20	1.0183143 +22	10	1.000084 +174	20	1.000065 +145	20	1.000090 +140	50	1.000062 +92	60
35B	1.0182478 −2.8	1.0182458 −3.1	....	.999994 +14	50	1.018304 +12	50	.999820 −90	50	.999880 −40	50	.999920 −30	50	.999970 0	50
40B	1.018247 −3	1.018245 −4	5	.999981 +1	10	1.018293	10	.999888 −22	20	.999905 −15	20	.999953 +3	20	.9999932 +23	20
44B	1.0182383 −12.3	1.0192494 +1000	2	.999977 −3	3	1.018291 −0.7	3	1.000042 +132	8.4	1.000040 +120	10.4	1.000030 +80	12.6	1.000042 +72	14.8
46B	....	....	....	.9999781 −2	5	1.018291 0	5	....	....	.999880 −40	60	.999915 −35	60	.999972 +2	60
47B	1.0182489 −1.7	1.0182492 +0.3	1	1.000010 +30	10	1.018320 +28	10	.999928 +18	100	.999935 +15	100	.999950 0	100	1.000040 +70	100
50B	1.0182485 −2.1	1.0182464 −2.5	10	.9999767 −3	10	1.0182896 −2	10	.999894 −16	50	.999870 −50	50	.999810 −140	50	.999880 −90	50
51E	1.0182495 −1.1	1.0182480 −0.9	2	1.0000183 +38	5	1.0183245 −33	5	1.000071 +161	30	1.0000924 +172	30	1.000063 +113	30	.999986 +16	30
53B	....	....	....	1.000028 +48	70	1.018337 +46	50	.999906 −4	50	.999925 +5	50	.999943 −7	50	.999940 −30	50
54B	1.0182467 −3.9	1.0182449 −4	10	.999984 +4	50	1.018290 −2	50	.999914 +4	100	.999940 +20	100	.999950 0	100	1.000004 +34	100
58E	1.018285 −34	1.018284 −36	30	1.000001 +21	50	1.018310 +19	50	.999934 +24	100	.999835 −85	100	.999910 −40	100	.999956 −14	100
59C	1.018262 +11	1.018262 +13	7	1.000011 +31	7	1.018313 +21	15	.999580 −330	10	.999800 −120	25	.998601 −1349	100	.999970 0	560

Table 2, Heckelmann 1–12–67

*DEV. = Deviation from median of all NBS and participants' readings, ppm.
E.A. = Participant's Estimate of Accuracy, ±ppm.

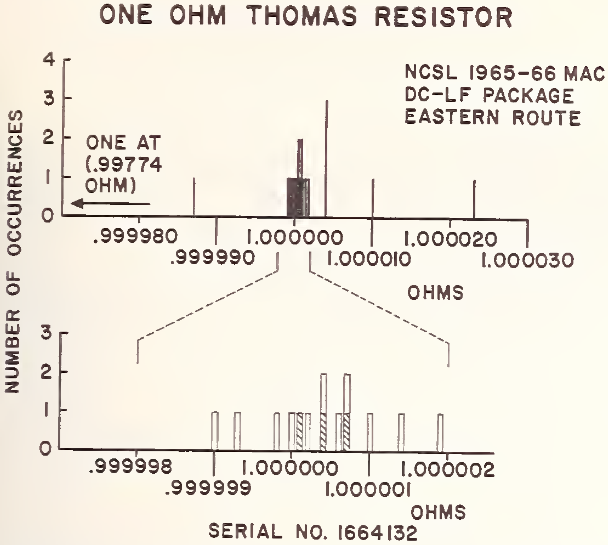

Figure 1. *Heckelmann. Deviations from average NBS value, computed by route supervisor for 1-ohm Thomas resistor.*

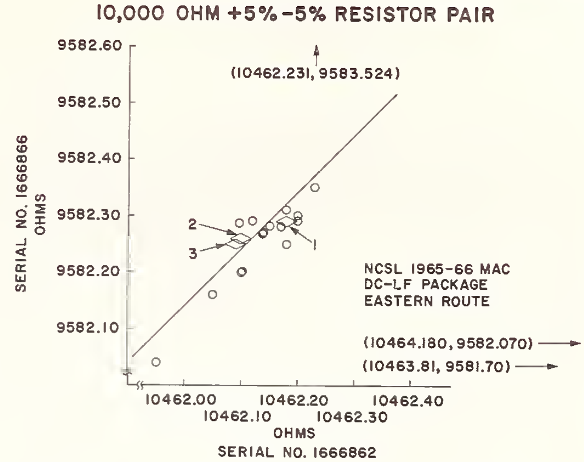

Figure 3. *Heckelmann. Youden diagram for nominal 10,000-ohm resistor pair, referenced to average NBS value.*

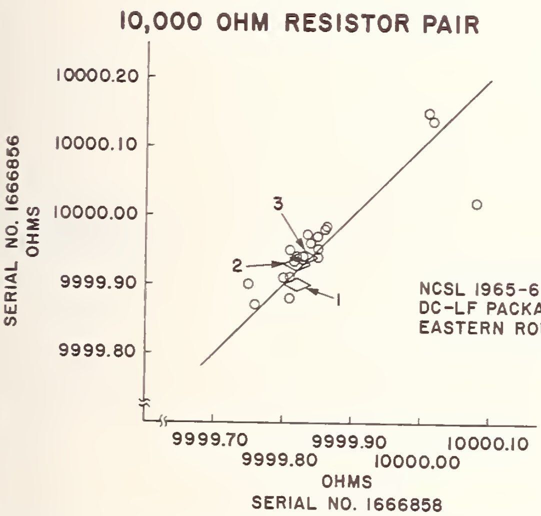

Figure 2. *Heckelmann. Youden diagram for 10,000-ohm resistor pair, referenced to average NBS value.*

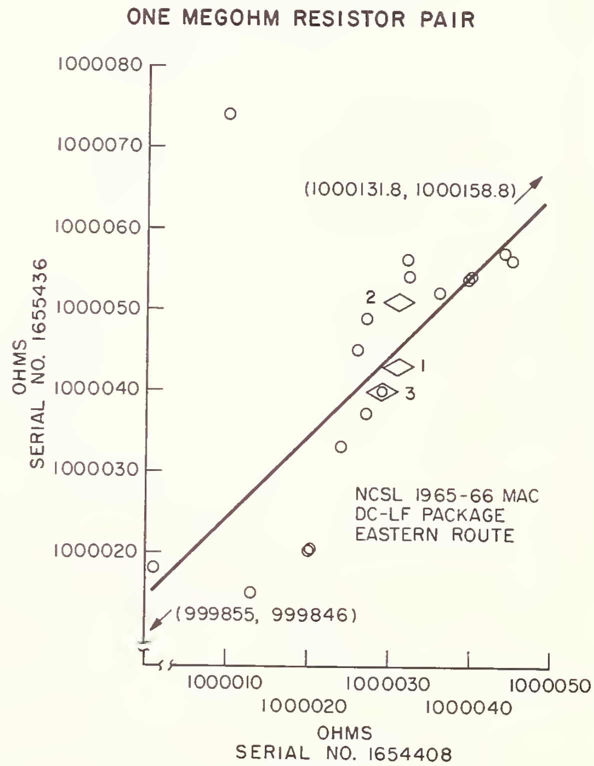

Figure 4. *Heckelmann. Youden diagram for 1-megohm resistor pair, referenced to average NBS value.*

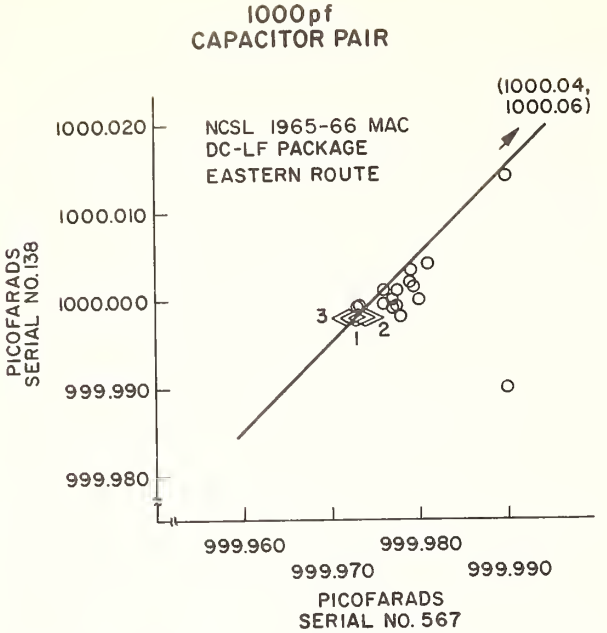

FIGURE 5. *Heckelmann. Youden diagram for 1000 pF capacitor pair, referenced to average NBS value.*

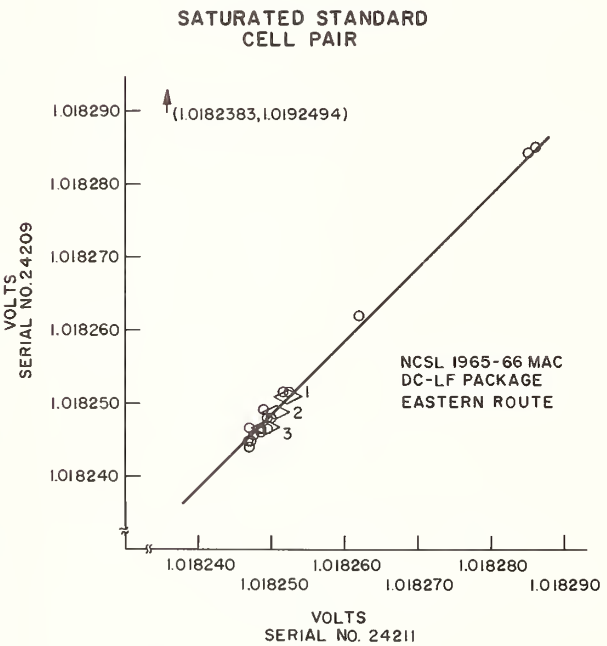

FIGURE 6. *Heckelmann. Youden diagram for a pair of saturated standard cells, referenced to average NBS value.*

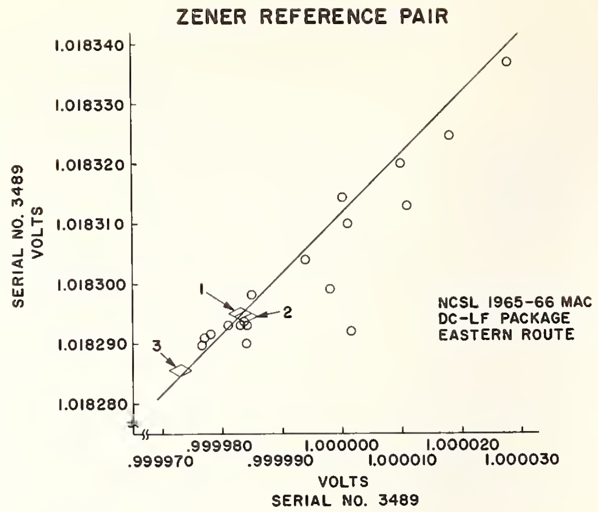

FIGURE 7. *Heckelmann. Youden diagram for a pair of Zener voltages, referenced to average NBS value.*

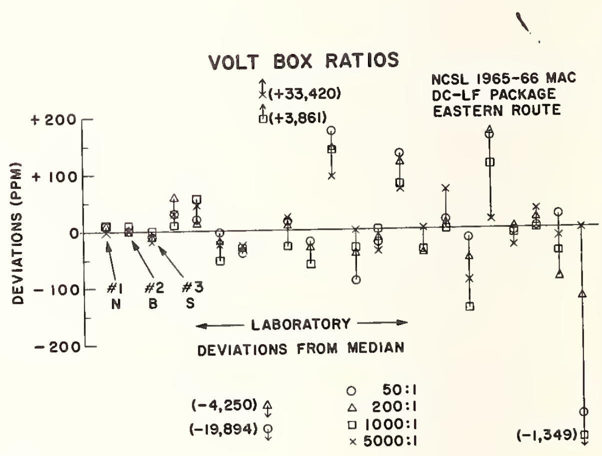

FIGURE 8. *Heckelmann. Deviations from average NBS value, computed by route supervisor for 4 volt-box ratios.*

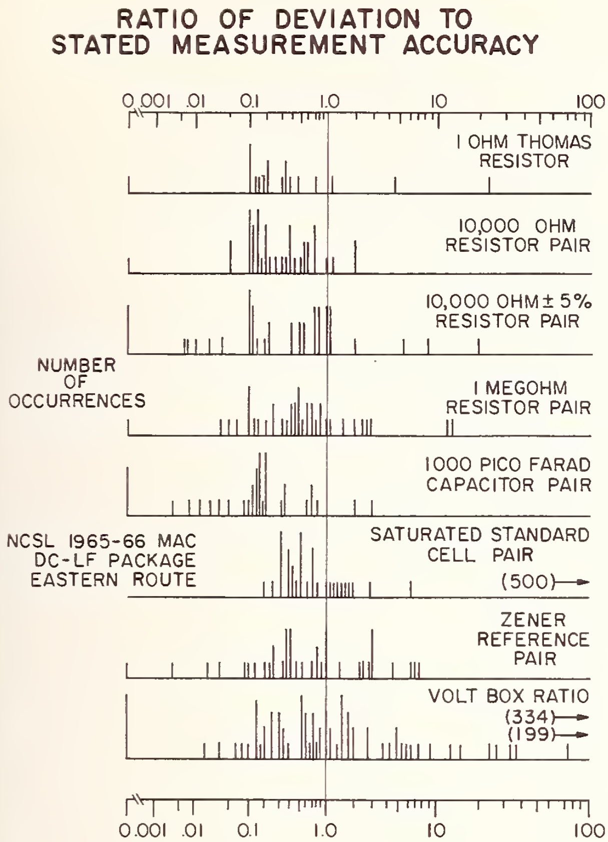

FIGURE 9. *Heckelmann. Ratios between actual deviations, computed by route supervisor, and the measurement accuracies estimated by participants.*

NCSL 66

Low Frequency Comparison—Western Route

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1.0 OHM & 1.0 MEGOHM RESISTORS NCSL 1965–66 MAC DC–LF WESTERN ROUTE

Lab. No.	S/N 1515170 1 ohm Thomas resistor	Deviation from NBS #1	Stated accuracy	4050B S/N 1654421	Deviation from NBS #1	4050B S/N LT4134	Deviation from NBS #1	Stated accuracy
	ohms	*ppm*	*ppm*	*ohms*	*ppm*	*ohms*	*ppm*	*ppm*
NBS #1	1.0000036	....	±1.0	1,000,026	....	1,000,203	....	±15
41J	1.0000047	+1.1	±20	1,000,047.0	+21	1,000,220.5	+17.5	±100
34F	1.0000037	+0.1	±3.0	1,000,030	+4.0	1,000,205	+2.0	±30
55J	.9999515	−52.1	±2.0	1,000,017.7	−8.3	1,000,190.7	−12.3	±25
33F	1.0000032	−0.4	±2.0	999,790	−236	1,000,010	−193	±120
27J	1.0000014	−2.2	±200	999,973	−53	1,000,137	−66	±250
25C	1.0000027	−0.9	±2.0	1,000,030	+4.0	1,000,205	+2.0	±20
18F	1.000004	+0.4	±3.0	1,000,027	+1.0	1,000,200	−3.0	±10
24J	1.0000034	−0.2	±3.0	1,000,057	+30	1,000,233	+30	±35
22F	1.0000006	−3.0	±5.0	1,000,021	−5.0	1,000,195	−8.0	±20
21J	1.000004	+0.4	±30	1,000,025	−1.0	1,000,200	−3.0	±50
23J	1.0000048	+1.2	±1.4	1,000,032	+6.0	1,000,204	+1.0	±10.2
42C	1.000008	+4.4	±10	1,000,040	+14	1,000,230	+27	±50
37F	1.0000027	−0.9	±5.0	1,000,015	−11	1,000,187	−16	±50
56F	1.0000039	+0.3	±2.0	1,000,033	+7.0	1,000,204	+1.0	±20
15J	1.000003	−0.6	±5.0	1,000,028	+2.0	1,000,201	−2.0	±13
14C	1.0000085	+4.9	±5.0	1,000,041	+15	1,000,219	+16	±20
32F	1.0000035	−0.1	±2.5	1,000,040	+14	1,000,207	+4.0	±22
29C	1.0000444	+40.8	±100	1,000,033	+7.0	1,000,212	+9.0	±100
30C	.999970	−33.6	±30	....	....	....	....	....
NBS #2	1.0000037	+0.1	±1	1,000,031	+5	1,000,202	−1	±15

Table 1, Ingraham 1–13–67

Lab. No.	4040B S/N 1666857	Deviation from NBS #1	4040B S/N 1666863	Deviation from NBS #1	Stated accuracy
	ohms	*ppm*	*ohms*	*ppm*	*ppm*
NBS #1	9,999.78	....	9,999.80	....	±7.0
41J	9,999.495	−28.5	9,999.595	−20.5	±100
34F	9,999.77	−1.0	9,999.79	−1.0	±10
55J	9,999.79	+1.0	9,999.81	+1.0	±10
33F	9,999.77	−1.0	9,999.78	−2.0	±7.0
27J	9,999.88	+10	9,999.91	+11	±200
25C	9,999.77	−1.0	9,999.79	−1.0	±10
18F	9,999.76	−2.0	9,999.76	−4.0	±8.0
24J	9,999.86	+8.0	9,999.85	+5.0	±50
22F	9,999.75	−3.0	9,999.77	−3.0	±10
21J	9,999.76	−2.0	9,999.78	−2.0	±30
23J	9,999.79	+1.0	9,999.80	0	±10
42C	9,999.80	+2.0	9,999.84	+4.0	±20
37F	9,999.69	−9.0	9,999.71	−9.0	±30
56F	9,999.74	−4.0	9,999.77	−3.0	±15
15J	9,999.77	−1.0	9,999.79	−1.0	±9.0
14C	9,999.71	−7.0	9,999.77	−3.0	±20
32F	9,999.79	+1.0	9,999.80	0	±8.0
29C	9,999.796	+1.6	9,999.826	+2.6	±100
30C	9,999.77	−1.0	9,999.80	0	±20
NBS #2	9,999.74	−4	9,999.80	0	±7

Table 2, Ingraham 1–13–67

10,000 OHM RESISTORS NCSL 1965–66 MAC DC–LF WESTERN ROUTE

Lab. No.	4040X S/N 1666853	Deviation from NBS #1	4040X S/N 1666851	Deviation from NBS #1	Stated accuracy
	ohms	*ppm*	*ohms*	*ppm*	*ppm*
NBS #1	10,462.07	....	9,583.80	....	±10
41J	10,461.796	−21.4	9,583.625	−17.5	±100
34F	10,462.10	+3.0	9,583.83	+3.0	±20
55J	10,462.11	+4.0	9,583.87	+7.0	±50
33F	10,462.05	−2.0	9,583.83	+3.0	±20
27J	10,462.33	+26	9,583.89	+9.0	±200
25C	10,462.06	−1.0	9,583.85	+5.0	±20
18F	10,462.06	−1.0	9,583.81	+1.0	±8.0
24J	10,462.21	+14	9,583.91	+11	±50
22F	10,462.10	+3.0	9,583.83	+3.0	±20
21J	10,462.10	+3.0	9,583.84	+4.0	±30
23J	10,462.13	+6.0	9,565.79	−1950	±23
42C	10,462.1	+3.0	9,583.9	+10	±30
37F	10,462.04	−3.0	9,583.86	+6.0	±30
56F	10,462.06	−1.0	9,583.81	+1.0	±15
15J	10,462.08	+1.0	9,583.84	+4.0	±10
14C	10,462.07	0	9,583.85	+5.0	±20
32F	10,462.10	+3.0	9,583.85	+5.0	±7.5
29C	10,438.97	−2200	9,583.73	−7.0	±100
30C	10,462.16	+9.0	9,583.86	+6.0	±30
NBS #2	10,462.01	−6	9,583.81	+1.0	±10

Table 3, Ingraham 1–13–67

NCSL 1965–66 MAC

STANDARD CELL PAIR — DC–LF WESTERN ROUTE

Lab. No.	Standard cell #24189	Deviation from NBS #1	Standard cell #24217	Deviation from NBS #1	Stated accuracy
	volts	*ppm*	*volts*	*ppm*	*ppm*
NBS	1.0182497	....	1.0182493	....	±1.0
41J	1.018375	+125	1.018369	+120	±30
34J	1.0182461	−3.6	1.0182442	−5.1	±3.0
55J	1.0182604	+10.7	1.0182584	+9.1	±2.0
33F	1.018250*	+0.3	1.018249*	−0.3	±10
27J	1.018221	−28.7	1.018216	−33.3	±200
25C	1.018250	+0.3	1.018248	−1.3	±3.0
18F	1.018249	−0.7	1.018248	−1.3	±5.0
24J	1.0182490	−0.7	1.0182472	−2.1	±4.0
22F	1.018251*	+0.4	1.018251*	+1.7	±10
21J	1.0182485	−1.2	1.0182419	−7.4	±3.0
23J	1.0182444	−5.3	1.0182419	−7.4	±2.2
42C	1.018255	+5.3	1.018253	+3.7	±10
37F	1.0182550	+5.3	1.0182534	+4.1	+5.0
56F	1.0182481	−1.6	1.0182465	−2.8	±5.0
15J	1.0182468	−2.9	1.0182455	−3.8	±3.0
14C	1.0182519	+2.2	1.0182507	+1.4	±3.0
32F	1.018258	+8.3	1.018256	+6.7	±5.0
29C	1.018248	−1.7	1.018246	−3.3	±15
30C	1.018257	+7.3	1.018255	+5.7	±10
NBS #2	1.0182477	−2.0	1.0182455	−3.8	±1.5

*Value corrected to 28 °C from 25 °C data.

Table 4, Ingraham 1–13–67

NCSL 1965–66 MAC

ZENER REFERENCE — DC–LF WESTERN ROUTE

Lab. No.	Zener S/N 3488 1.0000 V	Deviation from NBS #1	Zener S/N 3488 1.0183 V	Deviation from NBS #1	Stated accuracy
	volts	*ppm*	*volts*	*ppm*	*ppm*
NBS #1	.999958	....	1.018267	....	±5
41J	1.000059	+101	1.018361	+94	±100
34F	.999942	−16	1.018251	−16	±30
55J	.999937	−21	1.01825	−17	±10
33F	.999954	−4	1.018263	−4	±10
27J	.999940	−18	1.018251	−16	±200
25C	.99995	−8	1.01825	−17	±10
18F	.999947	−11	1.018255	−12	±5
24J	.999954	−4	1.018263	−4	±15
22F	.999954	−4	1.018269	+2	±30
21J	.999934	−24	1.018243	−24	±10
23J	.999960	+2	1.018264	−3	±51
42C	.999942	−16	1.018264	−3	±15
37F	.999956	−2	1.018265	−2	±10
56F	.999949	−9	1.018261	−6	±10
15J	.999956	−2	1.018267	0	±10: ±8
14C	.99995	−8	1.01826	−7	±20
32F	.99994	−18	1.01825	−17	±15: ±10
29C	.999967	+9	1.018278	+11	±20
30C	.999936	−22	1.018247	−20	±30
NBS #2	.999883	−75	1.018188	−79	±5

Table 5, Ingraham 1–13–67

VOLTBOX S/N 1679745 NCSL 1965–66 MAC DC-LF WESTERN ROUTE

Lab. No.	7.5 V range	Deviation from NBS #1	30 V range	Deviation from NBS #1	150 V range	Deviation from NBS #1	750 V range	Deviation from NBS #1	Stated accuracy
		ppm		*ppm*		*ppm*		*ppm*	*ppm*
NBS #1	1.00006	....	1.00006	- - - - - -	1.00011	....	1.00011	....	±20
41J	1.0000	−60	1.0000	−60	.99982	−290	1.00049	+380	±300
34F	1.00007	+10	1.000045	−15	1.00005	−60	1.00008	−30	±50
55J	1.00184	+1780	1.00187	+1830	1.00200	+1890	.98490	−1.5%	±20; ±100; ±500; ±2500
33F	.99992	−140	.99994	−120	.99991	−200	1.0000	−110	±20
27J	1.00003	−30	1.00000	−60	1.000033	−77	1.000098	−12	±300
25C	1.00008	+20	1.000075	+15	1.00009	−20	1.00012	+10	±20
18F	1.00008	+20	1.00006	0	1.00007	−40	1.00008	−30	±40
24J	1.000056	−4	1.000052	−8	1.000068	−42	1.00009	−20	±30
22F	1.000056	−4	1.00004	−20	1.000065	−45	1.000069	−41	±50
21J	1.00008	+20	1.00007	+10	1.00012	+10	1.00014	+30	±20
23J	1.000073	+13	1.000065	+5	1.000098	−12	1.000136	+26	±20
42C	1.00006_6	+6	1.00004_5	−15	1.00009	−20	1.00011_4	+4	±50
37F	$.99999_4$	−66	.99997	−70	$.99999_5$	−115	1.00002_2	−88	±30
56F	1.00007	+10	1.000063	+3	1.000105	−5	1.00011_4	+4	±30
15J	1.000087	+27	1.000073	+13	1.000120	+10	1.000143	+33	±60
14C	1.00006	0	1.000058	−2	1.000072	−38	1.00011	0	±10; ±10; ±20; ±50
32F	1.00007	+10	1.00005	−10	1.00010	−10	1.00010	−10	±50
29C	1.00007	+10	1.000046	−14	1.00010	−10	1.00017	+60	±200
30C	1.00013_6	+76	1.00008_5	+25	1.000121	+11	1.00017	+60	±50
NBS #2	1.00009	+30	1.00008	+20	1.00014	+30	1.00013	+20	±20

Table 6, Ingraham 1–13–67

1000pF CAPACITOR PAIR NCSL 1965–66 MAC DC-LF WESTERN ROUTE

Lab. no.	1404 A S/N 130	Deviation from NBS #1	1404 A S/N 563	Deviation from NBS #1	Stated accuracy
	pF	*ppm*	*pF*	*ppm*	*ppm*
NBS #1	1000.004	....	999.959	....	±20
41J	999.90	−104	999.85	−109	±2000
34F	1000.009	+5	999.968	+9	±50
55J	1000.003	−1	999.957	−2	±21
33F	999.999	−5	999.956	−3	±100
27J	999.97	−34	999.93	−29	±600
25C	1000.018	+14	999.978	+19	±20
18F	1000.001	−3	999.959	0	±30
24J	1000.007	+3	999.964	+5	±22
22F	1000.006	+2	999.959	0	±20
21J	999.998	−6	999.954	−5	±50
42C	999.99	−14	999.95	−9	±30
37F	1000.006	+2	999.958	−1	±50
56F	999.999	−5	999.957	−2	±25
15J	1000.008	+4	999.961	+2	±22
14C	1000.0064	+2.4	999.9653	+6.3	±25
32F	1000.005	+1	999.962	+3	±30
29C	1000.0006	−3.4	999.9576	−1.4	±100
NBS #2	1000.005	+1	999.963	+4	±20

Table 7, Ingraham 1–13–67

Lab. No.	R_0	$\frac{R-40}{R_0}$	ΔT	$\frac{R_{25}}{R_0}$	ΔT	$\frac{R_{100}}{R_0}$	ΔT	$\frac{R_{200}}{R_0}$	ΔT
	ohms		°C		°C		°C		°C
NBS*	25.5532	.839634	....	1.099252	....	1.392615	....	1.773512	....
34F	25.5533	.839640	+.0015	1.099249	−.0007	1.392604	−.0028	1.773495	−.0045
25C	25.5534	.839626	−.002	1.099239	−.0033	1.392601	−.0036	1.773510	−.0005
18F	25.5536	.839643	+.0022	1.099254	+.0005	1.392594	−.0054	1.773480	−.0085
21J	25.55350	.839628	−.0015	1.099257	+.001	1.392628	+.0034	1.773532	+.0053
23J	25.553_{26}	$.83963_{76}$	+.0009	1.09925_{02}	−.0005	1.39260_{80}	−.0018	1.77349_{95}	−.0033
55J	25.55350	.839623	−.0027	1.099257	+.0007	1.392621	+.0015	1.773492	−.0053
56F	25.5527_{2}	.839636	+.0005	1.099264	+.003	1.392631	+.0041	1.773535	+.0061
37F	25.55299	.839631	−.0007	1.099250	−.0005	1.392620	+.0013	1.773510	−.0005
32F	25.55319	.848973	+2.315	1.099433	+.045	1.392612	−.0008	1.773507	−.0013

Lab. No.	$\frac{R_{400}}{R_0}$	ΔT	$\frac{R_{419.505}}{R_0}$	ΔT	$\frac{R_{444.600}}{R_0}$	ΔT			
		°C		°C		°C			
NBS*	2.500153	....	2.568510	....	2.655802	....			
34F	....	....	2.568489	−.006	....	....			
25C	....	....	....	....	....	....			
18F	....	....	....	....	....	....			
21J	....	....	2.568524	+.004	....	....			
23J	....	....	2.568490	−.0057	....	....			
55J	2.499984	−.048	....	....	....	....			
56F	....	....	2.568557	+.0134	....	....			
37F	2.500100	−.015	....	....	....	....			
32F	....	....	....	....	....	....			

*At end of route.

Table 8, Ingraham 1–13–67

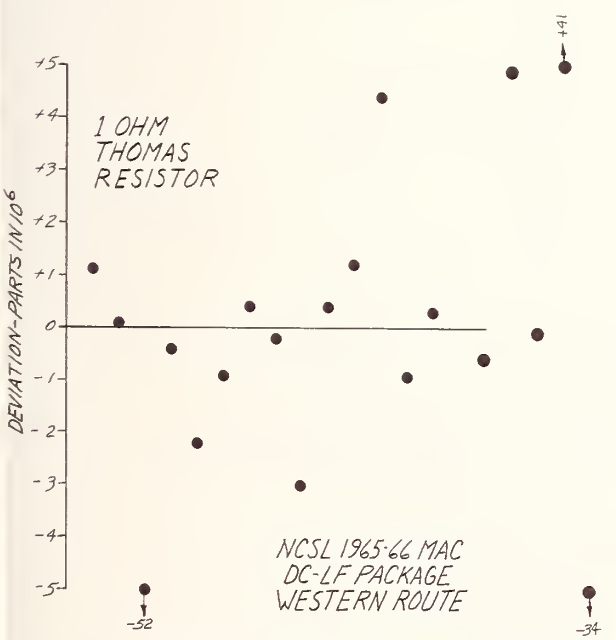


FIGURE 1. *Ingraham. Deviations from initial NBS value, computed by route supervisor for 1-ohm Thomas resistor.*

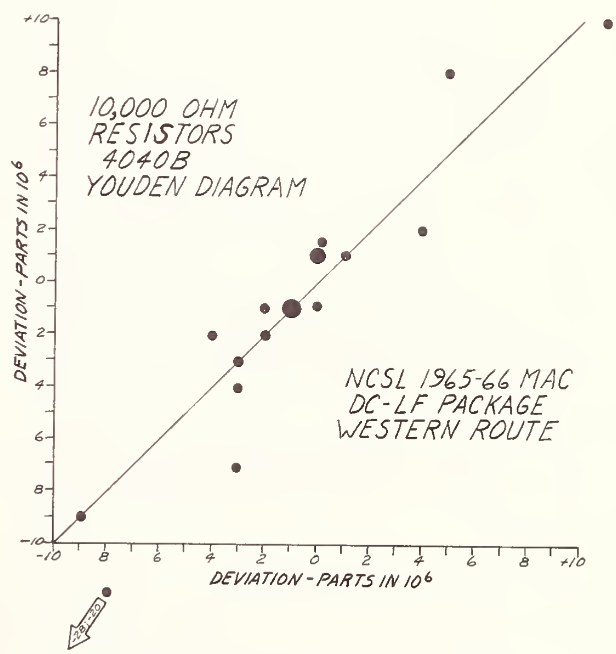


FIGURE 2. *Ingraham. Youden diagram for 10,000-ohm resistors 4040B, referenced from initial NBS value.*

256–114 O-67—3

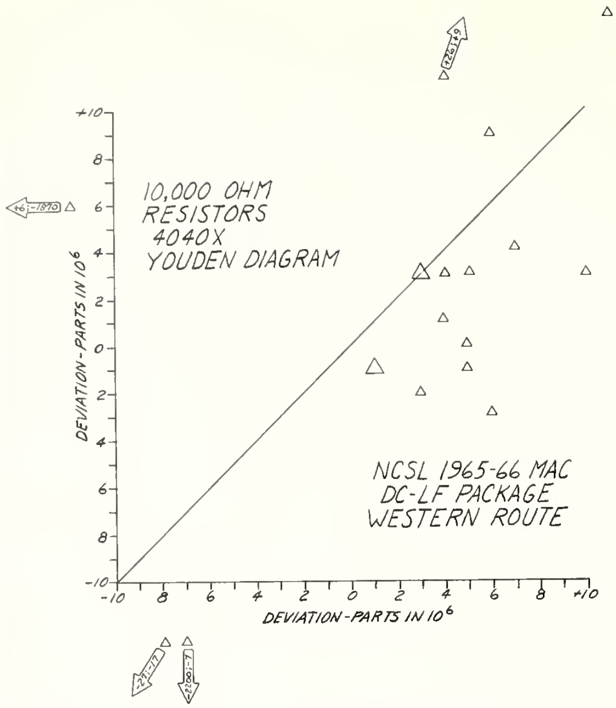


FIGURE 3. *Ingraham. Youden diagram for 10,000-ohm resistors 4040X, referenced from initial NBS value.*

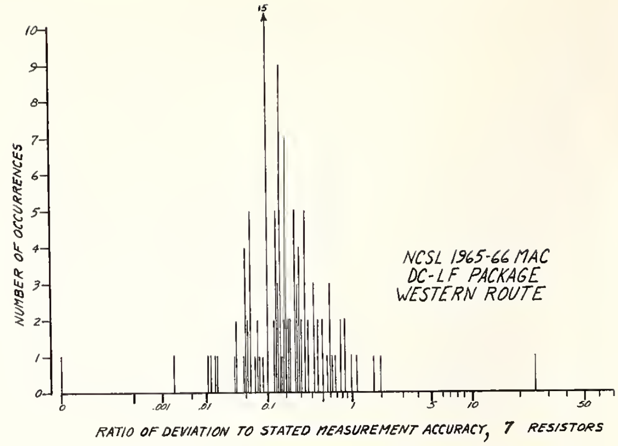


FIGURE 5. *Ingraham. Ratio between actual deviations, computed by route supervisor, and measurement accuracy stated by participants for 7 resistors.*

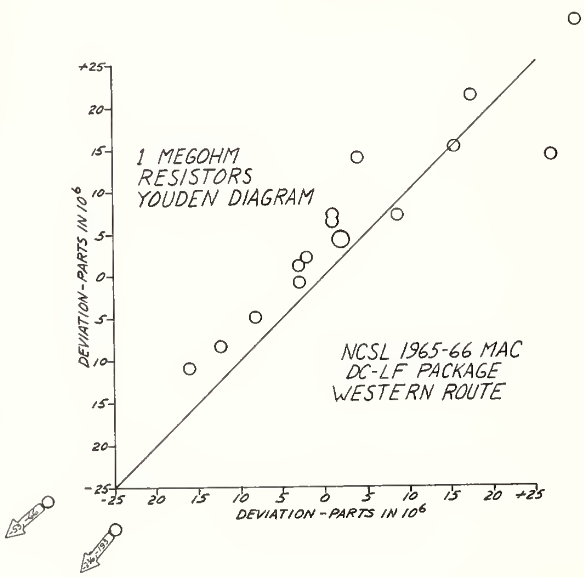


FIGURE 4. *Ingraham. Youden diagram for 1-megohm resistors, 1-megohm referenced from initial NBS value.*

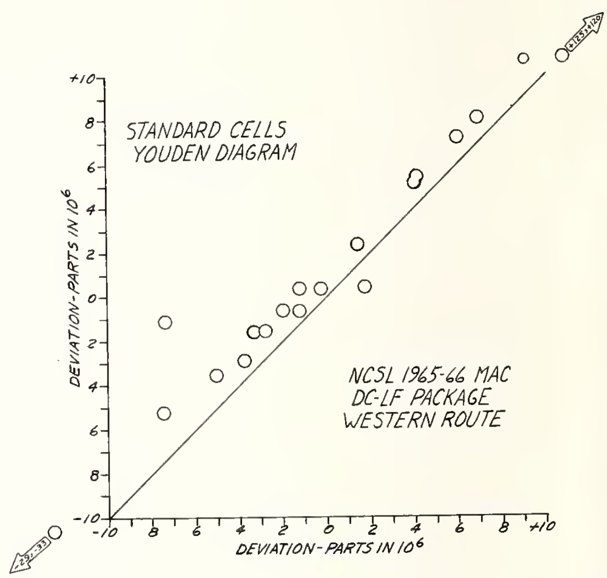


FIGURE 6. *Ingraham. Youden diagram for pair of standard cells, referenced to NBS initial value.*

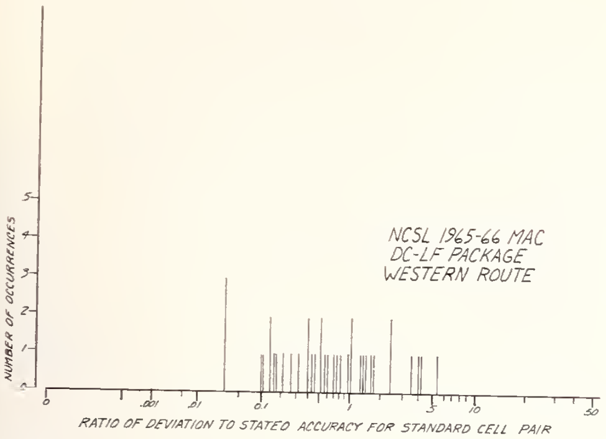


FIGURE 7. *Ingraham. Ratio between actual deviations, computed by route supervisor, and measurement accuracy stated by participants for standard cell pair.*

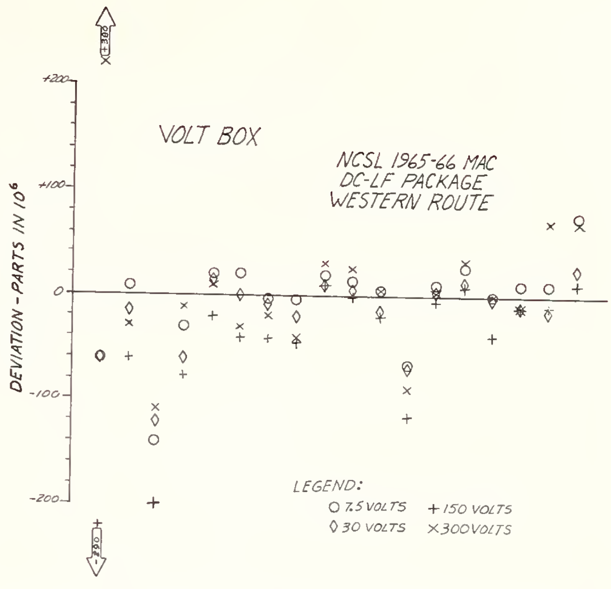


FIGURE 9. *Ingraham. Deviations from initial NBS value, computed by route supervisor for 4 volt-box ratios.*

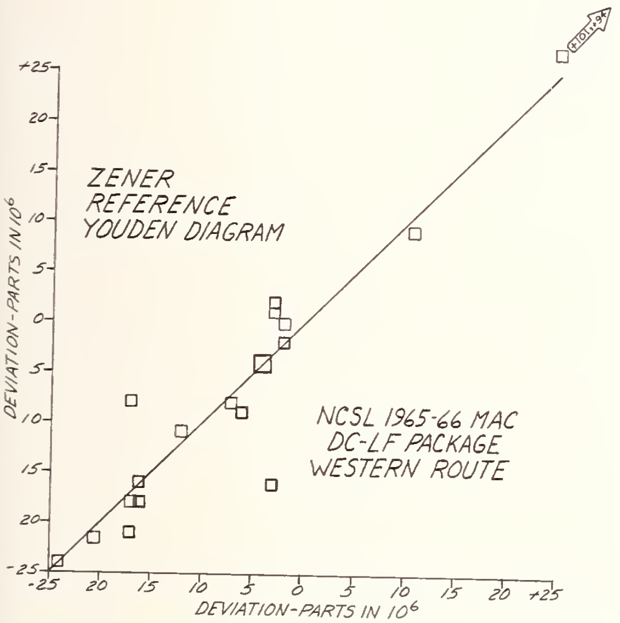


FIGURE 8. *Ingraham. Youden diagram for pair of Zener voltages, referenced to initial NBS value.*

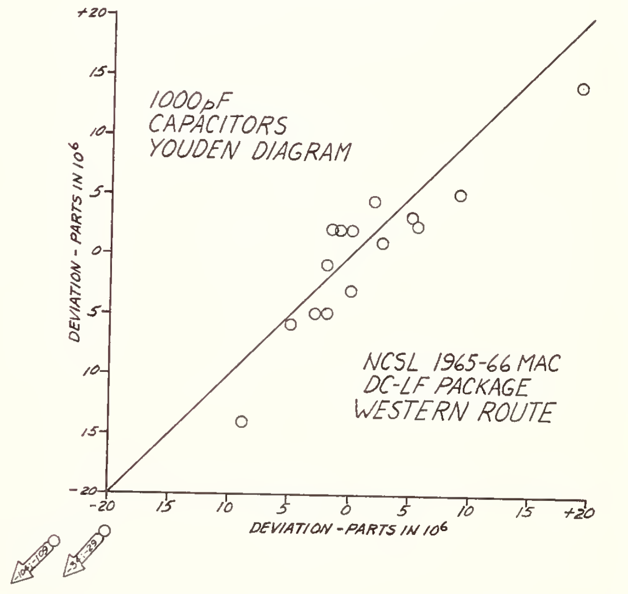


FIGURE 10. *Ingraham. Youden diagram for pair of 1000 pF capacitors, referenced to initial NBS value.*

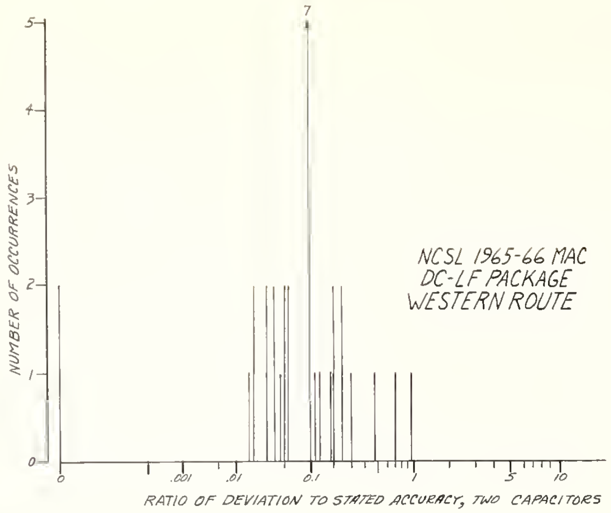


FIGURE 11. *Ingraham. Ratio between actual deviations, computed by route supervisor, and measurement accuracy stated by participants for 2 capacitors.*

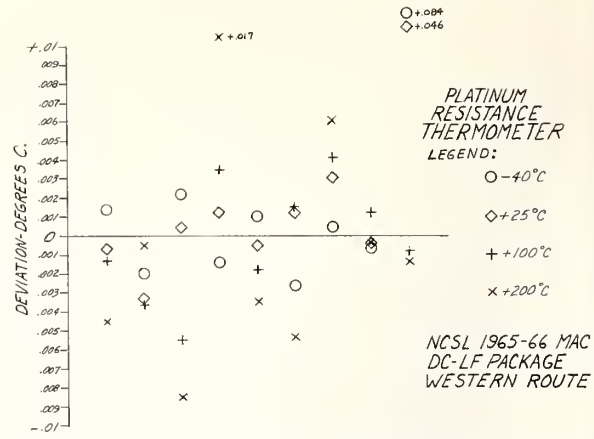


FIGURE 12. *Ingraham. Deviations from initial NBS value, computed by route supervisor, for 4 points on platinum resistance thermometer.*

High Frequency Comparison

H. D. Barnhart
General Electric Company

NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Reported Data

Participant's Code Number	Attenuator, Coax, Fixed 10 DB Unit I	Attenuator, Coax, Fixed 10 DB Unit II	Attenuator, Coax, Fixed 50 DB Unit I	Attenuator, Coax, Fixed 50 DB Unit II	20 DB Fixed Vane X Band Attenuator Unit I	20 DB Fixed Vane X Band Attenuator Unit II
NBS Dec.	10.34	10.23	49.87	50.15	20.09	20.08
NBS Apr.	10.33	10.23	49.86	50.15	20.09	20.07
NBS June	*	10.28	49.87	50.15	20.09	20.08
16E	10.13	10.23	49.75	49.91	20.14	20.09
17E	10.34	10.29	49.83	50.10	20.08	20.07
18F	*	10.20	49.82	50.12	20.12	20.10
20E	10.22	10.26	49.80	50.06	20.11	20.08
22F	10.16	10.29	50.07	50.37	19.99	19.99
32F	10.17	10.25	50.04	50.32	20.05	20.06
33F	10.11	10.19	---	---	20.09	20.08
34F	10.20	10.22	49.58	49.86	20.09	20.20
37F	10.20	10.20	49.90	50.23	20.10	20.10
43G	10.15	10.21	49.94	50.23	20.06	20.06
45A	10.09	10.24	49.80	50.09	20.07	20.08
48G	10.24	10.25	49.73	50.02	20.11	20.10
51E	10.24	10.41	49.59	49.95	20.075	20.077
56F	10.31	10.30	49.81	50.12	20.06	20.08
57G	10.23	10.17	49.76	50.07	20.06	20.04
58E	10.19	10.18	49.91	50.20	20.14	20.12

* Attenuator appears to have a sensitivity to temperature because of damage during MAC Program.

FIGURE 1. *Barnhart. Participant's reported data on attenuators.*

NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Measurements Uncertainties

Participant's Code Number	Attenuator, Coax, Fixed 10 DB Unit I (db)	Attenuator, Coax, Fixed 10 DB Unit II (db)	Attenuator, Coax, Fixed 50 DB Unit I (db)	Attenuator, Coax, Fixed 50 DB Unit II (db)	20 DB Fixed Vane X Band Attenuator Unit I (db)	20 DB Fixed Vane X Band Attenuator Unit II (db)
NBS Dec.	0.09	0.09	0.19	0.19	± 0.1	± 0.1
NBS Apr.	0.09	0.09	0.19	0.19	± 0.1	± 0.1
NBS June	*	0.09	0.19	0.19	± 0.1	± 0.1
16E	.21	.25	± .55	± .56	.27	.27
17E	0.2	0.2	0.3	0.3	0.1	0.1
18F	*	± 0.16	± 0.10	± 0.10	0.09	± .09
20E	± 0.15	± 0.05	± 0.2	± 0.2	± 0.1	± 0.1
22F	0.02	0.02	± 0.1	0.1	0.04	0.04
32F	0.2	0.2	0.25	0.25	0.1	0.1
33F	.15	.15	--	--	.05	.05
34F	± 0.25	± 0.25	± 0.5	± 0.5	± 0.05	± 0.05
37F	± 0.2	± 0.2	± 0.5	± 0.5	± 0.2	± 0.2
43G	± 0.16	± .07	± 0.20	± 0.18	± 0.07	± 0.07
45A	± .08	± .09	.1	.1	± .058	± .058
48G	.085	.090	0.110	.10	.071	.071
51E	± 0.06	± 0.06	0.15	0.3	± .08	± .08
56F	± 0.1	± 0.1	± 0.2	± 0.3	± 0.05	± 0.05
57G	± 0.05	± 0.05	± 0.1	± 0.1	± 0.04	± 0.04
58E	± .06	± .08	.15	.15	.07	.60

* Attenuator appears to have a sensitivity to temperature because of damage during MAC Program.

FIGURE 2. *Barnhart. Participant's estimates of measurement uncertainties on attenuators.*

NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Reported Data

			Wavemeter SN 15787		
Participant's Code Number	Q Standard Effective Q Unit I	Q Standard Effective Q Unit II	9.0 GHz Micrometer Setting MM	10.0 GHz Micrometer Setting MM	11.0 GHz Micrometer Setting MM
NBS Dec.	251	230	8.232	4.372	1.782
NBS Apr.	250	224	8.233	4.372	1.782
NBS June	252	229	8.233	4.372	1.783
16E	250	224.1	8.232	4.371	1.781
17E	241	215	8.232	4.372	1.782
18F	249	224	8.233	4.382	1.781
20E	244	216	8.232	4.371	1.782
22F	246	217	8.231	4.371	2.232
32F	244	214	8.232	4.371	1.782
33F	-	-	8.232	4.371	1.782
34F	249	223	8.232	4.371	1.782
37F	-	-	8.232	4.371	2.782
43G	-	-	8.231	4.371	1.782
45A	243.8	214	8.232	4.372	1.782
48G	244	217	8.2320	4.3720	1.7825
51E	241.2	214.2	8.231	4.371	1.782
56F	251	218	8.232	4.372	1.782
57G	-	-	8.232	4.371	1.782
58E	249.3	233	8.230	4.370	1.7805

FIGURE 3. *Barnhart. Participant's reported data on Q-standards and wavemeter.*

NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Measurements Uncertainties

Participant's Code Number	Q Standard Effective Q Unit I	Q Standard Effective Q Unit II	Wavemeter SN 15787
NBS Dec.	± 2	± 4	± 0.002 MM
NBS Apr.	± 2	± 4	± 0.002 MM
NBS June	± 2	± 4	± 0.001 MM
16E	± 3.5 %	± 3.5 %	.0048 %
17E	± 2 %	± 2 %	± 0.001 MM
18F	± 4 %	± 4 %	5 parts in 10^4
20E	± 2 %	± 2 %	± .001 ± 0.0002 % of freq.
22F	± 3 %	± 3 %	0.001 %
32F	± 2 %	± 2 %	± 1 part in 10^5
33F	-	-	± 1 part in 10^6
34F	± 3 %	± 3 %	± 0.1 dial div.
37F	± 5 %	± 5 %	0.001 %
43G	-	-	.005 %
45A	± 5 %	± 5 %	.001 %
48G	± 3 %	± 3 %	.05 dial
51E	± 1 %	± 1 %	1×10^{-6}
56F	3 %	3 %	Limited by dial readability
57G	± 5 %	± 5 %	± 1. dial div.
58E	± 2 %	± 2 %	± .001

FIGURE 4. *Barnhart. Participant's estimates of measurement uncertainties on Q-standards and wavemeter.*

NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Reported Data

Wavemeter

Participant's Code Number	51 GHz (Inches)			62 GHz (Inches)				74 GHz (Inches)				
NBS Dec.	.1155	.2830	.4510	.0665	.1850	.3035	.4220	.0395	.1320	.2240	.3155	.4080
NBS Apr.	.1155	.2830	.4510	.0665	.1850	.3035	.4220	.0395	.1320	.2240	.3160	.4075
NBS June	.1155	.2830	.4510	.0665	.1850	.3035	.4220	.0395	.1320	.2235	.3160	.4075
16E												
17E												
18F												
20E	.1157	.2832		.0665	.1848			.0397	.1318			
22F												
32F												
33F												
34F												
37F												
43G												
45A												
48G												
51E				.0665					.1317			
56F	.1157	.2832	.4511	.0665	.1848	.3033	.4217	.0397	.1317	.2237	.3158	.4077
57G												
58E												

FIGURE 5. *Barnhart. Participant's reported data on 51–62–74 GHz wavemeter.*

NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Measurements Uncertainties

Participant's Code Number	Wavemeter 51 GHz (Inches)	Wavemeter 62 GHz (Inches)	Wavemeter 74 GHz (Inches)
NBS Dec.	± .001	± .001	± .001
NBS Apr.	± .001 Est. Acc.	± .001 Est. Acc.	± .001 Est. Acc.
NBS June	± .001	± .001	± .001
16E			
17E			
18F			
20E	± .01 ± .003% of Freq.	± .01 ± .003% of Freq.	± .01 ± .003% of Freq.
22F			
32F			
33F			
34F			
37F			
43G	± .25 %	± .25 %	± .25 %
45A			
48G			
51E		± .05 %	± .05 %
56F	Limited By Dial Resettability		
57G			
58E			

FIGURE 6. *Barnhart. Participant's estimates of measurement uncertainties on 51–62–74 GHz wavemeter.*

NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Reported Data

Participant's Code Number	Thermistor Mount						Standard Mismatch
	1 MW			10 MW			Reflection Coefficient MM
	100 MHz	3.5 GHz	9.3 GHz	100 MHz	3.5 GHz	9.3 GHz	
NBS Dec.	.989	.945	---	.988	.948	---	.04964
NBS Apr.	.988	.939	---	.990	.943	---	.04967
NBS June	.981	.936	---	.990	.948	---	.04977
16E							.04920
17E							---
18F							.04760
20E	.961	.910	---	---	.909	---	.04900
22F							
32F	.994		.896	.990		.894	
33F							
34F						.985	.04997
37F							
43G	.983	.971	.859	.980	.973	.859	.05040
45A	.965	.935	.787	.965	.935	.787	.04860
48G	.980	.927	.794	.983	.924	.780	.05020
51E	.9913	.9421		.9853	.9501		.04200
56F				1.00	1.02	1.177	.05040
57G							.05010
58E		.966	.964		.955	.945	.05270

FIGURE 7. *Barnhart. Participant's reported data on thermistor mount at 1 mW and 10 mW.*

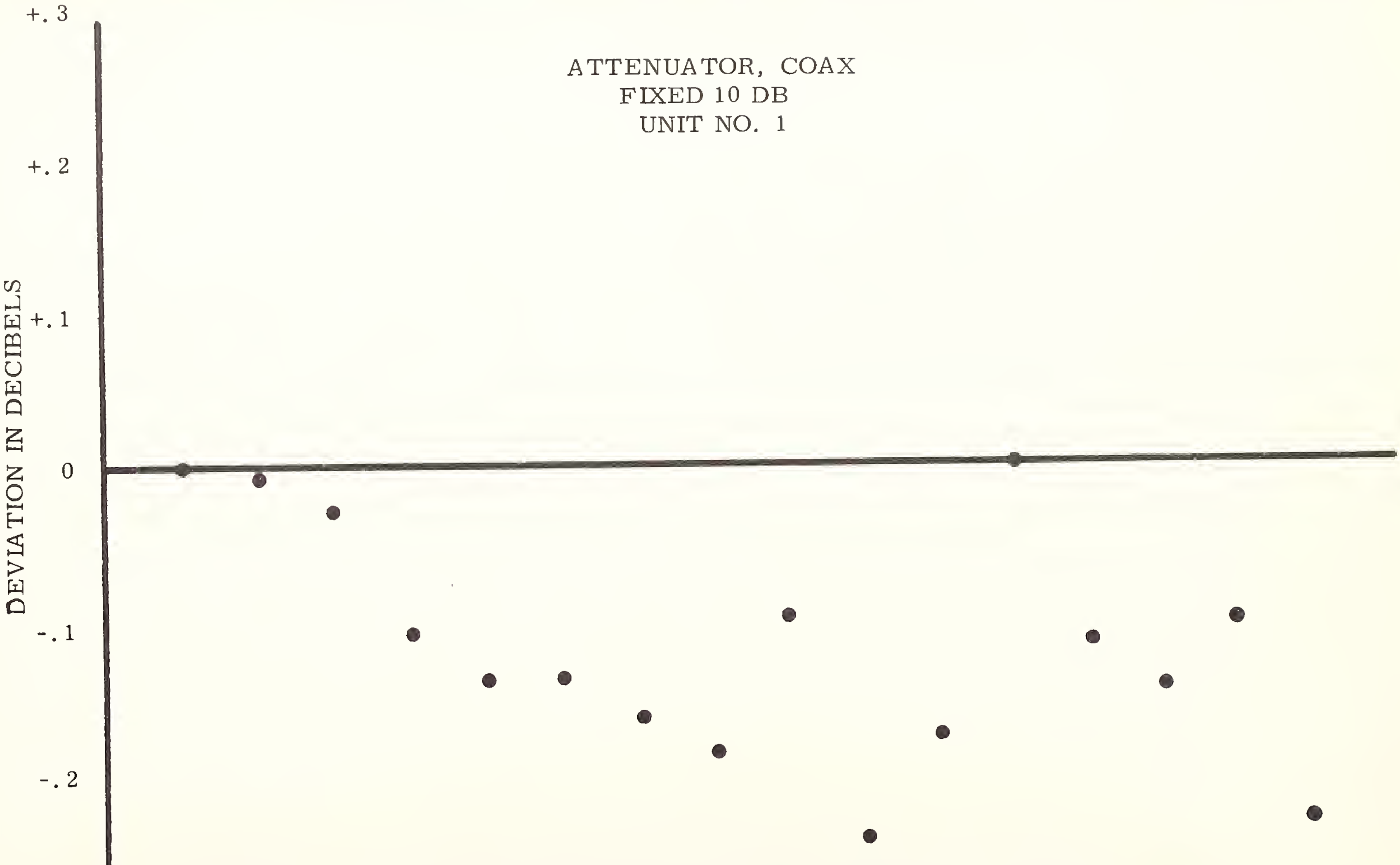
NATIONAL CONFERENCE OF STANDARDS LABORATORIES
1965 - 1966 MEASUREMENT AGREEMENT COMPARISON HIGH FREQUENCY PACKAGE

Participant's Measurements Uncertainties

Participant's Code Number	Thermistor Mount						Standard Mismatch
	1 MW			10 MW			Reflection Coefficient MM
	100 MHz	3.5 GHz	9.3 GHz	100 MHz	3.5 GHz	9.3 GHz	
NBS Dec.	1 %	1.5 %	-	1 %	1.5 %	-	± .0003 **
NBS Apr.	1 %	1.5 %	-	1 %	1.5 %		± .0003 **
NBS June	1 %	1.5 %	-	1 %	1.5 %		± .0003 **
16E							.012
17E							
18F							± .0065
20E	± 3 %	± 3 %	-	-	± 3 %	-	± .004
22F							
32F	2.3 %	-	6 %	2.1 %	-	5 %	
33F							
34F	-	-	-	2.5 %	-	-	1 %
37F							
43G	1.5 %	2.5 %	3.5 %	1.5 %	2.5 %	3.5 %	± 3 %
45A	2.0 %	2.0 %	2.5 %	2.0 %	2.0 %	2.5 %	± .006
48G	2.1 %	2.7 %	3.6 %	2.2 %	2.7 %	3.6 %	± .00075
51E	1.3 %	1.3 %	-	1.3 %	1.3 %	-	± .002
56F	-	-	-	± .05	± .05	± .02	± .001
57G							1 %
58E	-	± .043	± .055	-	± .043	± .055	± .001

** Estimated Accuracy

FIGURE 8. *Barnhart. Participant's estimates of measurement uncertainties on thermistor mount at 1 mW and 10 mW.*



NOTE: Attenuator became temperature sensitive, possibly due to having too much power applied somewhere in the audit cycle. Hand heat alone will lower value from 10.3 decibels nominal room temperature value to 10.1 decibels. At more elevated temperatures the attenuator exhibits a turnover and rises to 10.5 decibels. Data is plotted in random order. It is impossible to know which points are before or after.

Figure 9. *Barnhart. Deviations from NBS values, computed by route supervisor, for fixed 10-dB coax attenuator #1.*

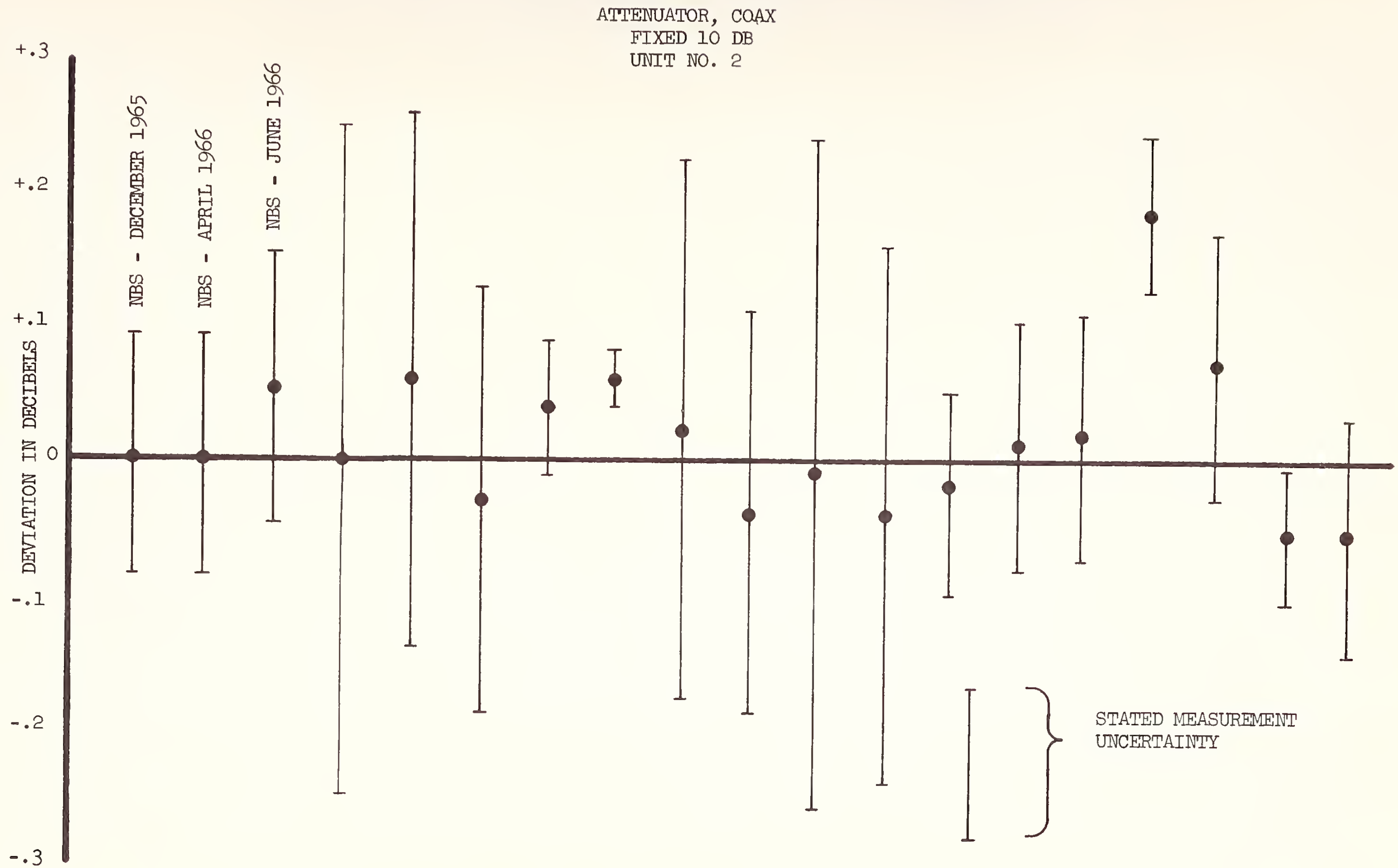


FIGURE 10. *Barnhart. Deviations from NBS values, computed by route supervisor, for fixed 10-dB coax attenuator #2.*

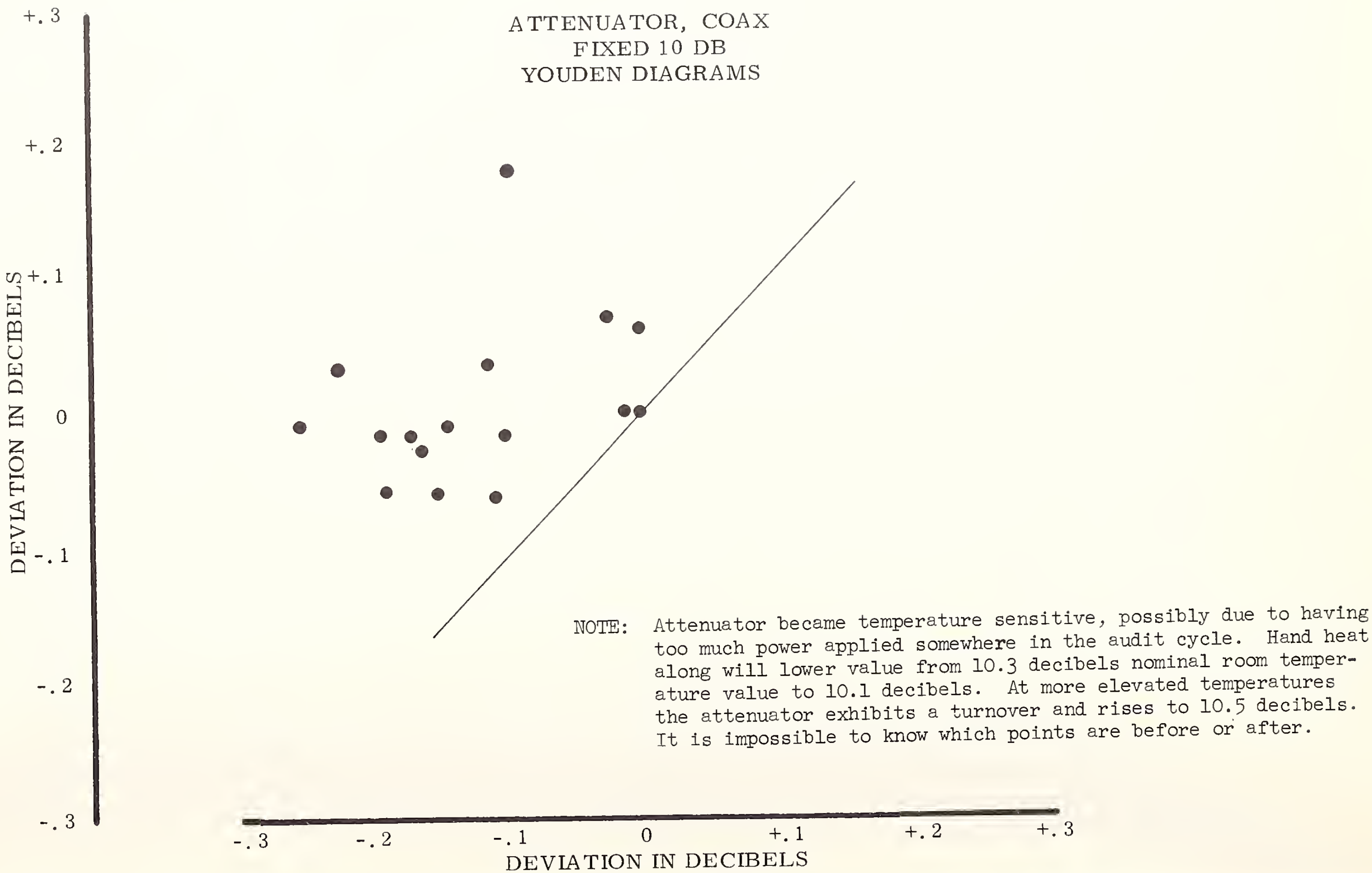


FIGURE 11. *Barnhart. Youden diagram for fixed 10-dB coax attenuator, referenced to initial NBS value.*

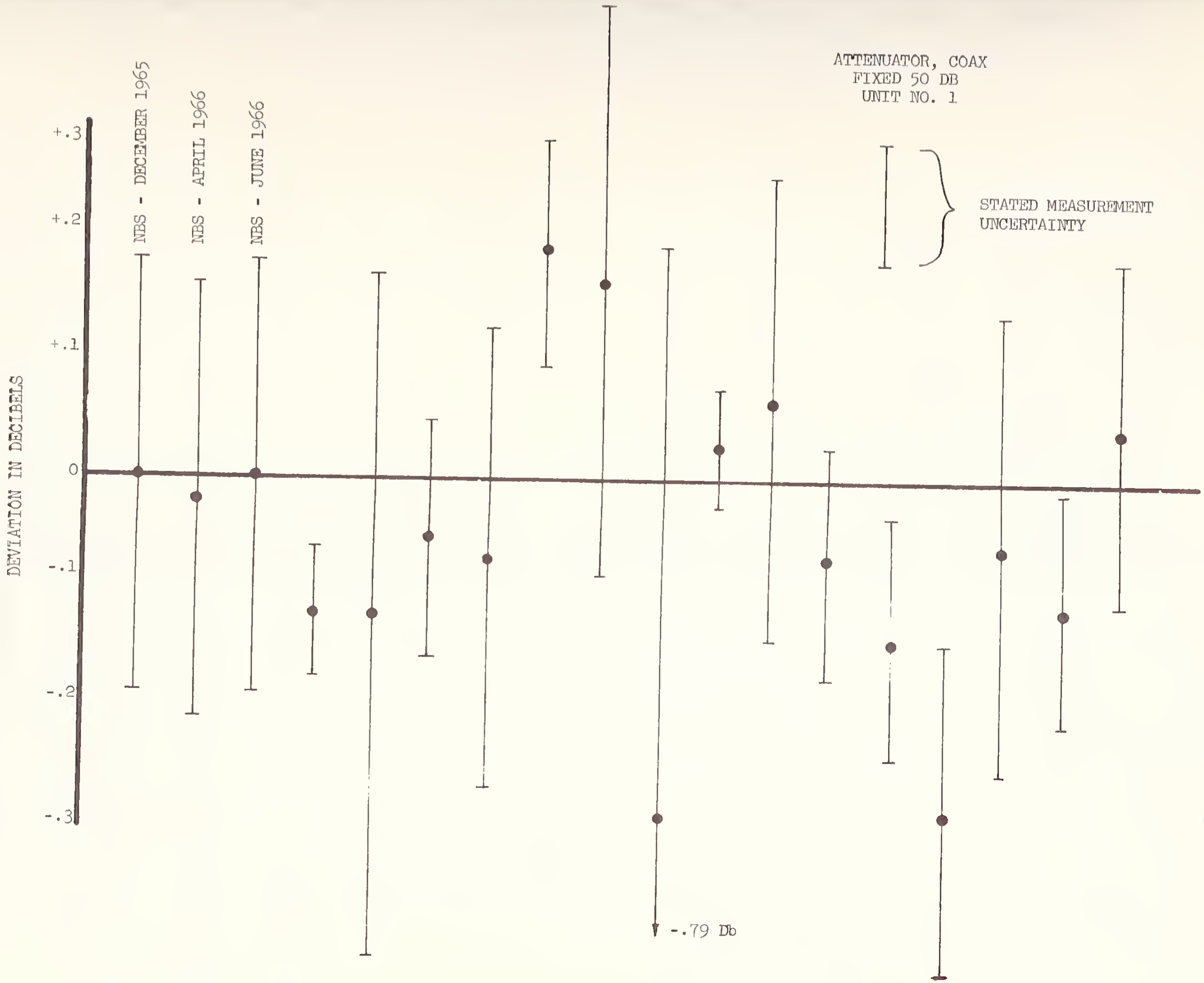


FIGURE 12. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for fixed 50-dB coax attenuator #1.*

256-114 O-67—4

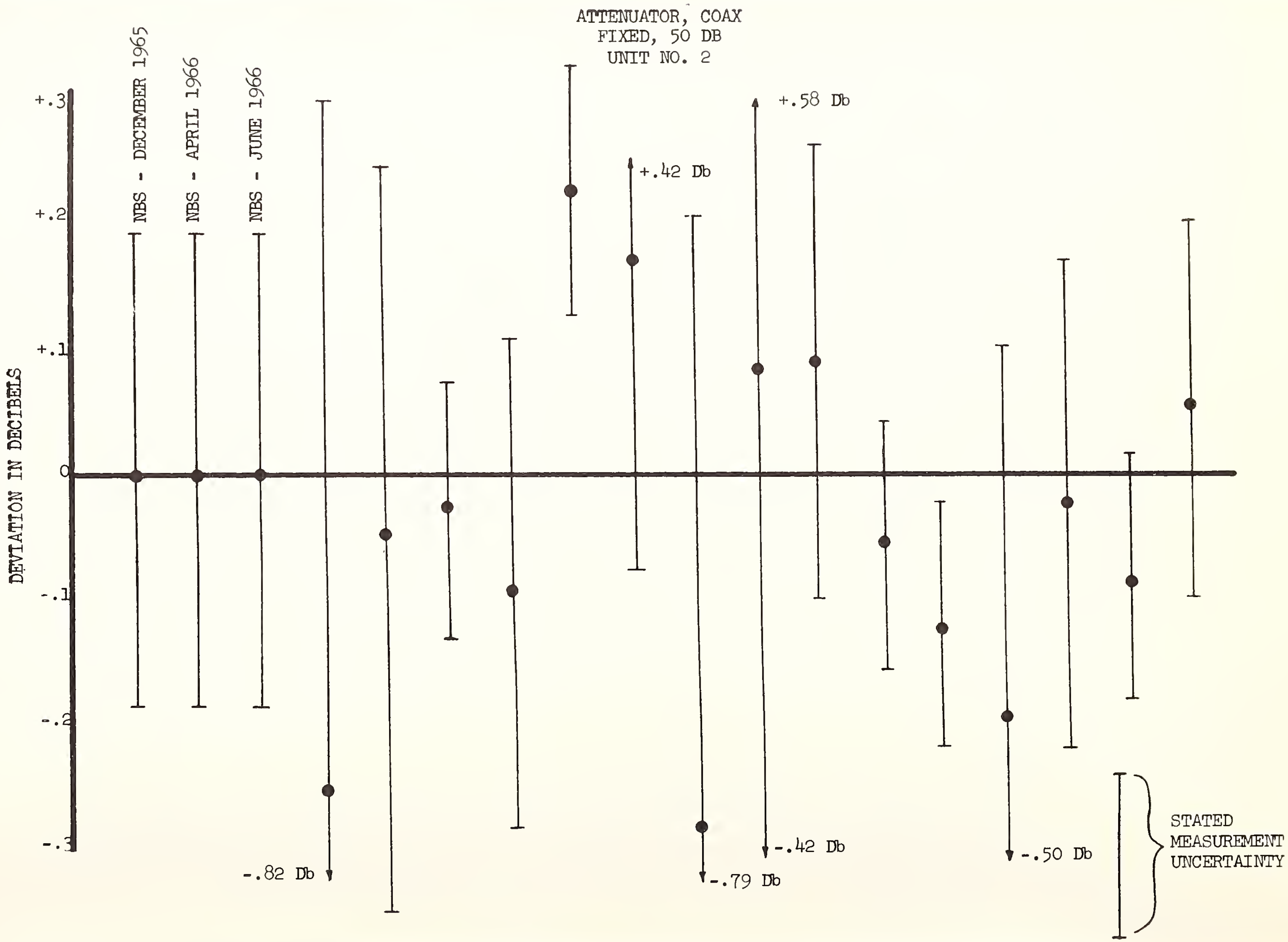


FIGURE 13. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for fixed 50-dB coax attenuator #2.*

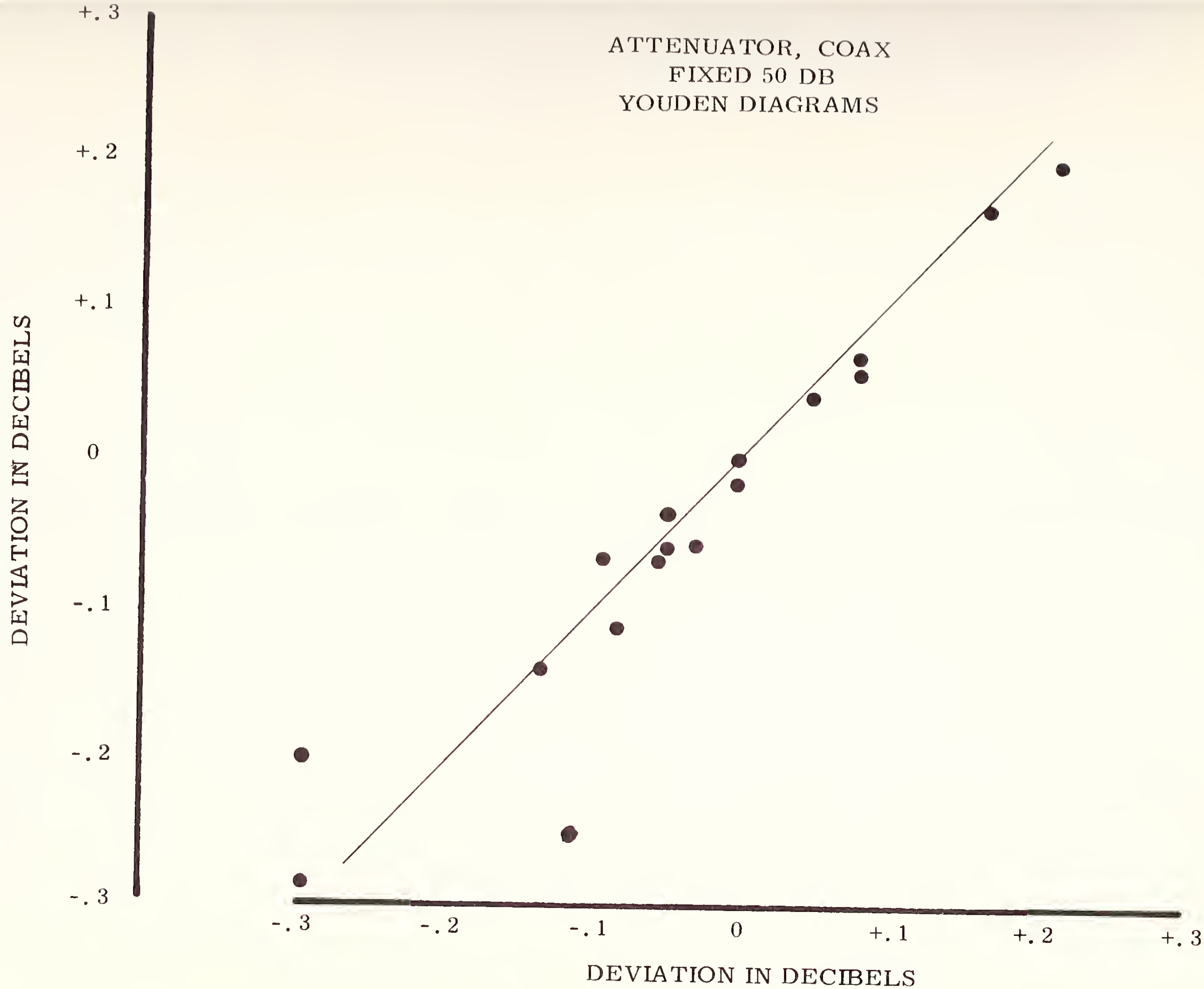


FIGURE 14. *Barnhart. Youden diagram for fixed 50-dB coax attenuators, referenced to initial NBS value.*

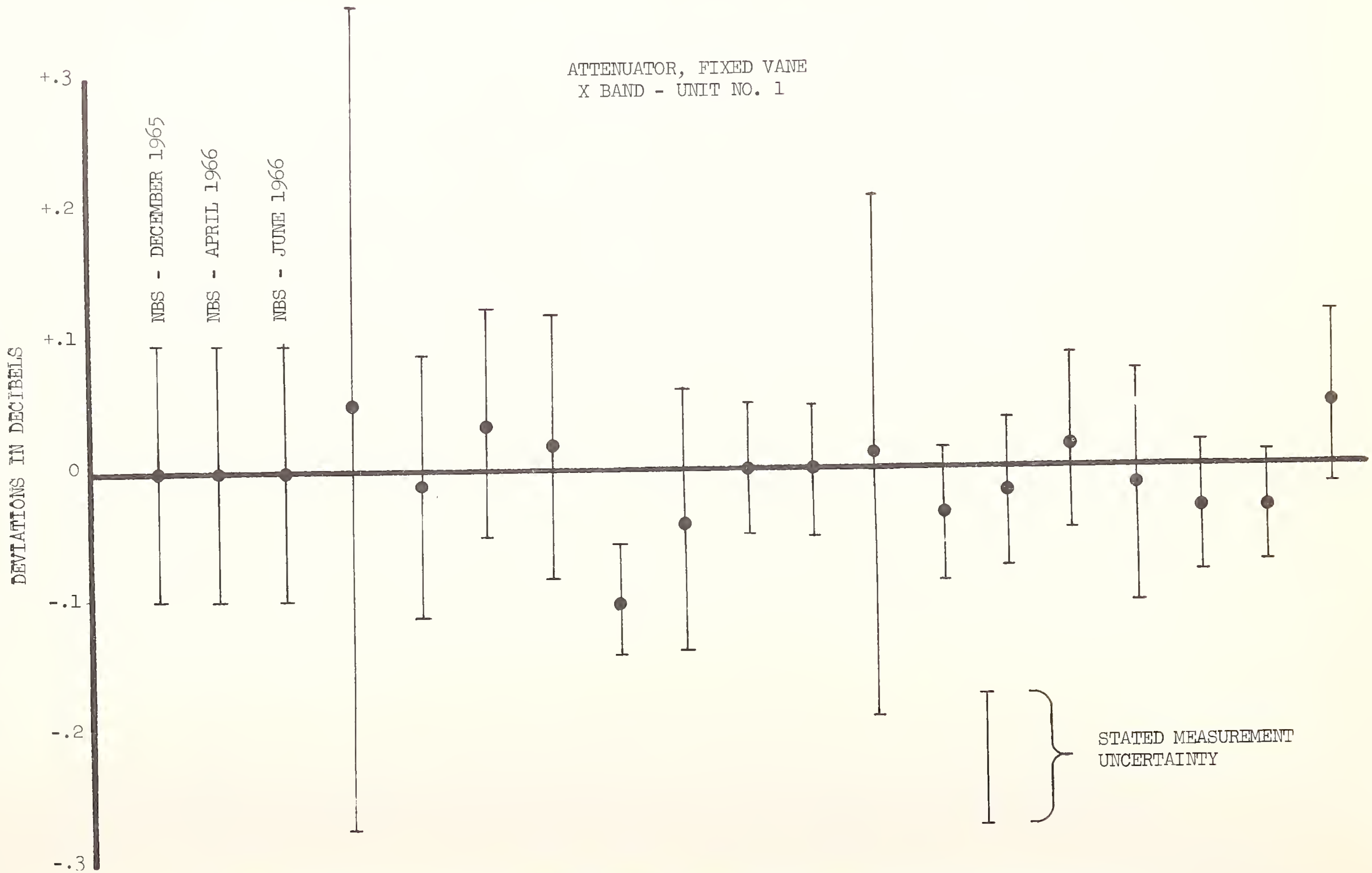


FIGURE 15. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for fixed-vane X-band attenuator #1.*

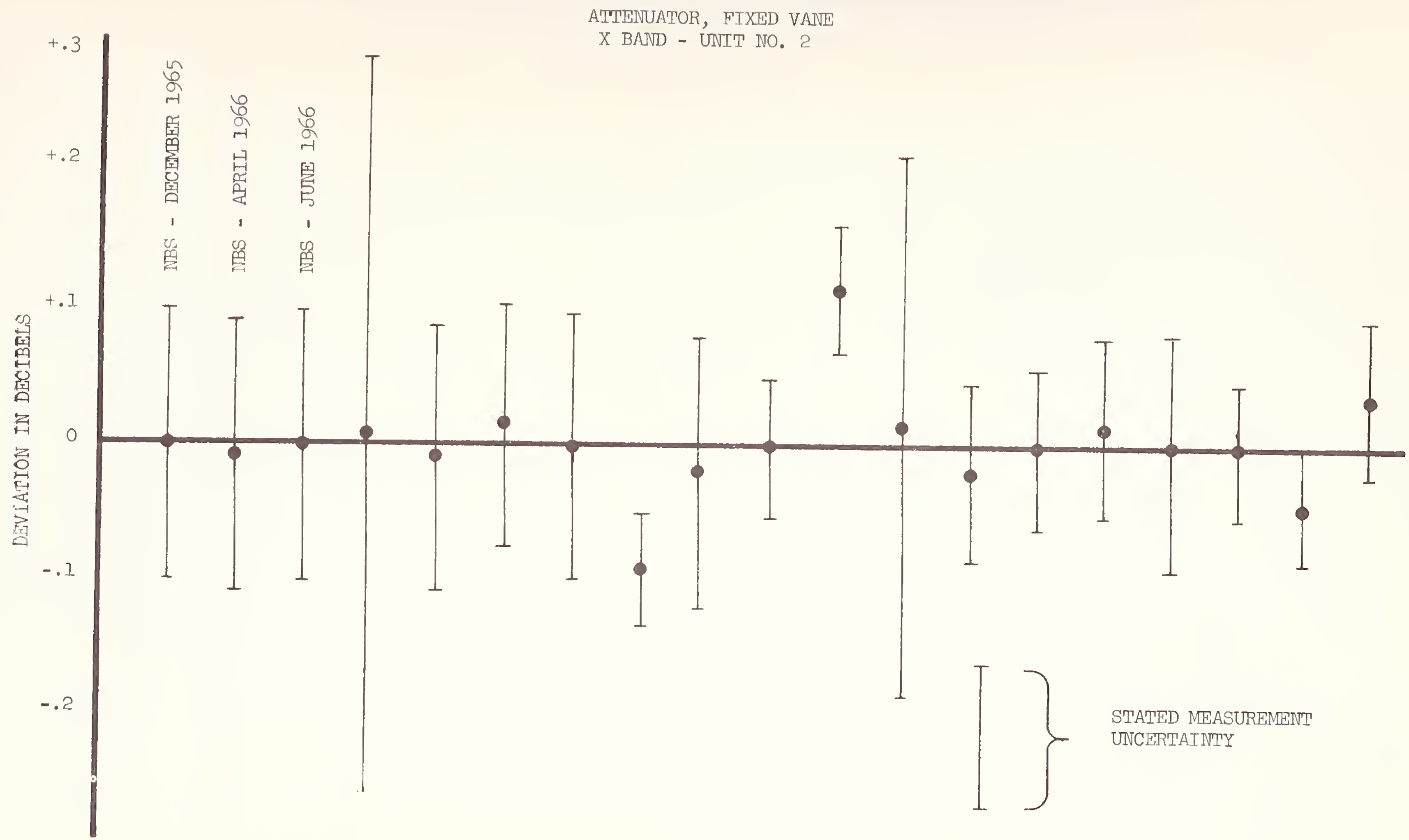


FIGURE 16. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for fixed-vane X-band attenuator #2.*

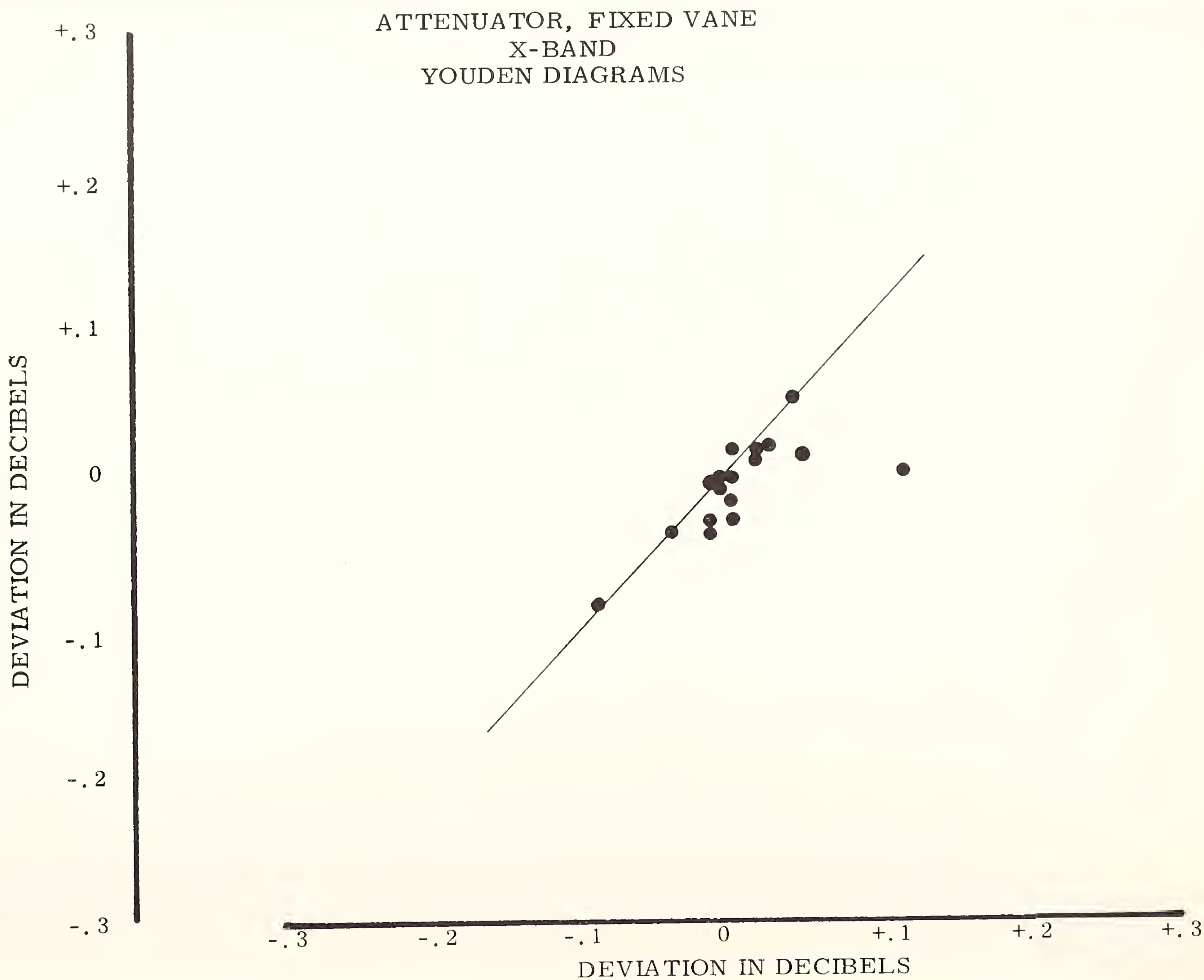


Figure 17. *Barnhart. Youden diagram for fixed-vane X-band attenuators, referenced to initial NBS value.*

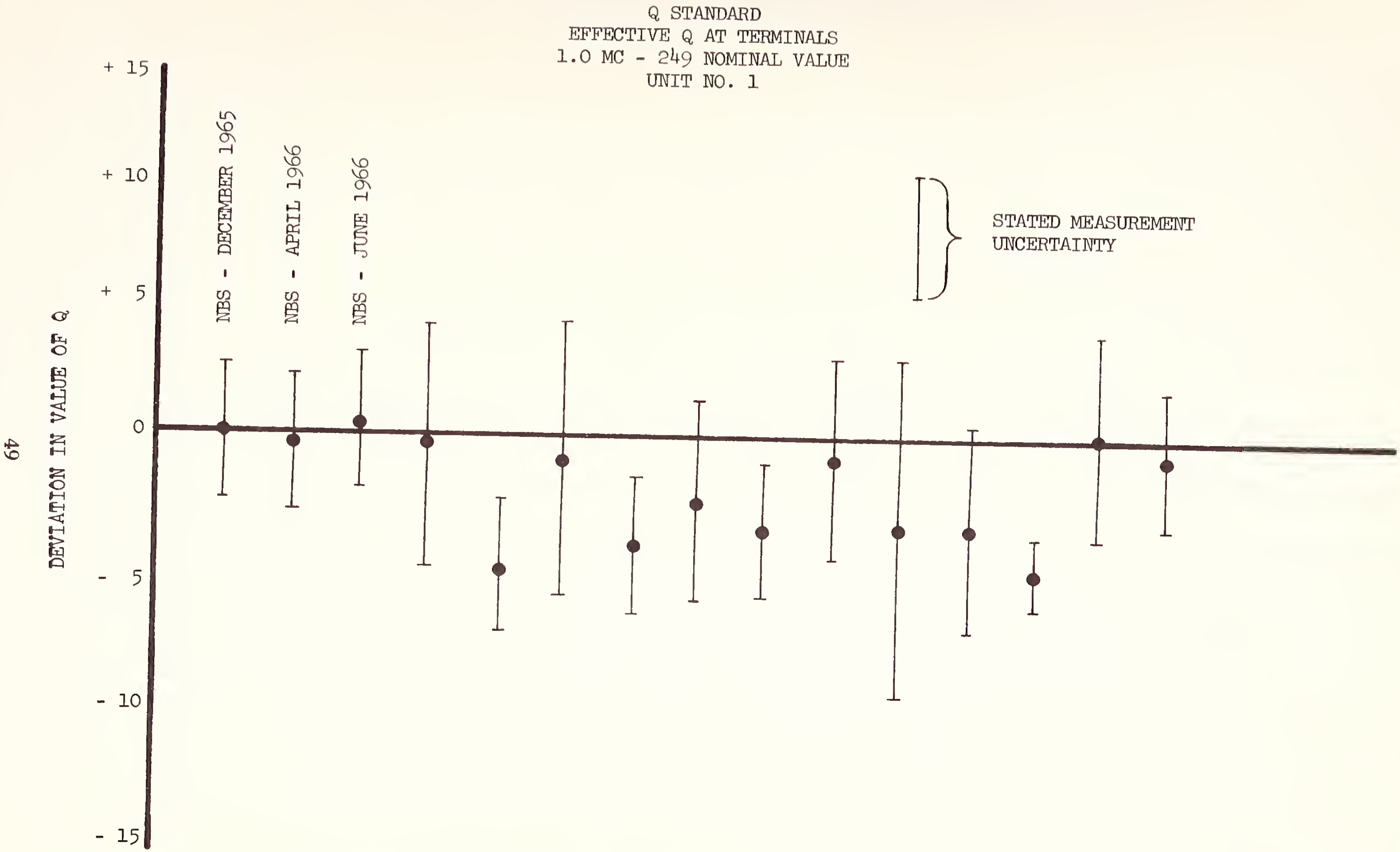


FIGURE 18. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for effective Q at terminals of standard #1, 1.0 MHz, Q=249.*

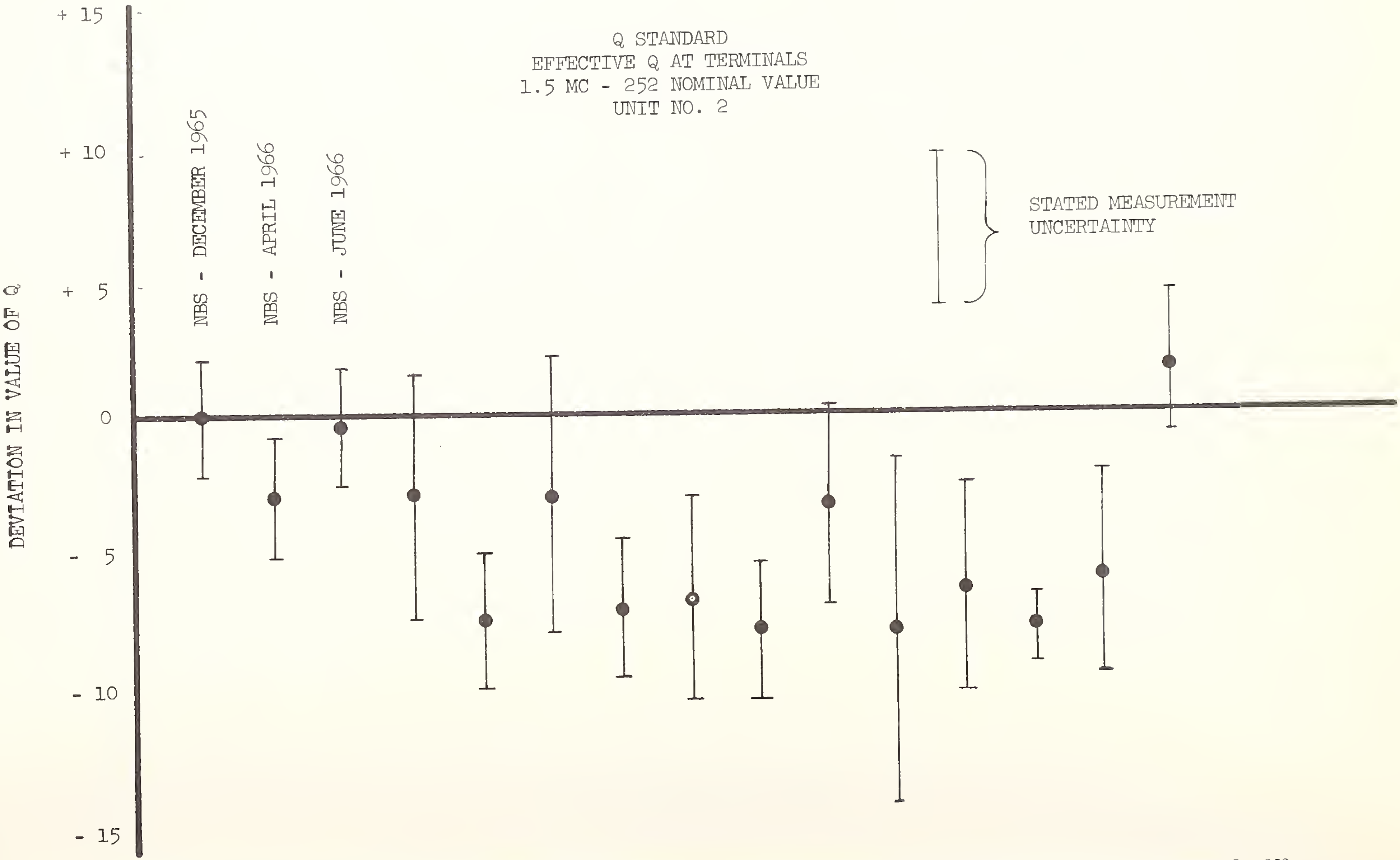


FIGURE 19. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for effective* Q *at terminals of standard #2, 1.5 MHz,* Q = 252.

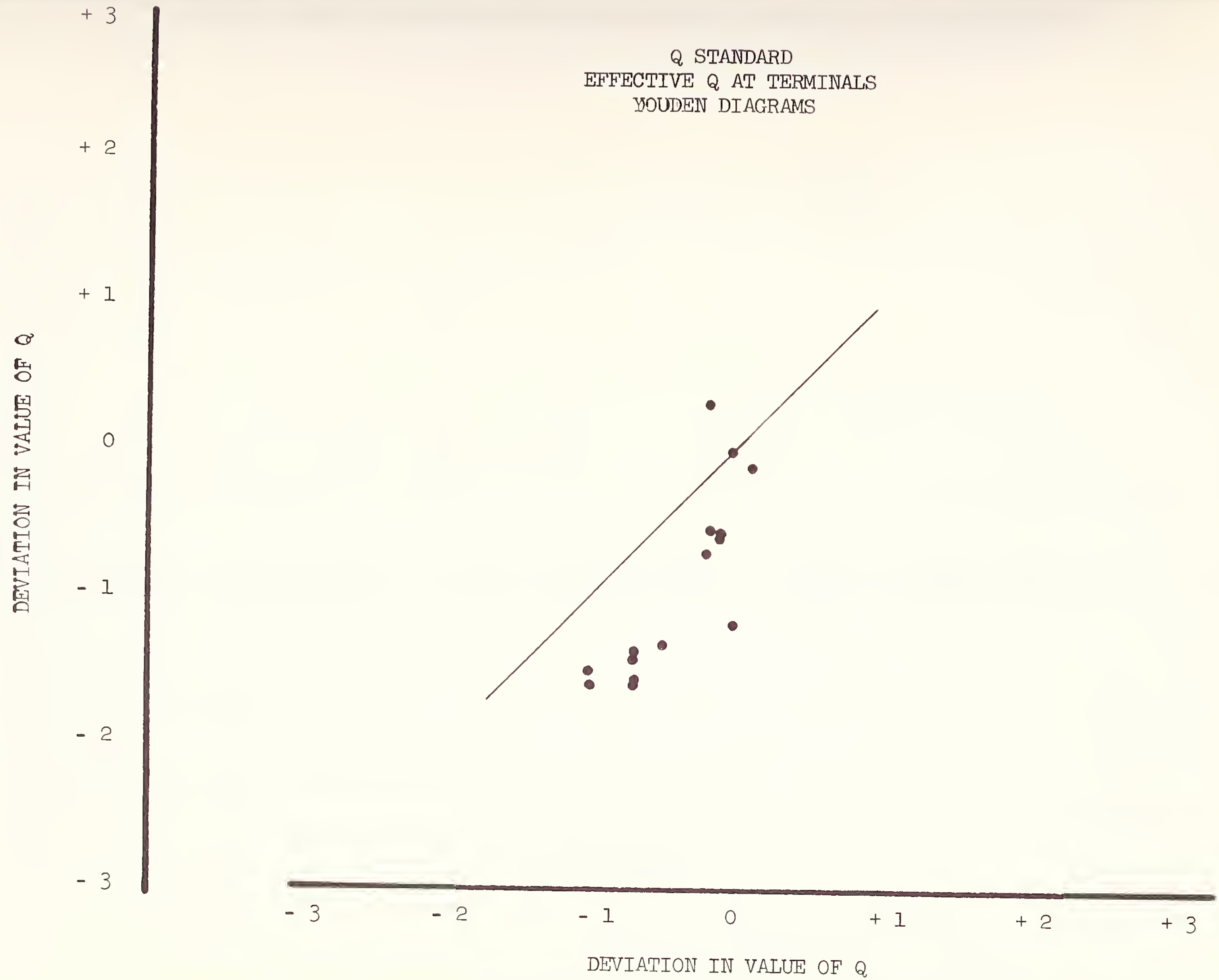


FIGURE 20. *Barnhart. Youden diagram for effective Q at terminals of standards, referenced to initial NBS value.*

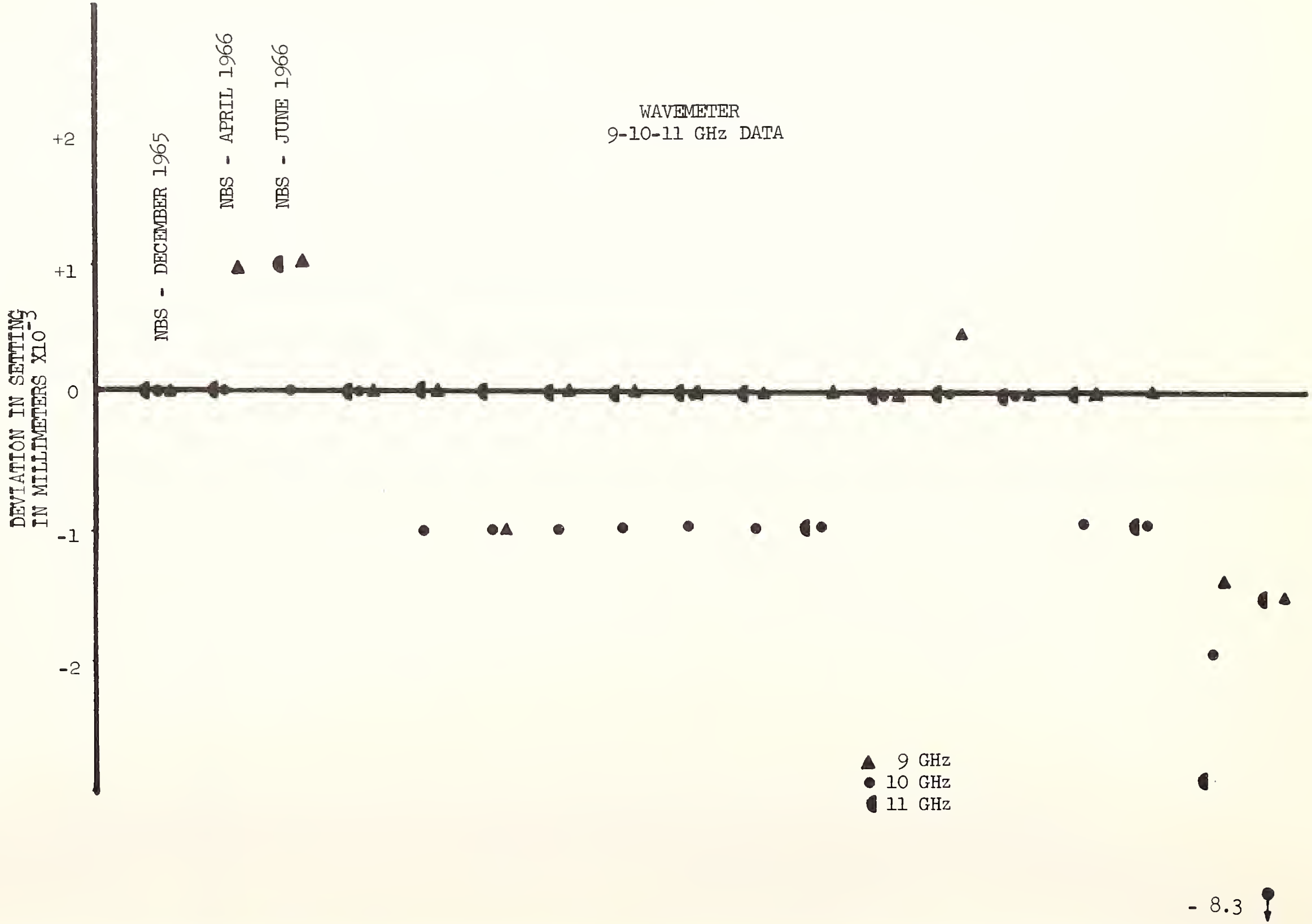


FIGURE 21. *Barnhart. Deviations for initial NBS value, computed by route supervisor, 9–10–11 GHz wavemeter.*

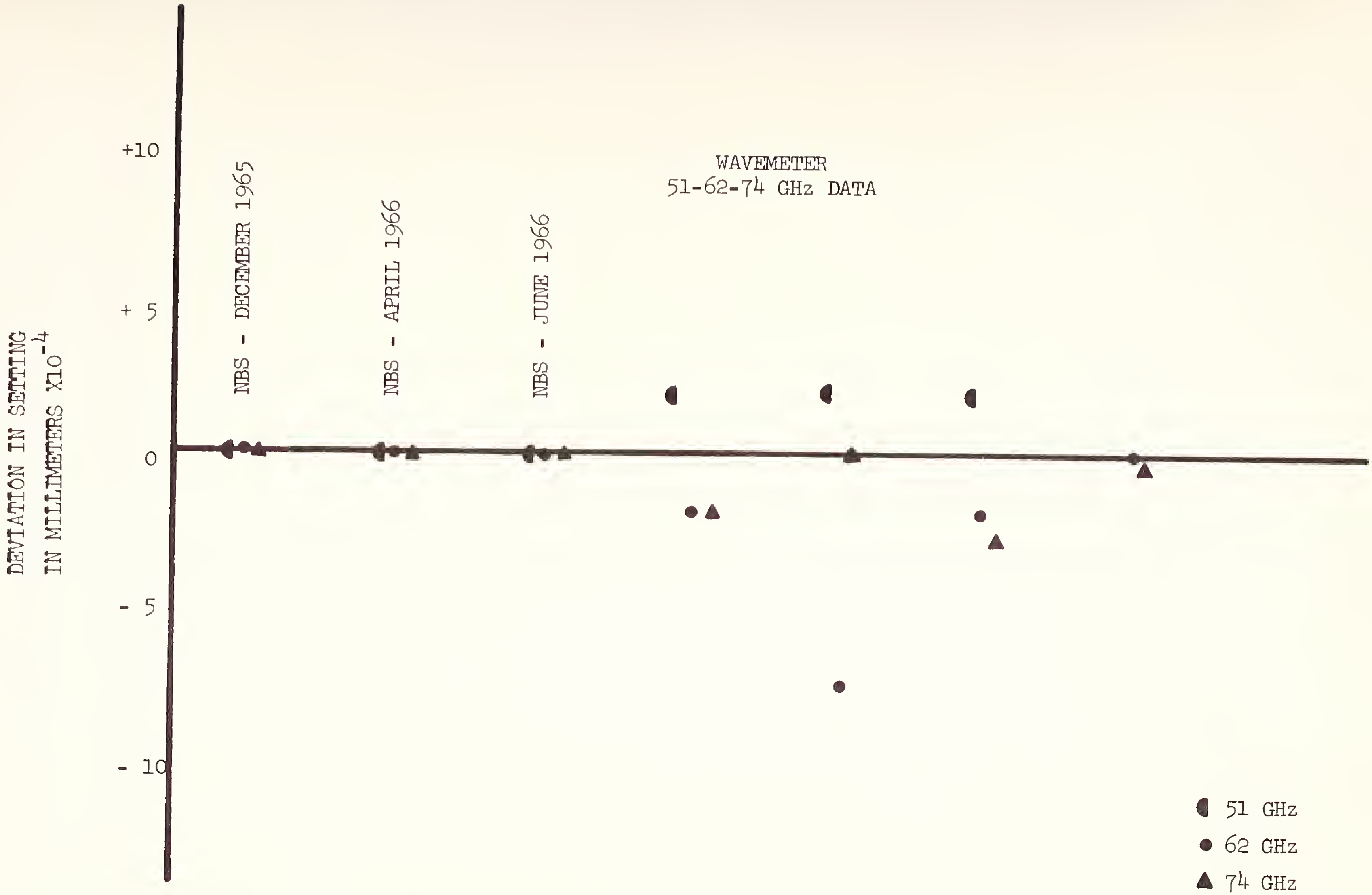


FIGURE 22. *Barnhart. Deviations for initial NBS value, computed by route supervisor, 51–62–74 GHz wavemeter.*

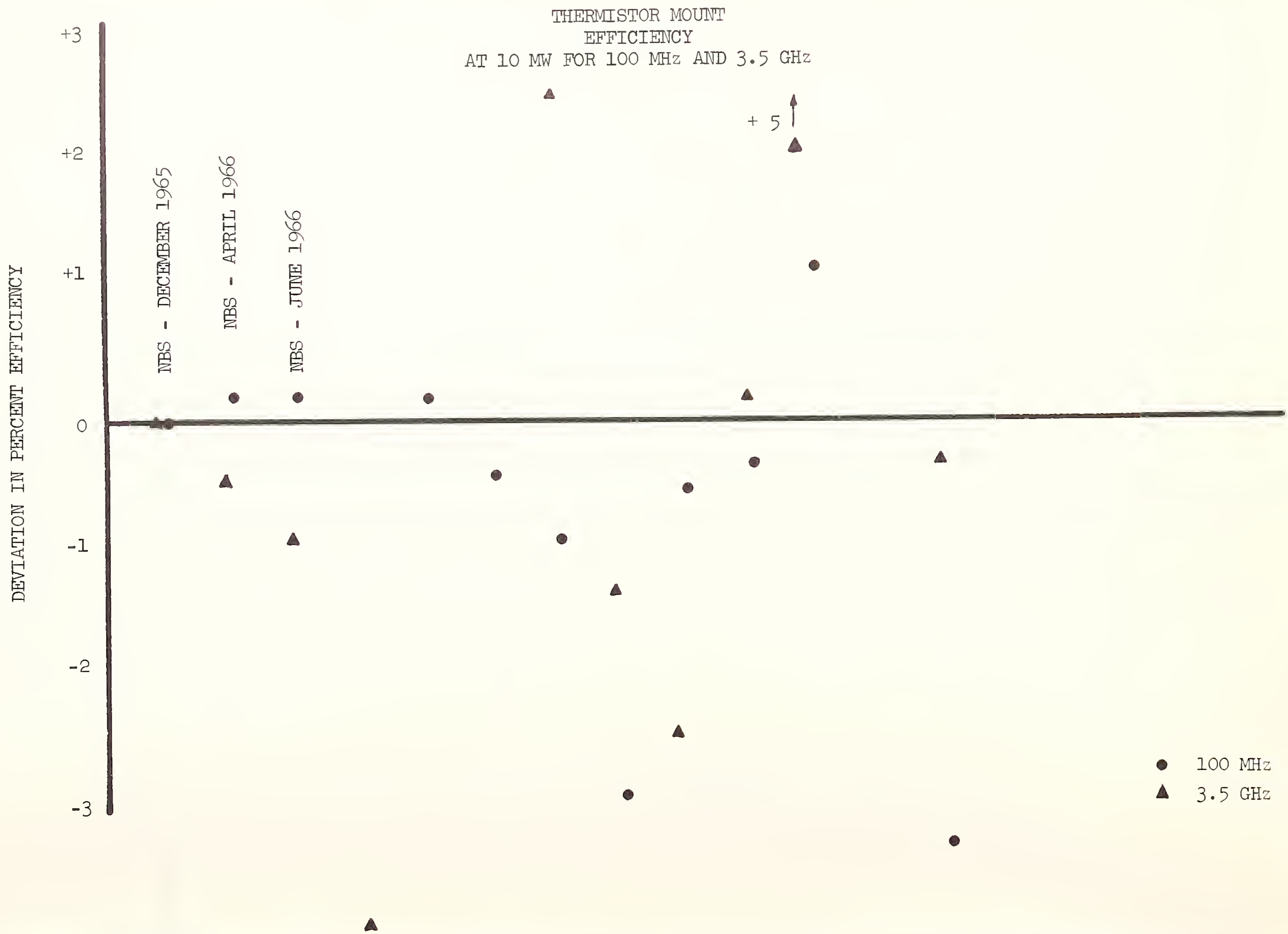


FIGURE 23. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for thermistor mount efficiency at 10 mW, 100 MHz and 3.5 GHz.*

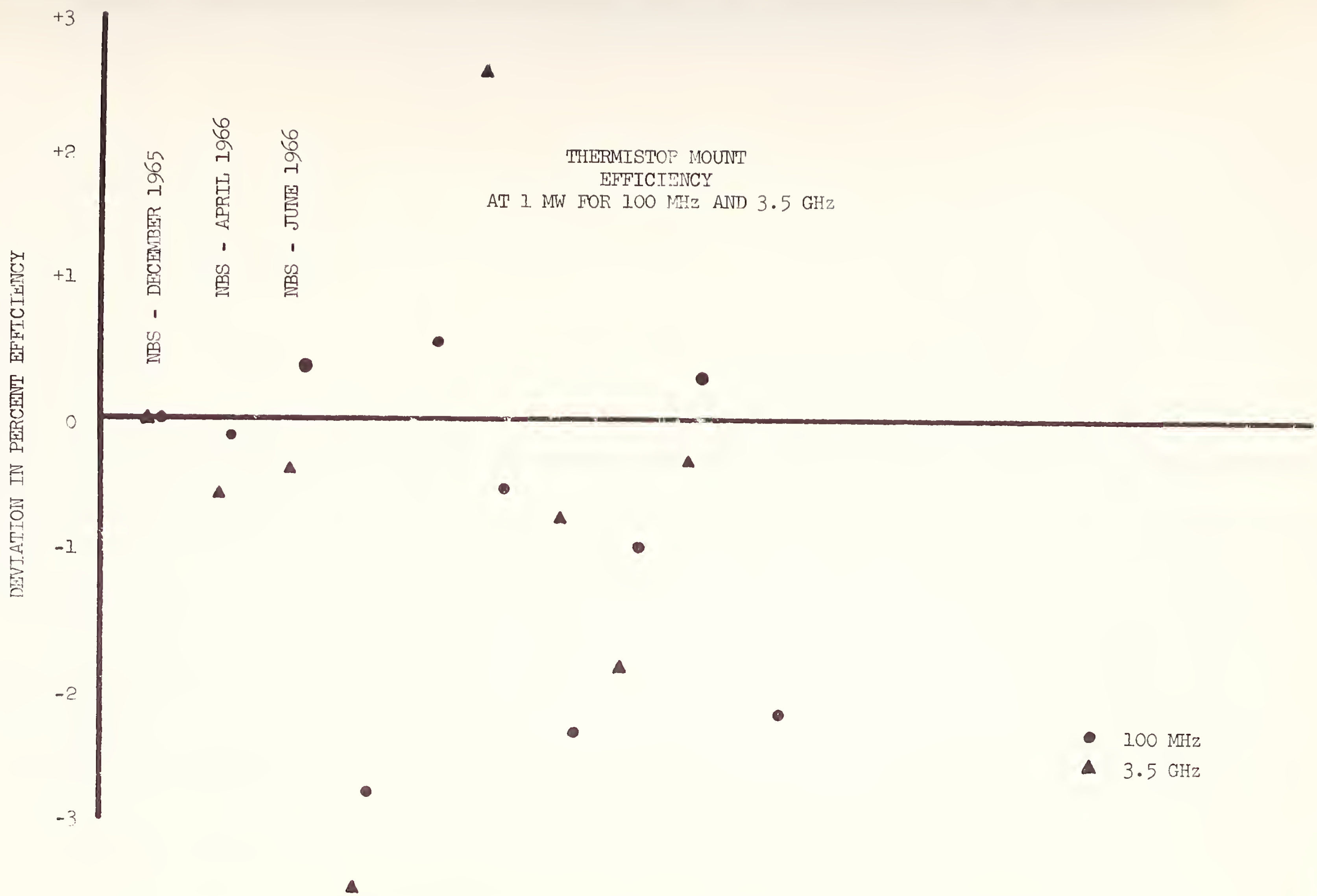


FIGURE 24. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for thermistor mount efficiency at 1 mW.*

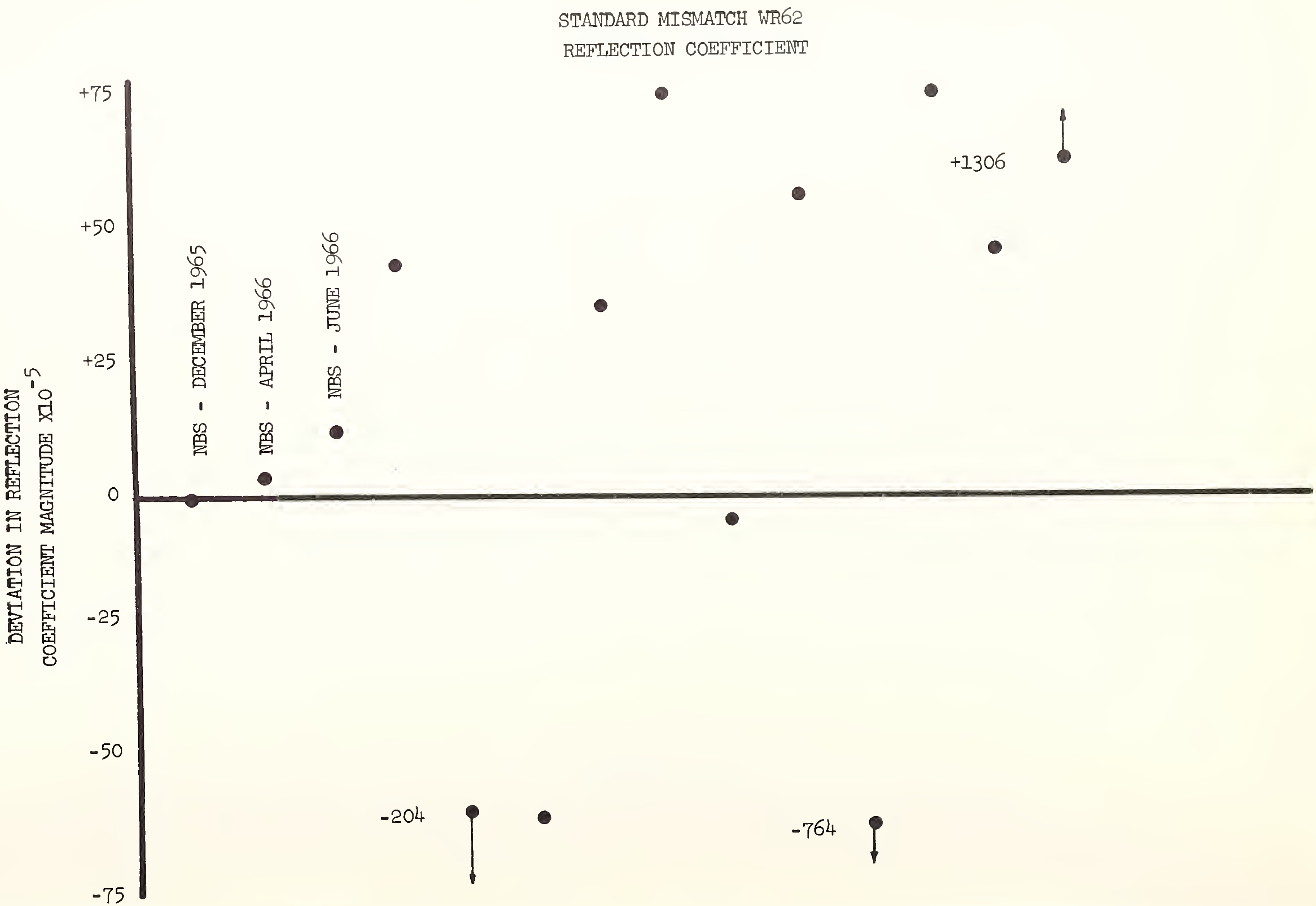


FIGURE 25. *Barnhart. Deviations from initial NBS value, computed by route supervisor, for reflection coefficient of standard mismatch, WR 62 waveguide.*

Mass-Dimension Comparison Physical Package

W. B. McCallum
General Electric Ordnance Dept., Pittsfield, Mass.

WEIGHTS 2kg – 100g — RECORDED VALUES AND ESTIMATED ACCURACIES — NCSL 1965–66 MAC

Participant	2kg (L)		2kg (S)		200g (L)		200g (S)		100g (L)		100g (S)	
	Value mg	EA ± mg	Value mg	EA ± mg	Value mg	EA ± mg	Value mg	EA ± mg	Value mg	EA ± mg	Value mg	EA ± mg
NBS	+96.81	0.7	+14.72	0.7	+39.38	0.25	+14.51	0.25	+19.46	0.25	+13.56	0.25
24J	+104.5	12.0	+20.7	12.0	+38.32	0.1	+14.42	0.1	+19.45	0.1	+13.6	0.1
21J	+98.0	1.5	+14.6	1.5	+39.5	1.0	+14.7	1.1	+19.44	0.1	+13.54	0.1
31K	+32.4	1.0	−44.8	1.0	+28.82	0.03	+3.72	0.3	+19.95	0.2	+11.85	0.02
57G	+9.8	0.6	+18.2	0.6	+39.4	105.00	+14.4	105.0	+19.4	55.0	+13.5	55.0
11D	+70.0	50.5	0	50.5	+40.45	0.3	+14.25	0.3	+18.55	0.15	+13.85	0.15
12K	…….	…….	…….	…….	+39.63	200.0	+14.45	200.0	+19.61	200.0	+14.34	200.0
49D	…….	…….	…….	…….	+39.48	…….	+14.53	…….	+19.44	…….	+13.80	…….
52D	…….	…….	…….	…….	+39.18	0.26	+14.04	0.26	+19.47	0.26	+13.55	0.26
41J	+78.0	10.0	+1.0	10.0	+51.5	1.0	−1.3	1.0	+19.41	0.12	+13.53	0.12
28K	+298.0	40.0	+213.0	40.0	+39.6	2.0	+14.5	2.0	+19.6	1.0	+14.1	1.0
23J	+98.7	8.0	+16.3	8.0	+39.55	0.7	+14.59	7.0	+19.5	0.4	+13.6	0.4
27J	…….	…….	…….	…….	…….	…….	…….	…….	+20.0	0.2	+10.0	0.2
43G	+100.0	…….	+17.0	…….	+39.5	…….	+14.6	…….	+19.29	…….	+13.45	…….
15J	+102.0	10.0	+23.0	10.0	+39.47	0.8	+14.49	0.8	+19.44	0.11	+13.59	0.11

Table 1, McCallum 2-16-67

WEIGHTS 1 g – 1 mg — RECORDED VALUES AND ESTIMATED ACCURACIES — NCSL 1965–66 MAC

Participant	1g		1g′		100 mg (PT)		100 mg (AL)		1mg	
	Value mg	EA ± mg	Value mg	EA ± mg	Value mg	EA ± mg	Value mg	EA ± mg	Value mg	EA ± mg
NBS	+.0238	0.004	−.0489	0.004	−.0169	0.003	−.755	0.010	−.0086	0.003
24J	+.018	0.01	−.046	0.01	+.011	0.01	−.852	0.01	+.013	0.01
21J	+.028	0.015	+.043	0.015	−.008	0.009	−.743	0.009	−.004	0.009
31K	−.024	0.01	+.047	0.01	…….	…….	−.755	0.001	−.007	0.0004
57G	−.008	15.0	+.003	15.00	−.015	9.0	−.767	9.0	−.006	24.0
11D	0	0.15	0	0.15	+.1	0.15	−.6	0.15	…….	…….
12K	+.019	10.0	−.021	10.0	−.012	10.0	−.149	10.0	−.007	6.0
49D	+.02	…….	−.03	…….	−.007	…….	−.654	…….	−.007	…….
52D	+.022	0.01	−.06	0.01	−.016	0.01	−.75	0.01	−.005	0.01
41J	+.018	14.0	−.025	14.0	−.014	14.0	−.742	14.0	+.002	14.0
28K	0	0.1	−.1	0.1	0	0.1	−.8	0.1	+.02	0.1
23J	+.028	0.021	−.048	0.021	−.017	0.006	−.754	0.022	−.005	0.009
27J	0	0.2	0	0.2	0	0.2	−.5	0.2	0	0.2
43G	+.020	0.034	−.048	0.034	−.005	0.006	−.737	0.007	−.006	0.006
15J	+.024	0.02	−.043	0.02	−.002	0.008	−.757	0.009	−.003	0.011

Table 2, McCallum 2-16-67

Participant	2kg(L)	2kg(S)	200g(L)	200(S)	100g(L)	100g(S)	1g	1g′	100mg (PT)	100mg (AL)	1mg
	(*mg*)	(*mg*)	(*mg*)	(*mg*)	(*mg*)	(*mg*)	(*mg*)	(*mg*)	(*mg*)	(*mg*)	(*mg*)
24J	7.69	5.98	1.06	0.09	0.01	0.04	.0058	.0029	.0279	.097	.0216
21J	1.19	0.12	0.12	0.19	0.02	0.02	.0042	.0919	.0089	.012	.0046
31K	64.41	59.52	10.56	10.79	0.49	1.71	.0478	.0959	....	0	.0016
57G	85.01	3.48	0.02	0.11	0.06	0.06	.0318	.0519	.0019	.012	.0026
11D	26.81	14.72	1.07	0.26	0.91	0.29	.0238	.0489	.1169	.155	....
12K	....	....	0.25	0.06	0.15	0.78	.0048	.0279	.0049	.606	.0016
49D	....	....	0.10	0.02	0.02	0.24	.0038	.0189	.0099	.101	.0016
52D	....	....	0.20	0.47	0.01	0.01	.0018	.0111	.0009	.005	.0036
41J	18.81	13.72	12.12	15.81	0.05	0.03	.0058	.0239	.0029	.013	.0106
28K	201.2	198.30	0.22	0.01	0.14	0.54	.0238	.0511	.0169	.045	.0286
23J	1.89	1.58	0.17	0.08	0.04	0.04	.0042	.0009	.0001	.001	.0036
27J	....	....	....	....	0.54	3.56	.0238	.0489	.0169	.255	.0086
43G	3.19	2.28	0.12	0.09	0.17	0.11	.0038	.0009	.0019	.018	.0026
15J	5.19	8.28	0.09	0.02	0.02	0.03	.0002	.0059	.0149	.002	.0056

Table 3, McCallum 2–16–67

GAGE BLOCKS RECORDED DIFFERENCE VALUES AND ESTIMATED ACCURACIES NCSL 1965–66 MAC

Participant	Gage Blocks—Steel				Gage Blocks—Chrome Carbide							
	B–682 0.650 in μ″	EA ±μ″	B–687 0.650 in μ″	EA ±μ″	B–1035 3.000 in μ″	EA ±μ″	B–1049 3.000 in μ″	EA ±μ″	RA12 2.000 in μ″	EA ±μ″	RA13 2.000 in μ″	EA ±μ″
NBS	+3.0	2.0	+2.0	2.0	+2.0	3.0	+3.0	3.0	+3.0	2.0	+3.0	2.0
55J	+2.6	2.0	+2.2	2.0	+0.8	3.0	+0.5	3.0	+1.9	2.0	+2.2	2.0
36D	+0.9	0.2	+0.9	0.2	+0.2	0.17	+0.5	0.27	−0.4	0.2	−0.4	0.2
21J	+2.4	2.9	+3.6	2.9	+3.8	5.8	+3.3	5.8	+3.6	4.9	+2.9	4.9
31K	+3.0	2.0	+2.0	2.0	0	3.0	0	3.0	−5 0	3.0	−6.0	3.0
57G	+2.0	3.0	+2.0	3.0	−1.0	3.0	+1.0	3.0	−3.0	3.0	−10.0	3.0
11D	+3.0	1.0	+3.0	1.0	+1.0	2.0	+2.0	2.0	+6.0	2.0	+6.0	2.0
27J	+8.0	3.0	+7.0	3.0	+5.0	3.0	+4.0	3.0	+2.0	3.0	+2.0	3.0
26D	+2.0	2.0	+2.0	2.0	−1.0	3.0	+3.0	3.0	+1.0	2.0	+5.0	2.0
41J	−3.0	9.0	−3.0	9.0	−29.0	15.0	−30.0	15.0	−17.0	9.0	−17.0	9.0
23J	+2.6	1.0	+2.7	1.0	+1.7	3.0	+3.2	3.0	+3.3	2.0	+3.3	2.0
43G	+0.91	1.3	+0.67	1.3	−1.93	3.7	−2.42	3.7	+0.42	2.2	+0.62	2.2

Table 4, McCallum 2–16–67

RECORDED VALUES AND ESTIMATED ACCURACIES

RING GAGES, ANGLE BLOCKS — NCSL 1965–66 MAC

Participant	Ring Gages				Angle Blocks			
	TN4–20770 Value Inches	EA ±μ''	SMC 25705 Value Inches	EA ±μ''	30° Value sec	EA ±sec	45° Value sec	EA ±sec
NBS	1.850185	10	1.850171	10	−1.2	1.0	+0.5	1.0
24J	1.850195	5	1.850180	5	−2.6	0.2	+1.5	0.2
36D	1.850192	2	1.850184	2	−0.1	0.07	+0.9	0.09
21J	1.850185	10	1.850172	10	−1.1	1.0	+0.3	1.0
31K	1.850168	8	1.850157	8	−1.2	6.0	+0.2	0.6
57G	1.850189	7	1.850178	7	+7.0	0.8	−5.0	0.8
11D	1.850183	10	1.850173	10	....	....	....	....
26D	1.850184	10	1.850172	10	−1.3	1.0	+1.0	1.0
41J	1.85020	10	1.85020	10	−2.3	1.5	−0.95	2.37
23J	1.850177	20	1.850163	20	−1.4	0.5	+0.25	0.5
27J	1.850198	3	1.850187	3	−4.7	3.0	−2.0	3.0
55J	1.850185	5	1.850195	5	−0.7	1.0	−0.8	1.0
43G	1.850165	15	1.850150	15	−0.39	0.9	+0.37	1.0

Table 5, McCallum 2–16–67

OPTICAL PYROMETER — RECORDED VALUES AND ESTIMATED ACCURACIES — NCSL 1965–66 MAC

Participant	Low scale						High scale					
	1,600 °F		1,900 °F		2,200 °F		2,200 °F		2,600 °F		3,000 °F	
	Value °F	EA ±F°	Value °F	EA ±F°	Value °F	EA ±F°	Value °F	EA ±F°	Value °F	EA ±F°	Value °F	EA ±F°
NBS	1,605.0	7.0	1,904.0	6.0	2,210.0	7.0	2,205.0	7.0	2,607.0	8.0	3,015.0	10.0
21J	1,603.0	30.0	1,895.0	40.0	2,204.0	40.0	2,201.0	40.0	2,608.0	45.0	3,018.0	50.0
31K	1,606.0	4.0	1,906.0	4.0	....	....	2,208.0	4.0	2,609.0	4.0	3,015.0	4.0
57G	1,597.0	4.0	1,893.0	4.5	2,187.0	5.0	2,191.0	5.0	2,593.0	5.5	2,986.0	6.0
41J	1,596.0	12.0	1,894.0	10.0	2,208.0	10.0	2,204.0	10.0	2,585.0	12.0	2,999.0	12.0
28K	1,606.0	7.0	1,905.0	6.0	2,209.0	7.0	2,208.0	8.0	2,606.0	10.0	3,011.0	10.0
23J	1,600.0	9.0	1,902.0	8.0	2,209.0	8.0	2,206.0	10.0	2,608.0	10.0	3,021.0	12.0
43G	1,605.7	9.5	1,906.5	7.5	2,211.4	8.0	2,209.2	8.0	2,609.1	9.2	3,013.7	10.3

Table 6, McCallum 2–16–67

256–114 O–67—5

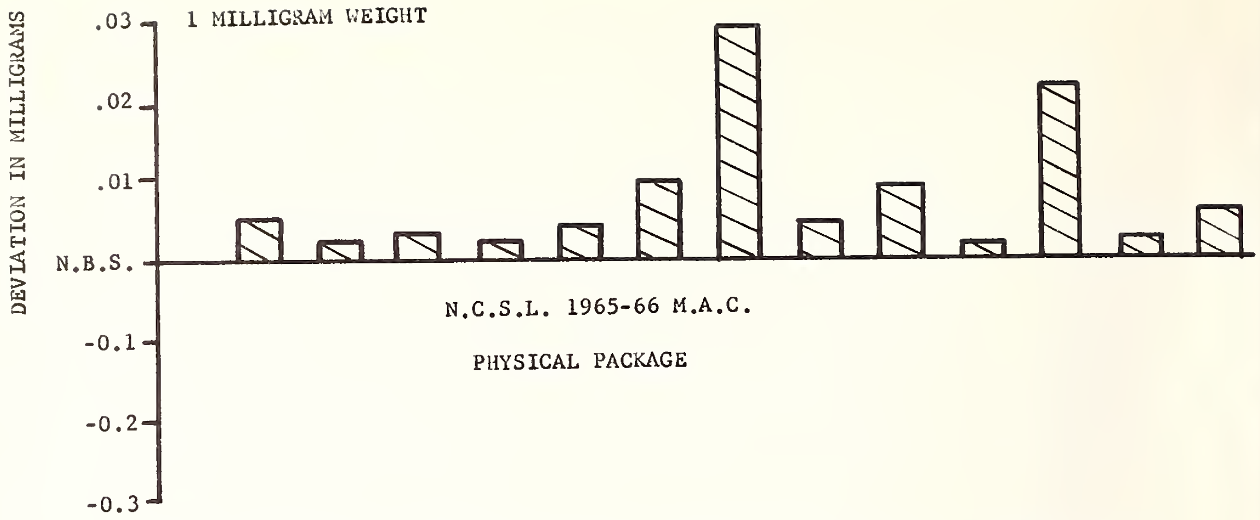


FIGURE 1. *McCallum. Deviations from NBS value, computed by route supervisor, for 1-milligram weight.*

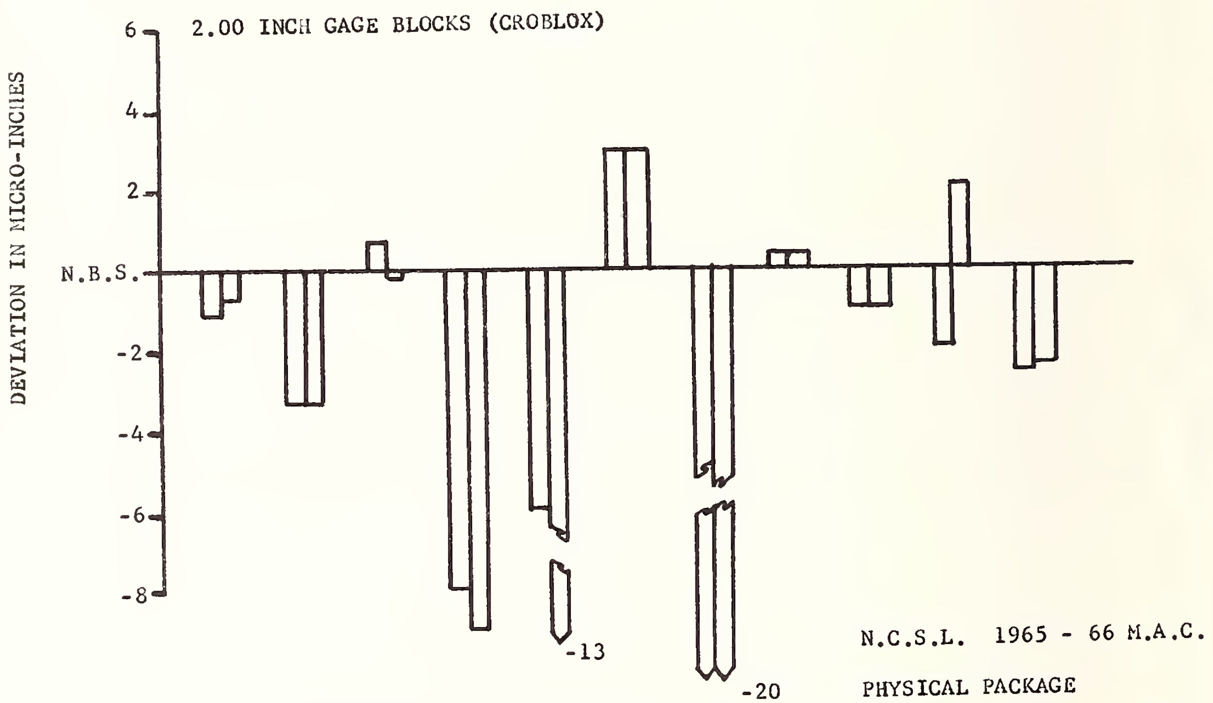


FIGURE 2. *McCallum. Deviations from NBS value, computed by route supervisor, for 2.00-in gage blocks' chrome steel.*

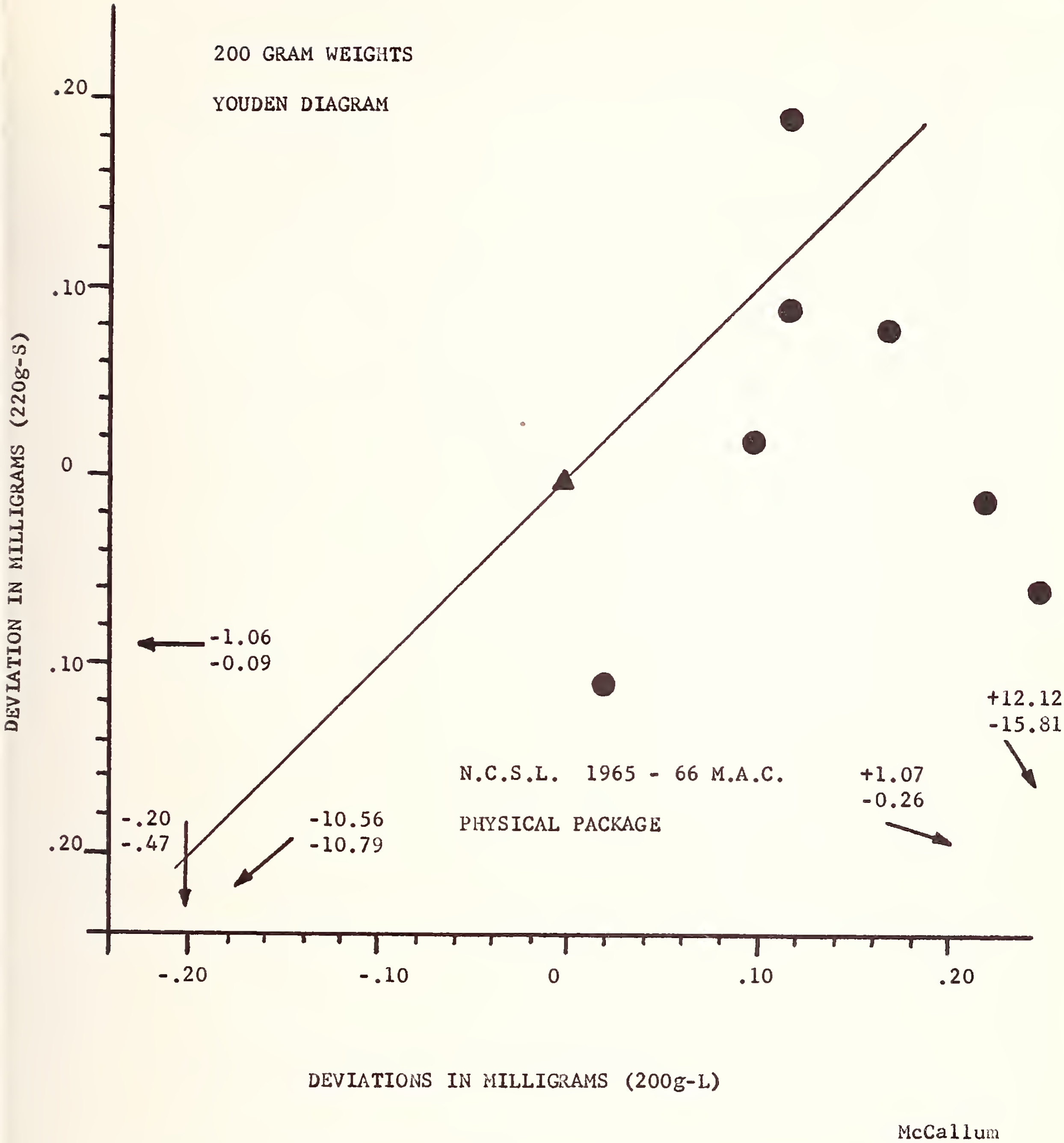


FIGURE 3. *McCallum. Youden diagram for a pair of 200-g weights, referenced to NBS value.*

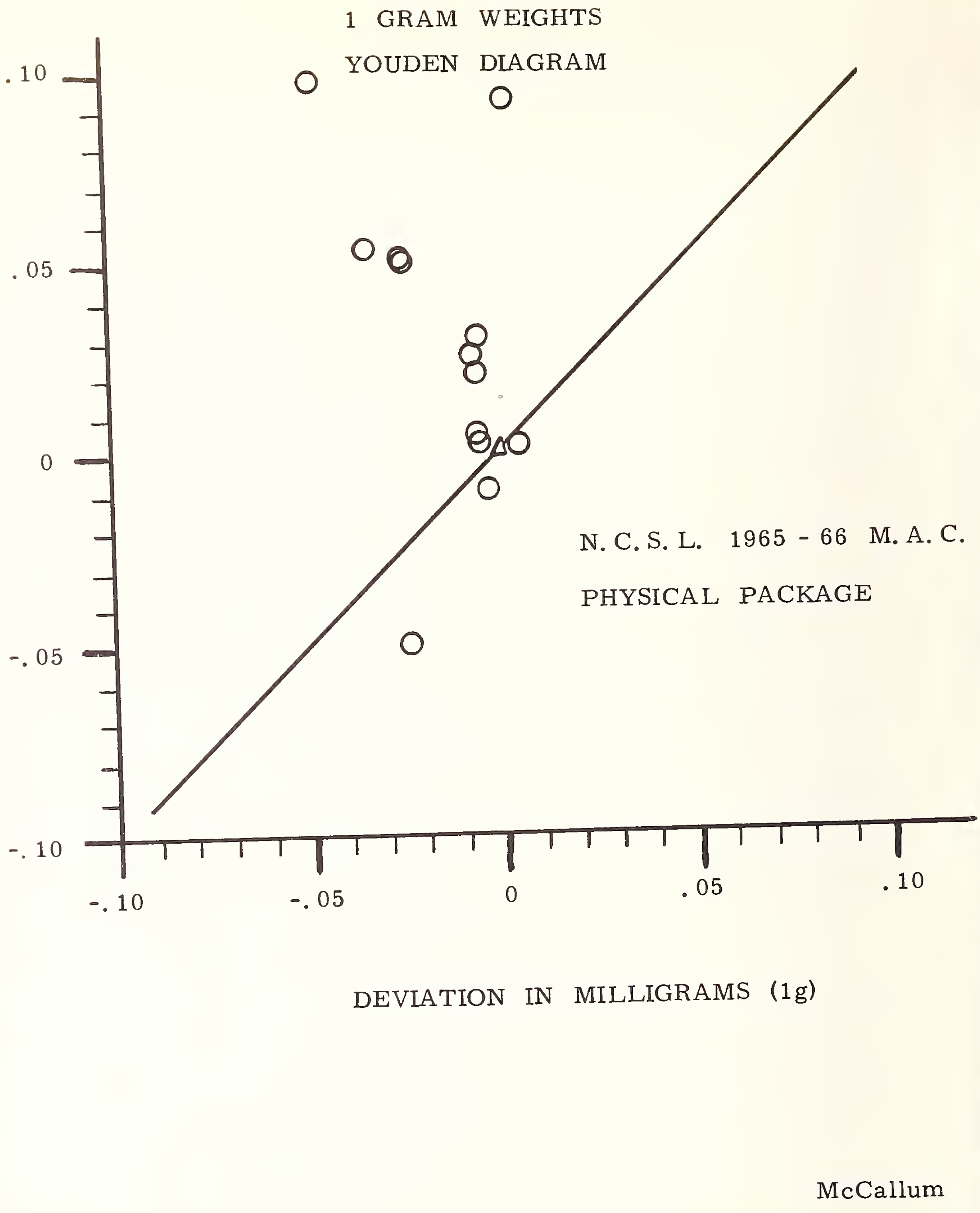


FIGURE 4. *McCallum. Youden diagram for a pair of 1-g weights, referenced to NBS value.*

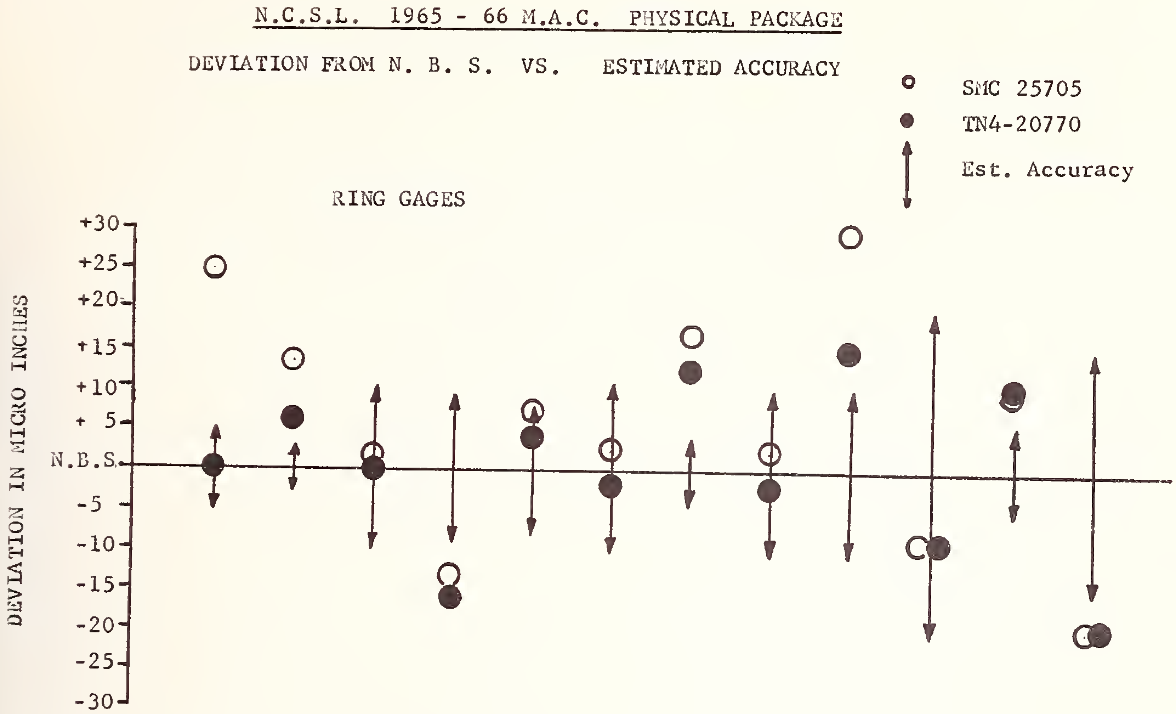


FIGURE 5. *McCallum. Deviations from NBS value, computed by route supervisor, for a pair of 1.85-in ring gages.*

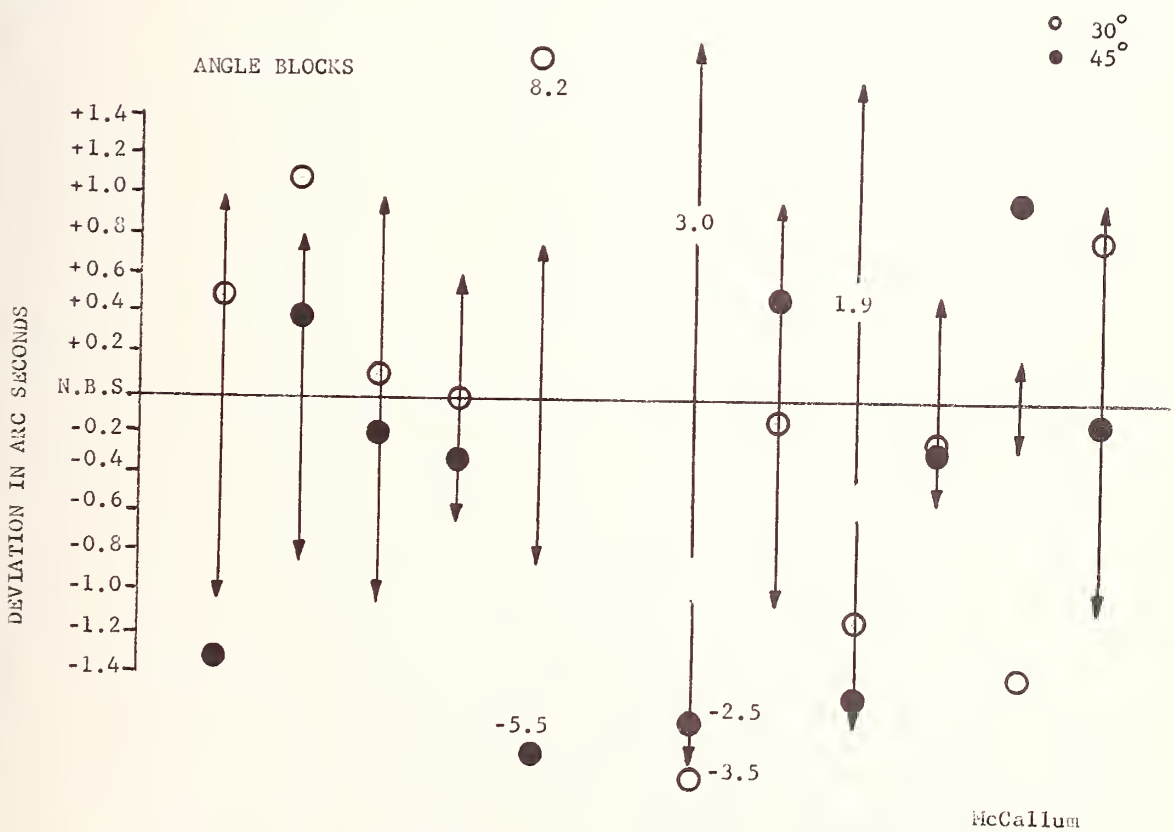


FIGURE 6. *McCallum. Deviations from NBS value, computed by route supervisor, for a pair of angle blocks.*

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SESSION 2. WHY CALIBRATE?

Chairman: J. L. Hayes, Metrology Technical Director,
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Session 2 consisted of a fifteen-minute animated (cartoon) color film entitled "Why Calibrate." The film was produced for the Quality and Reliability group of the Navy's Special Projects Office where direction of the POLARIS program emanates. The film was under the technical direction of the Navy's Metrology Engineering Center located at the Naval Plant Representative Office, Pomona, California.

The purpose of the film was to motivate personnel who deal with test equipment at all levels of operation (from the bench technician to the head of the entire organization) toward a better appreciation and understanding of the essentiality of calibration. By use of cartoon characters drawn from naval history circa 1800, the film shows first, the necessity for test equipment to measure weapon systems and their components to ensure operational readiness (both in the fleet and at shore production facilities); thence the necessity of *controlled* measurements at all these sites to ensure interchangeability, quality, and reliability of products; thence the necessity for calibration, to assure that all test equipment is within specifications by periodically testing it, and to assure that all measurements made by the test equipment relate to common measurement references or standards. The importance of calibration to mission success and product quality and reliability are summarized.

The film is presently in the process of being screened by DOD for release to the general public. Until official releases are made (and announced through the NCSL Newsletter and other technical journals) the film may be obtained by government contractors on a short-term-loan basis by sending a request via their cognizant contract administration or inspection agency to the nearest Naval District Headquarters, Attn: Film Library.

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SESSION 3. STATISTICAL PROCEDURES

DeWayne B. Sharpe, Chairman

Introduction

D. B. Sharpe, IBM Corporation, San Jose, California 95114

The Statistical Procedures Committee is a new one, and its creation symbolizes a new concept in metrology. Its formation recognizes measurement requirements which cannot be met simply by buying better equipment, but only by emphasizing technique and analysis. This emphasis has been seen in very few areas in the past.

The committee's first and most important task was to recruit members who have the interest and background to help with a project of this scope. The goal of the committee as assigned by NCSL is to: "Develop specific or generalized methods for compilation and analysis of measurement and calibration data by statistical or computational procedures". This means we must develop tools and communication links to bridge the gap between the practical metrologist and the statistician. This committee is not specifically oriented to computer or electronic data processing equipment, but it is obvious that this work will require some mechanical or electronic help. To become convinced that help will be needed, one has only to look at the vast array of data taken by even a small standards laboratory or at the calculations required to reduce this data.

We metrologists must learn how and when to use that help to best advantage. To do that we must learn to communicate between ourselves. Even more important, we have to communicate with our computers through the statisticians, mathematicians and programmers. This is where the NCSL's Statistical Procedures Committee can help. If we can help provide that communications link, we will have served our purpose.

Many of you may have seen the article entitled "New Measurement Communication Under Way" in the April issue of *Electronic Procurement*. This article quoted and commented on Dr. Astin's remarks before the American Standards Association meeting. A special point was made of the expanded communications made possible by increased use of the units of the International System and by the "systems" approach to measurement standards.

This discussion made me realize that our committee has a two-fold communications problem in our consideration of statistical procedures. First, even the practitioners of this art of measurement (and I think all of you will agree that it is still as much Art as it is Science) do not always mean the same thing when they use the same terms. In fact, there was a discussion during the session on the current Measurement Agreement Comparison about what was meant by "uncertainty". It is going to be very difficult for us to set up statistical procedures to analyze uncertainty if we are not talking about the same uncertainty. This is the first or verbal semantics part of our communications barrier.

Secondly, our computers and electronic or automatic data processing equipment have a language which has semantic problems too. Computers, being rather simple-minded animals, tend to have special languages which only they understand. Whole groups of people called programmers are busily employed interpreting what we laymen say into language the computer can understand. To compound the problem, the computers manufactured by different companies do not use the same language, and even within the same company programs written for one machine type are not necessarily usable on another type of machine.

These then are our communications problems—just a few of the things which keep us from doing the job we would like to do. We certainly are not the first people in history to have a semantics problem, but when we brag about our efforts toward "standardization" it seems to me we ought to be doing something about standardizing our communications.

We hope this committee can serve you by recommending and disseminating a glossary of terms to be used in data reduction, and by doing the same thing for procedures for statistical evaluation of the measurement processes. Finally, we hope to be able to recommend standards for computer programs to facilitate their interchange among interested laboratories. We have not yet devised a system for interchanging these procedures, but this obviously is a goal we should strive toward.

Some time back, Joe Cameron listed three major tasks as he saw them:

1. To establish guidelines for statistical evaluation of procedures for the measurement process.

2. To develop procedures for review and dissemination of proposed methods for physical and statistical analysis for individual measurement processes.

3. To develop guidelines and review procedures to insure adequacy of content and interchangeability of computer programs and to serve as a clearinghouse for computer programming efforts by providing a means for disseminating information on existing programs.

I cannot improve upon those goals, but I do feel we need to add two others to them. They are:

4. Provide a language of agreed-upon terms to aid this communications problem.

5. To find ways of stating uncertainty, accuracy, confidence and the host of similar terms which will be acceptable to the metrologist, to the statistician, to the computer and, most important, to the user of the measurement equipment.

An Approach to the Measurement Process

J. M. Cameron, National Bureau of Standards, Washington, D.C. 20234

In an industrial process where it is important that the output of the process be within prescribed limits, certain process parameters have to be known and maintained within their own control limits. For a measurement process one must do likewise if the uncertainty limits, which bear the same role as the tolerance limits on a process, are to have credibility. It is useful to view the measurement of a single item as a production process whose output is a sequence of non-identical numbers. The description of such a process and the study of the properties of such sequence of measurements is one of the tasks of metrology.

Note that it is the process that remains as the principal feature—the equipment, the operators, the procedures used, and the objects calibrated—these pass on to other destinations. Fortunately, many calibration processes, although sited in different laboratories, involve essentially the same equipment, the same procedures, and the same environmental controls. Hence, the definition of what constitutes a single measurement or what constitutes the calibration of an unknown is nearly the same at all locations, or hopefully can be made to be that way. It is this feature of the measurement system that leads to the compatibility and consistency of measurement in this country and makes possible the viewing of the whole aggregate as a measurement system. Because of this conscious attempt to achieve uniformity, one would expect to be able to exploit modern computers in reporting on these processes. As a matter of fact, under the usual manpower limitations, computer utilization becomes almost essential if one is to perform the analysis needed to maintain surveillance on the process and to demonstrate that the present results are usable. Computer programs to accomplish this would have a degree of universality and their dissemination would certainly help to unify our measurement system. Because one must specify to the computer exactly what it is to do in terms of the basic arithmetic operations, it is essential that one have an extremely detailed statement of what the process is, what values are to be measured (and how), what corrections are to be applied, what tests of both environmental and measurement parameters must be passed for acceptability, and what methods should be used in assessing the errors, both systematic and random.

Another by-product of having a computer process the data is that one can maintain one's laboratory notebook on the machine. We have made some attempts in this direction here at the Bureau. An advantage of this is that the machine can perform all the numerical checks that one considers necessary, including the preliminary tests involving differences that one ordinarily looks at. This will avoid "conditioning" the data by judgments made prior to getting all the data and thereby, perhaps, biasing what is going on.

The final report should include administrative matters such as the name and address of the people involved, and so forth. It should include the actual data and their analysis and also the report of test. One of the most important outputs of any program of this kind is related to the behavior of the process, providing information for updating the process parameters and making sure they are still in control. This will make possible studies of process performance and facilitate the conducting of experiments on the measurement process as it stands, in much the same way one does with an industrial process.

The role of this committee would be to focus attention on matters relating to the statistical-analysis and data-handling aspects. For example, it is essential that one check on the input data to a computer program; if it is known that all the readings must be positive, a check on this should be made. Requirements on data checking ought to be written into specifications for a computer program for use in calibration. There should be certain statistical tests for the conformity of today's values with the process from which it arises, so that when they are within the desired limits, one knows that the process is in a state of control, a fact upon which the uncertainty statement relies. The role of the statistician and the computer expert is to call attention to the methodology they have available, to assist the metrologist in using to the fullest the information that may be locked up in his laboratory notebook for lack of computing manpower. The committee's role should be to launch a collaborative effort to develop standards for the documentation of programs, so that they serve as a lucid means for communication and as a positive influence in achieving interlaboratory comparability.

An example of what is possible may be found in the December 1965 issue of the "NBS Technical News Bulletin", which announced that a computer program for thermocouple tables had been developed by R. L. Powell and L. L. Sparks of the Cryogenic Properties of Solids Section of the Boulder laboratories of the Bureau. They will provide a computer program to enable you to compute your correction tables for the range from 4° Kelvin to about 300 °K (approximately room temperature). The user can measure the EMF of a thermocouple at several known temperatures and then utilize the program to print out an error table for that particular thermocouple.

The Anaheim Survey on EDP Usage

D. B. Sharpe

When this committee was first suggested at the NCSL workshop in 1965 in Anaheim, we made a spontaneously designed survey. There were some 38 people who completed this questionnaire. It was a fair sampling of the people in the industry. Considering the short time that was spent in getting it out, we got some rather interesting comments.

First of all, we asked how many people were using some form of automatic data processing equipment at that time. Seventy-nine percent said they were using some kind of EDP equipment for one purpose or another. About 10 percent, 4 people, said they were using it for parameter and data reduction only. Another 10 percent said they were using it for calibration recall data, work accountability, or manpower controls. Six people, or about 15 percent, said they were using EDP equipment for several of those purposes. Another 12 people, or 30 percent, said they were using EDP, but didn't mention the specific uses. There were 10 percent who said they planned to use EDP equipment for one or another use in the very near future. Thus about 80 percent of the respondents either used or planned to use EDP equipment in conjunction with their calibration and standards laboratory activities. To get an idea of what the future of exchanging or sharing programs might be, we asked if they could provide programs for outside use. Eleven of the 38 said they were sure they could, and another 10 said they'd have to check. Only 5 were sure they could *not* share programs, and the rest either said might be able to, or did not respond. So I would look forward to a future program similar to our NCSL Procedures Library, by which we could share programming information also.

This was a first try at a questionnaire to see what kind of interest there might be. We intend to prepare a more comprehensive questionnaire, and mail copies to all attendees at this conference. We would like each of you to complete it to the best of your ability. Even more important are your comments, criticisms, and suggestions, which we would certainly appreciate to help guide us in future efforts.

With the idea of getting some help on this committee, our survey also asked how many would be able to help develop or coordinate programs. Surprisingly enough, a larger percentage said they'd be interested in helping than were actually using EDP. This is most encouraging, for the committee's primary task has been to recruit members who have the interest and background to help with a project of this scope. If you would like to volunteer yourself or if you have some bright young engineer or statistician in your group who would like to work on this please contact me or Mr. Cameron.

Session 4. Information for Standards Laboratories—What?—Where?

Orval L. Linebrink, Chairman
Batelle Memorial Institute, Columbus, Ohio

Introduction

I wish to take just a few minutes to give a framework within which we can direct the presentations and our discussions this afternoon. The Information Committee, as you oldsters in NCSL may have noticed, has changed its title in the process of evolution. Originally it considered an information center, predicated on the tact that we should have an Information Center. The current assignment to the committee drops the word "Center". The work is directed more toward identifying information of interest to standards laboratories and promoting its dissemination. The committee has done a number of things, perhaps its most productive effort being a workshop held a year ago at Columbus, Ohio. At that workshop, a large variety of information questions were discussed, and a number of projects were suggested, some of which have been attempted and some of which are still being considered. One in particular was that of having each of the member organizations share in the building of a standards bibliography of reference sources. Announcements were made in the NCSL Newsletter, but we haven't had very much response in the way of contributions. Another interesting suggestion coming out of that workshop was that one of the things people in standards laboratories need is a reference list of people who are experts in the various areas of metrology. You might be thinking about this, because I want this session to be largely an audience participation session, and you will have your opportunity to not only contribute but to ask questions. In planning for a session here, we found there was considerable confusion about this so-called information explosion. The fragmentation is considerable when one looks for standards laboratories type information. We looked around to see what keys to this information existed. In the new Federal Clearinghouse Announcements listing the various categories of information, we find that about the closest it comes to measurement standards is the broad title Instrumentation and Control. Our committee has been in contact with the management of the Clearinghouse and we have received some consideration in this matter, but I think the specific action to correct this is still pending. We hope that a more definitive category can be developed.

For this particular session, we want to ask ourselves, "What is it we are looking for?" "What are the information bits that standards laboratory people need?" We have three of the panel members here. There was to be a fourth, but due to a change in jobs, Charles Stone will not be with us. The panel that will be presenting ideas to you comprises Frank Sciacchitano from Grumman Aircraft; Dick Frick, who is not able to be here but has sent a substitute—Lawrence Darling from Univac, Utica branch; Eshmal Porter from McDonnell Aircraft, and Dr. H. L. Mason from NBS. The first three of these gentlemen will be speaking from the standpoint of what their own laboratories need, and Dr. Mason will give us some clues as to where this information might be found. Then we will have a discussion among the panel members and among members of the audience.

You be thinking about what do you need, and if you need something these gentlemen don't bring out, by all means bring it to our attention. We are going to have a Committee Meeting this evening in which we hope to tie up the bits of information from this session into a program of action for the future.

Information Needs and Their Satisfaction

Frank J. Sciacchitano, Grumman Aircraft Engineering Corporation, Bethpage, Long Island, N.Y.

In order to acquire a variety of opinions on the information needs of a standards laboratory, I devised a questionnaire for submittal to key personnel in the different elements of Grumman Aircraft's calibration system. It listed about a dozen topics thought to be of prime interest in the operation of a standards laboratory. People were asked if they would indicate their sources of information on these topics, what they thought of these sources in terms of adequacy, and what they would like to see to assist them in obtaining better information. Their answers and comments have been arranged in a composite that we hope will be a meaningful observation on the information habits of our different laboratory stations.

The topics are numbered in an order of satisfaction, the first being considered most satisfactory in terms of information available, while the last were found to have sparse references or references needing more clarification.

TOPICS: 1) Establishing the need and requirements of a Standards Laboratory (scope, size, and structure); 2) Environmental Design; 3) Administration.

SOURCES: a. Attendance at symposia, conferences, workshops, seminars of technical societies and NBS.

b. Proceedings of technical societies such as (1) 16th Annual ISA Conference, 1961; (2) 1962 NCSL Standards Laboratory Conference, NBS Misc. Pub. 248.

c. Periodicals such as ISA Journal, IEEE Spectrum, Instruments and Control Systems.

d. Miscellaneous sources like (1) George Washington University Lecture Notes, June 1962; (2) Laboratory Practice notebooks of military calibration agencies; (3) NBS publications, such as Circ. 578, Suggested Practices for Electrical Standardizing Laboratories.

TOPIC 4: Equipping a Laboratory

SOURCES: a. Manufacturers' manuals.

b. Opinions of other users, our own technicians, our sub-contractors, other similar laboratories.

TOPIC 5: State-of-the-art Awareness

SOURCES: a. NBS periodicals such as Technical News Bulletin and Journal of Research.

b. Technical society publications (mentioned above).

c. Manufacturers' bulletins re their measurement studies.

d. Visits with NBS personnel.

TOPIC 6: Personnel Training

SOURCES: a. Proceedings of the 1962 Standards Laboratory Conference—NBS Misc. Pub. 248.

b. Training course outlines, such as those of ISA.

TOPICS: 7) Work Flow Techniques; 8) Data Handling Techniques; 9) Recall System Methods; 10) Instrument Performance Analysis.

SOURCES: a. Company EDP and ADP programs.

b. Some information in technical society proceedings and publications.

TOPIC 10: Calibration Procedures

SOURCES: a. I.C.P.'s, T.O.'s, Manufacturers' manuals, MIL–C–24133.

b. NCSL Calibration Procedures Library.

TOPICS: 12) Traceability Policy; 13) Accuracy Ratio Policy; 14) Calibration Interval Policy.

SOURCES: a. DOD documents such as MIL–Q–9858, MIL–C–45662, MIL Handbook 52, SLIM, BuWeps Instructions, Pomona Metrology Handbook.

b. NASA documents, such as NPC–200–2–3, SP 89–Q, NHB5300.2, etc.

Summary of Comments Offered

(1) Although there appears to be a relatively large amount of information available to operators of standards laboratories, it is the opinion of our people that some improvement is desirable. First of all, there appears to be too much duplication of the same subject(s)—generated by too many different agencies. The user is faced with forcing a composite and perhaps expensive solution to fulfill the sum of all such specifications. Secondly, the terminology is often unclear, appears evasive in some cases, and is open to varying degrees of interpretation. Such terms as "error ratio", "approved laboratories", "reliable equipment shall be used", "approved environment", etc. are considered to be equivocal and subject to wide differences of opinion by customer and contractor alike.

(2) It is hoped that somewhere an impartial, highly objective body (this might be NCSL and/or NBS) will be established to act as a clearinghouse that hopefully could reduce the number of specification documents that the contractor must use in making technical and operational decisions. Also, that the resulting minimal document(s) will be written in clear unequivocal language, not only to define the customers' wishes, but also to assist the laboratory staff and company management in estimating and justifying the costs of calibration.

The Collection and Use of Data

Lawrence Darling, Univac Corp., Utica, N.Y.

Since I am substituting here at short notice, I am due a certain amount of leeway, I think, so I am going to deviate a bit from the stated program and concentrate on one specific problem—Standards Laboratory Data Reduction. Maybe that is a rather odd thing for a man from Univac to discuss. The point is that we can collect a lot of data on our standards, but then to handle this data in an economical manner is really the key problem. It probably takes us about three times as long to process the data as it does to collect it. From an economical viewpoint, this involves a lot of money. Of course, we do have some of this data on a computer, but it has to get to the computer, and after it gets out of the computer it has to be used.

I have discussed the problem with quite a few people and have found there is very little effort put forth to devise an economical way of collecting the data. It is rather expensive to have a technician be an expert on both the reduction of data and the instrumentation for collecting data. Let the experts or the computer do the reduction. What the technician needs is a very simple and straightforward format to follow in recording his results, but I have not found one that did not require a great deal of effort. In a small standards laboratory such as we are, one doesn't do the same thing every day, so we cannot trust this to memory. This simply reinforces the fact that we need a precise way of collecting the data at our regular calibration facilities and at a routine level. How do we really know that we need to check every little piece? How effective is our checking if we don't have some way to pump this information back into the calibration system? We need a simple system for collecting data and for utilizing it in a way that is compatible with the work of a statistical committee. It does not need as sophisticated a scheme as was discussed this morning, but a simple procedure, first for collection and then for use.

In the small laboratory, the manager has to wear many hats, and he cannot be really expert in all technical aspects, and in economic aspects and managerial aspects as well. A nice, concise text that contains an outline of the latter two in one cover would be very handy. I have never seen such a publication, but this would be very useful to a manager. It would be food for thought and perhaps give him some guidelines from which he could operate.

We feel we need in our laboratory separate statements of the derivation, the implementation, and precise examples of calibration information. Most periodical articles have all three of these aspects intermixed. However, we are dealing with three different levels of personnel; we don't need to know the derivation while we are collecting data, and we don't need to know what to do with it while we are collecting it. If there were more examples given on each of the subjects discussed, this would be a great help. A definition of the terms used would also be an asset, and could be included at the beginning of each article. We would then have a fighting chance of extracting from the article what the writer has to offer us.

The Laboratory: A Complex Instrument

E. L. Porter, McDonnell Aircraft Co., St. Louis, Mo.

Before purchasing a new instrument, it is common practice to study, very carefully, all information available on that instrument, and if possible to evaluate similar instruments under conditions of use. When the instrument is purchased for use in the laboratory, it comes usually with a manual containing information for its use, care, and maintenance. One might admit, of course, that this information is not absolutely essential, but it is certainly helpful. A standards laboratory might be considered, from a company point of view, as an instrument purchased for the purpose of helping to assure product quality through good measurements. This instrument is quite complicated, even in its simplest form. Purchasers of such an instrument, however, are seldom provided with the usual condensed specification which describes in detail how much floor space is required; what kind of power and other utilities will be necessary; or what environmental conditions must be provided for proper instrument performance.

There is no table of performance specifications which describes range, accuracy, or reliability of this unique instrument—not even a statement or guarantee of quality. The truth is that this is a do-it-yourself project with as many parts as needed and few instructions. There is available, however, a lot of useful information which if used wisely can save headaches and save the purchaser money. Perhaps the information available may not apply directly to the specific problem under consideration, but it will be useful to have an understanding of space and environmental requirements, work-flow planning, recall cycles, automated or manual record-and-recall systems, personnel training, calibration costs, maintenance programs, and staffing and support requirements. This information is needed not only before purchase but after installation to help maintain a properly functioning instrument.

The purchaser is, of course, interested in what can be done with this instrument, how well it performs, and how much it costs. This is a matter of some choice, and decisions should be based upon a knowledge of several important factors. Information is needed to make these decisions wisely. Based upon requirements for the parameters to be measured, their range, accuracy, and the extent to which the standards laboratory is to operate independently of such support as NBS calibration; what measurement techniques exist and which of these best fit the requirements for range, accuracy, and cost? Do these techniques lend themselves to available commerical equipment? Can they be upgraded in performance if necessary? Do they offer the degree of effectiveness required? How can the various parameters measured be most effectively related through NBS to the rest of the National Measurement System?

The continued proper functioning of the standards laboratory will require that its management keep informed. As changes occur in our National Measurement System the individual laboratory must relate to them. Management techniques can be improved through the use of up-to-date information prepared by people who are working with new ideas and trying to achieve greater effectiveness or efficiency.

The measurement staff of this standards laboratory also needs information. Technological advances in the instrument field bring new instruments which require new measurement techniques, greater accuracy, and the development of new measurement capabilities in the laboratory. Through pioneering activities, not only in NBS, but in the universities and many industrial organizations, the state of the art in precision measurement is constantly being advanced in many directions. Unless the staff maintains awareness of these changes, substandard performance or needless expenditures for equipment may result.

If precision measurements are to be practical, they must in most cases be related to the definite needs of the manufacturing or field activity they support. A standards laboratory staff worth its salt can assist the test engineer or technician who is trying to make good measurements under less than ideal conditions. His work requires a knowledge of instrumentation and a thorough grounding in the theory of measurements and equipment, and will be helped by explanation of new instrumentation methods.

This brief outline touches only a part of the information needed by the people involved in the operation of a standards laboratory. Their needs of course will vary, and depend on many factors. What information is needed in the operation of your standards laboratory?

Information Now Available

H. L. Mason, National Bureau of Standards, Washington, D.C.

I have only recently learned, from the other members of the panel, just what standards laboratories are seeking in the way of information. As a result, I have had to take something of a shot-gun approach in producing the two-part document that follows. Part 1 lists various agencies, mostly Federal, that make a business of supplying information. Part 2 is a list of subjects in which I believe many NCSL members would be interested.

Returning to Part 1, the agencies, my first section lists the information centers within the National Bureau of Standards. There are twenty-three of them. They begin with the Analytical Chemistry Division and the Applied Mathematics Division, and proceed alphabetically through Mechanics, Metallurgy, and Metrology, ending up with Polymers, Radio Standards Engineering, and Radio Standards Physics. In most cases, the title of a single typical publication is included.

The second section of Part 1 deals with the Clearinghouse for Federal Scientific and Technical Information which is actually part of the National Bureau of Standards but has its own type of services, including bibliographies, a fast announcement service, packaged reviews, technical translations, abstracts of U.S. Government research and development reports, and a government-wide index of these reports. The semi-monthly abstract journal has recently begun to list researches in progress—those on which no published reports are yet available.

The third section of Part 1 lists several other federal agencies and professional societies, including the Agency for International Development, the Business and Defense Services Administration, the Engineering Index, the Isotopes Information Center at Oak Ridge, the National Referral Center for Science and Technology (this is a sort of "who knows what," at the Library of Congress), the National Science Foundation, and the Patent Office. Under each of these major agencies, I have added a brief comment as to what is available from them, and also given a single example of the sort of document that they put out. It would obviously take too long to detail all of their activities, but I trust you can get an idea from what I have listed here.

On precision measurements, one of the best means of getting information is through the seminars which the Bureau has been offering now for three years. It proposes to give six more in the fall of this year and spring of next year. Their arrangements are still tentative, but subjects offered will probably include high frequency and microwave phase shift, high frequency voltage, time and frequency, precision and accuracy, thermometry, and length. Some others have been suggested, and during the question period I am going to ask for a vote on how many people you are interested in sending to attend one or more of these seminars, and what additional suggestions of title subjects you wish to make.

NCSL Panel on Information—Part 1, Agencies

1.1 Information Centers at National Bureau of Standards, Washington, D.C. 20234, and Boulder, Colorado 80302.

a. Analytical Chemistry Division, Dr. W. W. Meinke, Chief—301-921-2851

Standard reference materials for radiochemical, spectrochemical and electrochemical analysis. NBS Misc. Publ. 260, Standard Reference Materials: Catalog and Price List (Oct. 1965), U.S. GPO, 45 cents: supplemental quarterly insert sheets.

b. Applied Mathematics Division, Dr. E. W. Cannon, Chief—301–921–2541

Mathematical tables, statistical and numerical analysis, mathematical physics, operations research. Natrella, M. G., Experimental Statistics, NBS Handbook 91 (Aug. 1963) U.S. GPO, $4.25; reprint of parts of the Engineering Design Handbook, Army Materiel Command.

c. Atomic Energy Levels Information Center, Atomic Physics Division, Dr. K. G. Kessler, Chief—301–921–2001

Spectroscopic data for all elements, except rare earths, that concern atomic energy levels, electron configurations, quantum numbers, magnetic splitting factors, and ionization potentials. NSRDS–NBS 3, Selected Tables of Atomic Spectra: Section 1, Si II, Si III, Si IV (June 1965), U.S. GPO, 35 cents.

d. Atomic Transition Probabilities Data Center, Atomic Physics Division, Dr. K. G. Kessler, Chief—301–921–2001

Atomic transition probabilities and cross sections useful for plasma physics and astrophysics. NBS Misc. Publ. 278 (Apr. 1966), A Bibliography on Atomic Transition Probabilities, U.S. GPO, 55 cents.

Chemical Kinetics Information Center, Dr. David Garvin, Director—301–921–2271.

Rapid access to research on rates of chemical reactions; bibliographic information to NSRDS and the scientific community.

Mass Spectrometry Data Center, Dr. Henry Rosenstock, Director—301–921–2792.

Abstracts from 1,000 basic documents since 1955 on the energetics of ionization processes, on appearance potentials, and on ion-molecule reaction mechanisms and rates.

e. Building Research Division, Dr. Allen A. Bates, Chief—301–921–3375

Properties and performance of building materials, structures and equipment; methods for testing materials, mechanisms, and structures; fire resistance; building codes and safety standards; structural engineering, air conditioning, heating and refrigeration; floor, roof and wall coverings; heat transfer.

f. Technical Information Exchange, Center for Computer Sciences and Technology, Miss Margaret Fox—301–921–3517

Systems analysis and design, evaluation and development of circuitry; logical organization of processing and control systems; automated collection, transmission, and presentation of experimental data; techniques for machine processing of syntactic and graphic forms of data. NBS Tech. Note 268, Transistorized Building Blocks for Data Instrumentation III (May 1966) U.S. GPO, 60 cents.

g. Cryogenic Data Center (Boulder) V. J. Johnson, Chief—303–442–3256

Tables and charts of thermophysical property data, Mollier diagrams of cyrogenic fluids, thermal conductivity, and thermal expansion data.

h. Electricity Division, Dr. C. H. Page, Chief—301–921–2701

Measurement of resistance, capacitance, inductance, current, voltage, power and energy, from dc up to 30 kHz; data on dielectric, magnetic and electrochemical properties. A list of publications in the field, LP 38 (Aug. 1966), available on request: Electrical units, instruments and measurements; bibliography covering absolute measurements, precise calibrations, textbooks, standards.

i. Electron Devices Data Service, Electronic Instrumentation Division, M. G. Domsitz, Chief—301–921–3357.

Electrical and technical characteristics of receiving tubes, microwave tubes, and semiconductor devices. Up-to-date information. Data on microwave tube characteristics are supplied yearly to the Microwave Engineers Handbook, published by Horizon House, Dedham, Mass.; pp. 238–250 in the 1966 edition.

j. Heat Division, Dr. R. P. Hudson, Chief—301–921–2034

Thermometry from 2 °K to 1700 °C, molecular spectroscopy, thermal diffusivity, heat capacity, heat of combustion. NBS Mono 90 (Feb. 1965), Calibration of Liquid-and-Glass Thermometers, U.S. GPO, 25 cents; includes good practice for design and use.

k. In organic Materials Division, Dr. E. Ambler, Chief—301–921–2891

Constants, properties, constitution and microstructure of nonmetallic inorganic substances, including ceramics, glass, and refractories, at very high and low temperatures, high pressures, and great purity. NBS Mono 25, Standard X-ray Diffraction Powder Patterns; Sec. 3 (July 1964) U.S. GPO, 40 cents.

l. Instrumentation Information Center, Electronic Instrumentation Division, M. G. Domsitz, Chief—301–921–3357.

Art, science, and technology relating to devices that extend the perceptual, manipulative, intellectual, and communicative capabilities of man. Information retrieval by NBS-developed "Peek-a-Boo" System.

m. Information Center of the Joint Institute for Laboratory Astrophysics (University of Colorado), Lee J. Kieffer, Director—303–447–3121.

Interaction of electromagnetic and corpuscular radiation with the earth's upper atmosphere and the interplanetary medium, plasma physics, ionosphere and exosphere scatter, airglow and aurora, ionosphere radioastronomy. JILA Information Center Report No. 2, A Bibliography of Low-Energy Electron Collision Cross-Section Data. *Electron Impact Ionization Cross-Section Data for Atoms,*

256-114 O-67—6

Atomic Ions, & Diatomic Molecules, Part I, Rev. Mod. Phys. **38,** 1–35, 1966.

n. Mechanics Division, B. L. Wilson, Chief–301–921–2101

Measurement of sound pressure and intensity, shock, vibration, force, strain, pressure, vacuum, viscosity, rate of gas and liquid flow, gravitational constant, rheological quantities, properties of materials and structural elements. NBS Mono 67 (Dec. 1963), Methods for the Dynamic Calibration of Pressure Transducers, U.S. GPO, 60 cents; mathematical models, mathematical and instrumental methods of analysis, evaluation.

o. Metallurgy Division, Dr. M. R. Meyerson, Acting Chief–301–921–2811

Fatigue and fracture, creep, corrosion, electrodeposition, phase transformations, crystal growth, diffusion, surface reactions, crystal imperfections. Reprints available on request: Gage blocks of superior stability: I. Initial developments in materials and measurements, J. Res. NBS, **64C,** No. 3 (July–Sept. 1960); II. Fully hardened steels, Trans. Am. Soc. Metals **57,** Mar. 1964, p. 3; III. Attainment of ultrastability. loc. cit. p. 164.

p. Metrology Division, A. G. McNish, Chief–301–921–2171

Measurement of length, mass, volume, density, color, light (visible, ultraviolet, infrared), photographic films, optical components. NBS Misc. Publ. 256 (1964), Ellipsometry for Frustrated Total Reflection; reprints on request.

q. Office of Industrial Services, Dr. G. S. Gordon, Chief–301–921–2434

Cooperation with private industrial research organizations to stimulate private research competence and to promote interchange of technical information; coordination of NBS research associates program. Brochure, An Invitation to Join in Research (Feb. 1966), available on request.

r. Information Services, Office of Standard Reference Data, Dr. H. M. Weisman–301–921–2583.

Compilation and critical evaluation of quantitative information on the physical and chemical properties of substances; coordination and integration of data centers nation-wide; critical reviews of the state of knowledge. NSRDS–NBS 1, National Standard Reference Data System: Plan of Operation (Dec. 1964), U.S. GPO, 15 cents.

s. Office of Technical Information and Publications, W. R. Tilley, Chief–301–921–2493

News of NBS research and service activities written for scientists, engineers, and executives. NBS Technical News Bulletin, monthly, $1.50 per year in U.S., $2.25 for foreign mailing, U.S. GPO; includes a regular section on standards and calibration. Journal of Research of the National Bureau of Standards; Sec. A, Physics and Chemistry, 6 per year, domestic, $5, foreign $6; Sec. B, Mathematics and Mathematical Physics, quarterly, domestic $2.25, foreign $2.75; Sec. C, Engineering and Instrumentation, quarterly, domestic $2.75, foreign $3.50, U.S. GPO. Technical Highlights: an annual report, U.S. GPO, $1. R. D. Huntoon, Status of the National Standards of Physical Measurement, Science (Oct 8, 1965) **150,** No. 3693, 169–178, reprint on request.

NBS Calibration and Test Services, NBS Misc. Publ. 250 (Oct. 1965), with supplemental insert sheets, U.S. GPO, $1.

NBS Tech. Note 262, Accuracy in Measurements and Calibrations, 1965 (June 1965), U.S. GPO, $1.

NBS Misc. Publ. 253, General Physical Constants Recommended by NAS–NRC (Nov. 1963), U.S. GPO, $2.50 per 100.

NBS Misc. Publ. 268, Electrical Engineering Units and Constants (June 1965), U.S. GPO, $6.25 per 100.

t. Office of Weights and Measures, M. W. Jensen, Chief–301–921–2401

History of weights and measures, standards, laws, and administration, methods for use of officials of the States. NBS Handbook 99 (Apr. 1965), Examination of Liquefied Petroleum Gas Liquid-Measuring Devices, U.S. GPO, 35 cents.

u. Polymers Division, Dr. J. D. Hoffman, Chief–301–921–2994

Properties of rubber, textiles, paper, leather, plastics, and dental materials, as related to molecular size, shape, distribution and flexibility of the polymer chains. Reprint on request: Utility of the Tait Equation Relating Volume and Pressure in the Study of Transitions in Polymers, Polymer Letters **2,** p. 703 (1964).

v. Radio Standards Engineering Division (Boulder), Dr. H. M. Altschuler, Chief–303–442–3131

Measurement of voltage, power, field strength, resistance, capacitance, inductance, noise attenuation, and reflection; all at radio and microwave frequencies. Reprint available on request: A Variable Impedance Power Meter and Adjustable Reflection Coefficient Standard, J. Res. NBS **68C** (Eng. and Instr.), No. 1, 7–24 (Jan.–Mar. 1964).

w. Radio Standards Physics Division (Boulder), Dr. Yardley Beers, Chief–303–442–3455

Measurements of atomic frequencies and time intervals, radio plasmas, radio and microwave materials, quantum electronics. Frequency and time broadcasts. NBS Misc. Publ. 236 (1966 ed.), Standard Frequency and Time Services, U.S. GPO, 15 cents.

x. Photonuclear Data Center, Dr. E. G. Fuller, 301–921–2625

Data on photonuclear reactions; cross sections; ground state capture reactions; electron scattering. NBS Misc. Publ. 277, Photonuclear Data Index, 1955–1964, U.S. GPO, 55 cents.

1.2 Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, National Bureau of Standards, Institute for Applied Technology, Springfield, Va. 22151.

a. Bibliographies; e.g., SB 475 (Suppl. 1) Information and Storage, SB 488 (Suppl. 2) Masers and Lasers.

b. Fast Announcement Service; choice of 57 categories, including Automation, Control Systems and Instrumentation, Quality Control Standards and Specifications, Testing and Analogies, $5 per year, U.S. GPO.

c. U.S. Government Research and Development Reports; $30 per year, domestic; $37.50, foreign; $3.00 single copy, U.S. GPO. Semi-monthly journal abstracting R&D reports, e.g., SC–DC–66–1118, Clean Assembly Practices Guide (Oct. 1965, $3); ORNL–3909, Minimum Significant Number of Successes in a Binomial Sample (Feb. 1966, $3); AD 607 893N, A Study of Manpower Requirements for Technical Information Support Personnel (Jan. 1964, $3); drafting reproduction, technical writing, library standards, spare parts provisioning; AD 624 560 (Nov. 1965) President's Committee on Scientific and Technical Information, Recommendations for National Document Handling Systems in Science and Technology.

d. Packaged Reviews; resumes, abstracts, and bibliographies, $3.00, e.g. OTR 132, High Temperature Adhesives above 500 °F; OTR 124, Nondestructive Evaluation of Materials.

e. Technical Translations; $12 per year, plus $4 for foreign mailing, available from the Clearinghouse. Semi-monthly journal listing foreign technical literature from government and private services.

f. Government-Wide Index to Federal Research and Development Reports; monthly, $22 per year, domestic; $27.50, foreign; $3.00 single copy, available from the Clearinghouse. New reports available from the Clearinghouse that are announced by the Department of Defense, NASA, and AEC.

1.3 Other Federal and professional agencies

a. Agency for International Development, U.S. Department of State. Catalog of Investment Information and Opportunities e.g. 2/05/02371, Demand for Measuring Tools, Gauges, and Instruments in India, $1.00.

b. Business and Defense Services Administration, U.S. Department of Commerce, Washington, D.C. *U.S. Industrial Outlook*, annual (U.S. GPO, $1). Retrospective statistics and forward estimates, industry by industry, including SIC 3611, 3622, 3811, 3821, 3822, 3831.

c. Engineering Index, Inc., 345 E. 47th Street, New York, N.Y. 10017.

Exploits 2000 titles, prints 47,000 abstracts annually; experimenting with machinable copy, using EJC Thesaurus of Engineering Terms (being revised May 1966) for Plastics and Electrical/Electronics.

d. USAEC, Division of Technical Information Extension, P. O. Box 62, Oak Ridge, Tennessee 37830.

Directory of USAEC Specialization and Data Centers gives addresses of and information about 26 centers, history, scope, services, staff, and qualified users; free on request. *Isotope and Radiation Technology* is a quarterly technical progress review emphasizing isotope applications.

e. National Referral Center for Science and Technology, Library of Congress.

Identification of all significant information resources in science and technology, acquisition of data concerning their specialized capabilities, guidance about their use. Libraries, centralized information centers, professional societies providing contact with individual specialists, industrial firms extending information service beyond their own organization, Government agencies able to provide assistance in specific areas. *Directory of Information Resources in the United States*, (Jan. 1965) U.S. GPO, $2.25; Vol. I covers physics, biology, engineering.

f. National Science Foundation, Washington, D.C.

Scientific Information Notes, bi-monthly, U.S. GPO, $1.25 per year, $1.75 foreign; news briefs, meetings and notes, research and development, activities abroad, publication notes.

g. Patent Office, U.S. Department of Commerce, Washington, D.C.

Patent Gazette, weekly, $50.00 per year; single copies of patents.

h. Atomic and Molecular Information Processes Information Center, Oak Ridge National Laboratory, P.O. Box Y, Oak Ridge, Tenn. 37830.

Physics of particle collisions, ionization, excitation, and dissociation in gas and plasma systems. *Directory of International Workers* lists 1400 professional scientists interested in atomic and molecular activities.

NCSL Panel on Information—Part 2, Subjects

2.1 Directories and indexes

a. Goldman, Sylvia—Guide to the Literature of Engineering, Mathematics, and the Physical Sciences, edition 2, May 1964, 85 pp., Clearinghouse AD 608 053. Abstracting journals, periodicals, books.

b. Jenkins, F. B.—Science Reference Sources (Feb. 1966), $2.50, Illini Union Bookstore, Champaign, Illinois; includes engineering, agriculture, medicine as well as pure science; 1300 items.

c. Klein, B., ed.—Guide to American Business Directories, edition 6, McGraw-Hill, 1965.

d. Kruzas, A. T., ed.—Directory of Special Libraries and Information Centers, edition 7, Gale Research Company, 1963, $25.

e. Palmer, A. M., ed.—Research Centers Directory, edition 2. Gale Research Company 1965, $35. Guide to university-sponsored and other non-profit research organizations established on permanent basis; with Supplements 1, 2, 3, 4.

f. Smith, J. F. and Brombacher, W. G.—Guide to Instrumentation Literature, NBS Misc. Publ. 271, July 1965, U.S. GPO, $1.25. A source list of indexes, bibliographies, books, guides, periodicals.

g. Stevens, M. E.—Automatic Indexing: A state-of-the-art report, NBS Mono. 91, Mar. 1965, U.S. GPO, $1.50. New uses of machines for compilation and generation of indexes to technical literature.

2.2 Electricity

a. Beatty, R. W.—Microwave Impedance Measurements and Standards, NBS Mono. 82, Aug. 1965, U.S. GPO, 20 cents. Tutorial review covering fundamental theory, definitions, the conventional slotted line, reflectometer techniques.

b. Beatty, R. W.—Microwave Standards and Measurements, a progress review 1960–1963, IEEE Trans. IM–12, No. 3, 134–138 (Dec. 1963).

c. Blair, B. E.—Control of WWV and WWVH Standard Frequency Broadcasts by VLF and LF Signals, Radio Sci. J. Research NBS **69D,** No. 7, 915–928 (July 1965).

d. Broadhurst, M. G.—Q-Meter Measurements up to 260 MHz, NAS–NRC Publ. 1141, pp. 77–80 (1964).

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Panel Discussion Period

Linebrink: We have seen some examples of what the needs are, and we have a thumbnail sketch of some of the Federal agencies that can supply information. That these sources are functioning may not be well known. For example, how many here do not subscribe to the NBS Technical News Bulletin? (Response—about 25 percent were not subscribers.) One of the things that we must recognize is that each laboratory will have a different need. There are conditions and requirements that will differ in kind and in quantity, and therefore you have to make the best use of what is available and do it in the most economical fashion.

How many feel that the availability of standards laboratory information is the big problem—that is, where can what exists be found? We are going to try to get you folks into the discussion. You may have items of information that other people do not. If our committee can do anything to bring the needs and the sources together, this will be a big step forward.

Question: What is the volume of inquiries that come to the Bureau each year?

Mason: The inquiries are very diverse, and many come directly to one of the 23 different information centers in the Bureau, each with its own specialized field. However, Mr. Tilley's office handles something over 5000 inquiries per year.

Linebrink: From past conversations with Reeves, I think that usually when an inquiry comes to his office it is routed to one of these centers for answering. This should result in your being referred to the Bureau's experts for that particular measurement, and this is frequently the best way to provide the answers to your problems. The facts required to solve the problems that we have are what we need in the way of information.

Question: A couple of years ago at Boulder, a course in Electrical Measurements was made available to members of NCSL and the lecture notes went like wildfire. I have one, and everybody I have shown it to since wants a copy. It is one of the best things I have ever seen. Here is a written source of information on how to make these decisions, presented by real experts in their field. It is needed by private industry and it costs money. Is it available?

C. Johnson: The notes were printed by Boeing, were used by Univac and others, and over 1000 copies have been distributed. Reprints might be made if there is sufficient demand. Address further inquiry to me at Boeing, Seattle.

Question: Can members of NCSL assist the committee in getting an acceptable category in the Clearinghouse index?

Linebrink: We are working on this subject now and may make use of your offer.

Question: Much information on techniques are buried in desk drawers. How can we get it out?

Mason: NBS Handbook 77, Precision Measurement and Calibration, is a three-volume compilation of techniques as of 1961. It is available from the U.S. Government Printing Office: Vol. I, Electricity and Electronics, $6.00; Vol. II, Heat and Mechanics, $6.75; Vol. III, Optics, Metrology and Radiation, $7.00. We are considering the preparation of another series of publications on techniques, but it may be 8 to 10 months before these become available. Some additional sources of information available to you are:

1. References in the NCSL Newsletter, C. E. White, Editor.
2. Referral Center, Library of Congress, Phone 202–783–0400.
3. NBS, Gaithersburg, Maryland, Phone 301–921–1000.
4. NBS, Boulder, Colorado, Phone 303–447–1000.

SESSION 5. CALIBRATION PROCEDURES

**Chairman: Donald De Lauer, USAF Calibration & Metrology Div.
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OPERATION OF NCSL'S CALIBRATION PROCEDURE LIBRARY

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Due to the increasing national interest in the NCSL Calibration Procedure Library, the Procedures Committee felt that a paper should be given at this conference which would describe the operation of the library.

The Library is supported jointly by the Air Force and NCSL, with the Air Force providing the management, the facility, and one clerk, while NCSL provides one clerk and the texts of procedures. It is physically located at Vandenberg Air Force Base in California and occupies a 1500 square foot area. Presently there are 28 filing cabinets filled with procedures and specifications, and normally, five duplicate procedures for each instrument model number in the Library.

All of these procedures have been contributed by NCSL Members who have signed the Library Agreement. This agreement was prepared by the Procedures Committee to provide basic operating instructions for the Library and to clear the legal questions associated with NCSL's distribution of the procedures. It took months to prepare the agreement and for the legal departments of many organizations to pass on its contents. However, this caution and consideration has proved to be worthwhile since there has been no problem with the document thus far.

In actual Library operation there are a variety of actions. First, is the process of receiving a procedure: The submitted procedure is given a Library number for filing purposes and is examined to determine all of the model numbers for which the procedure is applicable. The following indexing information and nomenclature is then extracted and written on regular key-punch sheets for each model number covered by the procedure:

a. Library number assigned.
b. Manufacturer's name abbreviated to 10 characters.
c. Manufacturer's code symbol.
d. Model number of the instrument.
e. Date of the procedure.
f. Number of pages in the procedure.
g. Originator of the procedure.
h. Originator's procedure number.
i. Credit code given the Originator.

A folder for the procedure is then established and is filed by Library number.

The key-punch sheets are sent to the Vandenberg Computer Operations Section on a daily basis and are key punched, printed, and returned to the Library for checking. After checking, they are returned to Computer Operations for inclusion in an accumulated change memory bank. Each week an accumulated index is delivered to the Library and each month these changes are distributed to the Members. All of the inputs, over 18000 entries, comprise the Master Index.

The Master Index, sorted by instrument manufacturer and then by model number, is distributed to each Library Member every six months. In addition to the distributed Master Index, the Library receives an index sorted by Library number, and one sorted by instrument model number. From time to time, special indexes have also been prepared, such as the one listing only the Air Force 33K Tech Orders, Navy procedures, etc., but the Master Index is the workhorse of the system.

To obtain procedures, Members use the NCSL Procedures Library Request form or telephone their requests to the Library. This form has provisions to check alternatives if no procedures are available, and a place to indicate that Air Force, Navy or Army procedures are not desired. This latter choice was put on the form to eliminate duplication, as many companies already have a complete set of Air Force, Navy and/or Army procedures. Procedure requests are filled and mailed on the day they are received. To date, the Library has received 2702 requests and has been able to fill 1602 of them, or 59%.

A procedure-writing control system has recently been inaugurated which provides information as to procedures being prepared by Library Members. Through this system, the Library will be able to inform a Member that a requested procedure is being written, and has a tentative completion date.

If this date is satisfactory, the Member will automatically receive the procedure when it is received by the Library. If the date is not satisfactory and the requestor can better the date, he will be requested to write the procedure. In this manner, we hope to reduce duplication and channel the writing efforts of our Members.

Lastly, the Library analyzes the effectiveness of its program through the Evaluation Report. The top half of this form is completed by the Library, and the lower part by the requestor, within 30 days after receipt of a procedure. The useability of the procedure in indicated by an assigned percentage, and based on reports received is currently averaging 26.3%.

Much greater usage is expected as procedures begin to follow a more generalized format and more standardization is achieved in measurement techniques for a given calibration task. As more organizations join and participate in this program, the Library should be able to fill a larger percentage of the requests.

Remember, you do not have to have contributed to the Library to be able to request procedures, but the success of this program and its value to NCSL Members depends on more of you joining, and participating in *your* Calibration Procedure Library Program.

THE DCAS AND THE CALIBRATION LABORATORY

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Since Defense Contract Administration Services itself is a new development, I would like to spend a few moments discussing this organization. DCAS, as it is commonly called, consists of 11 basic geographical Regions. Below the Regional level, 23 geographical districts and various geographical and plant offices have been established.

Each Regional organization, in addition to its staff responsibility for the entire Region, is assigned an operational area of responsibility. This was done to lessen "ivory tower" outlook which staff personnel without operational responsibilities tend to develop. Each DCAS component includes the principal functional elements of quality assurance, production and contract administration. Additional elements such as administrative services are added to the smallest component, the office, on an as-required basis. The District level is essentially the same as the Region. The full organization at the Regional level includes the Office of Data and Financial Management (with the important contractor payment function), an Office of Counsel, and Office of Industrial Relations (the regional personnel office) and a Public Affairs Assistant.

The organization for Quality Assurance provides for three staff units, an operational element, and a specialized Safety and Flight Operational Component.

Plans and programs responsibilities include, among others, the important responsibility for developing management and workload data systems and analyzing the output of these systems as an aid in making management decisions and manpower adjustments. The commodity specialists are in the Material Quality staff. Typical skills include electronics, general materials, propellants, petroleum, and medical items. These specialists provide support to operating personnel, participate in pre-award surveys involving their specialty, and conduct audits and investigations into commodity problem areas. The Quality Assurance engineering element is staffed largely with professional engineers and statisticians. They provide guidance in application of analytical and statistical techniques and in situations where professional engineering skills are required. They also provide support in materials and processes, in metrology, and in nondestructive testing.

The Government Quality Assurance Representative is responsible for evaluation of the contractor's quality program, when MIL–Q–9858A is specified, or quality system, when MIL–I–45208A is specified, or calibration system, when MIL–C–45662A is specified. Today I'll confine my remarks to the areas concerned with metrology and calibration. DCAS QA will determine the contractor's achievement of accuracy by reviewing his work standard capability directly concerned with the range, tolerance, and accuracy of test equipment. His analysis will determine whether test equipment accuracies required in production can be achieved, have validity, and can be maintained.

The contractor's achievement and maintenance of the required accuracies will be assessed by a continuing review of his records of measurements performed during production, and by random physical verification of such measurements. This assessment includes actual calibration check of items of test and measuring equipment as well as measurement of product. When we have satisfied ourselves concerning his methods of achieving the required accuracies, we will then turn to his methods of maintaining these accuracies—his calibration system. His written description of his calibration system, as required by MIL–C–45662A, will serve as the basis both for our initial evaluation of his system and for our continuing surveillance of it during production.

Evaluation will be based on the contents of MIL–HDBK–52, "Evaluation of Contractor's Calibration System." Using his written description as a guide, we will examine:

1. His list of measuring equipment, test equipment, and measurement standards.
2. His environmental controls.
3. His calibration intervals.
4. His calibration procedures.
5. His calibration sources.
6. His records and labels.

In examining the contractor's list of measuring equipment, test equipment and measurement standards, we will be looking for his coverage of calibration requirements and the adequacy of his standards. Is there a proper ratio between the accuracies of his test and measuring equipment and those of his measurement standards? Is the calibration of his measurement standards traceable to specific origins? Do his environmental controls provide proper conditions for the maintenance of the accuracies required by the need of his particular measurement standards? Has he assinged a calibration interval to each piece of measuring and test equipment and each of his measurement standards? How was the interval selected? Will there be a record maintained for each calibration to provide history of the equipment to more adequately adjust these intervals? What sort of recall system is provided? Does it promptly remove equipment from service and return it for calibration within the required interval?

Next, has he provided a calibration procedure for each distinct type of measurement standard and measuring or test equipment requiring calibration? We will determine that all calibration procedures contain minimum information such as:

1. Identification of the procedure to a specific type or group of equipments.
2. Specific information such as calibration points, environmental requirements, calibration conditions and accuracy requirements.
3. A brief description of the scope, principle and/or theory of the calibration method.
4. A list of all standards and accessory equipment required to perform an effective calibration.
5. A complete and accurate step-by-step procedure for calibration.
6. Specific instructions for obtaining and recording the test data including data sheets.

Are the procedures kept current? Is there a revision system? Finally, are these procedures kept readily available to the calibration personnel?

Now, what about calibration source? Is it carefully selected and identified so that each piece of equipment is supported by a train of successive calibrations traceable to NBS or to an independently reproducible standard? I'd like to point out at this time that the contractor is responsible for assuring that any commercial sources used are capable of performing in accordance with MIL–C–45662A. He should therefore have on file the qualifications of such sources, records of traceability for their reference standards, and an agreement that they will conform to the applicable requirements of 45662A. Finally, and most important, will he maintain adequate records for each item of test and measuring equipment and each measurement standard? Also, will he place a label on each calibrated item for positive visual control? The records maintained will provide the objective evidence needed to determine the degree of control achieved by his system.

To sum up, DCAS QA will review the supplier's written procedures for adequacy, conduct continuous surveillance of his operations for compliance to his procedures, and conduct such verification of test and measurement equipment, measurement standards, and product as needed to assure the validity and accuracy of results.

MANUFACTURER'S RESPONSIBILITY IN WRITING CALIBRATION PROCEDURES

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The Calibration Procedures Committee has for the past two years devoted its efforts towards the establishment and operation of a Procedures Library in an effort to reduce the tremendous duplication of effort in writing the procedures needed by calibration laboratories throughout the nation. During the course of discussion at a recent committee meeting the question was raised, "What is the manufacturer's responsibility for calibration procedures?" The committee agreed that the major responsibility for calibration procedures belongs to the manufacturer. Other Metrology people and some manufacturers have also voiced this opinion. Who other than the designer of the instrument should be in a better position to provide the best calibration procedure? However, manufacturers have been supplying operating and service manuals with their equipment for many years. Why then are we all writing calibration procedures? Basically, it is because the equipment manuals are not adequate and do not meet the needs of metrology and calibration agencies.

In years past, and presently in more cases than we like to admit, it was fairly common practice for the calibration supervisor or engineer to train his own personnel in the techniques to be used for each piece of test equipment. Some of these methods were written down, while others would be hopefully retained in memory. Altogether, we felt quite capable in performing these measurements. Yet over the years the varieties of test equipment have multiplied and become much more complex and sophisticated. There has been a continuing lack of calibration personnel. Thus we have experienced higher costs associated with maintaining this wide range of test equipment. This has placed greater importance on those calibration and maintenance procedures which are capable of assuring accurate and reliable test equipment at the least possible cost. It has been necessary for most calibration agencies to supplement the manufacturer's manual in order to achieve the desired results. The military services have long recognized the necessity for procedures which would provide uniform calibration results, and they too have been forced to supplement the manufacturer's manual.

Many of us work as contractors or sub-contractors to Department of Defense or NASA agencies and are governed to a large degree by the military standards involved in our contracts. Most of us are completely familiar with MIL–C–45662–A which covers contractor calibration system requirements. Most of us are judged by MIL Handbook 52, titled "Evaluation of Contractor's Calibration System," and utilized by DoD personnel for guidance in interpreting the MIL spec requirements. One of its statements in the section on calibration procedures calls for "A complete and accurate procedure for calibration, arranged in a step-by-step manner, clearly and concisely written." This is where most manufacturer's manuals fail to meet our present day needs. Each of us has had to duplicate other's efforts, at a tremendous cost to the government, to fulfill the DoD requirements for uniformity and accuracy of measurements.

Whose fault is it that we are involved in such a dilemma? It involves a problem all of us must face, must share the blame, and should all share in the search for a solution. This problem is the lack of understanding and communication between the manufacturer and the calibration agencies. The manufacturer by the nature of his business has been busy trying to provide instruments with the measurement capabilities required by industry to meet its ever-increasing technological requirements for products. He has succeeded in a very admirable fashion, but the metrology and calibration agencies, acting as a middle man required to calibrate the instruments, have not fared so well.

A major step was taken when MIL–C–24133 was adopted. It covered requirements for the preparation of calibration procedures for precision test and measuring equipment used by DoD agencies. This same specification was adopted by the NCSL Calibration Procedures Committee as a model format for writing calibration procedures to be placed in the Procedures Library. The cost savings already effected—and yet to be fully realized—by utilization of the Procedures Library are of tremendous importance to the Department of Defense and the Nation. Such savings should ease the strain on budgets within your own company for performing this task. An even greater saving can be achieved if the original manufacturer's manual would support the requirements of DoD and the metrology and calibration agencies.

During the past year notable strides have been made by some manufacturers. They have provided procedures and operating and service manuals which contain the necessary information to satisfy both the operator of the equipment and the calibration agency. There are many examples of progress but there are many more areas which are deficient. If the manufacturer is to respond to our needs for adequate calibration procedures, what are the things we require of him?

a. An understanding of the MIL specs under which we operate, namely MIL–C–45662A and the interpretative MIL Handbook 52.

b. Recognition of our lack of highly skilled calibration and maintenance technicians.

c. The constant emphasis on reducing the high costs of calibration.

d. A general lack of capital funds to buy every piece of calibration equipment recommended.

Now, what about the procedures? MIL–C–24133 is suggested as a standard guide. There are many additional features that have been recommended by metrology people:

1. Separate the calibration from the repair, but refer to specific repair paragraphs when calibration does not meet specifications.

2. Make use of trouble-shooting guides for specific malfunctions.

3. Prepare calibration set-ups.

4. Perform calibration by use of front-panel checks.

5. Procedure should be able to check all specifications claimed.

6. Suggested calibration equipment should have equivalents listed.

7. All test aids, loads, etc., described by schematic with component parameters stated.

8. Use of photographs or drawings to locate check points and components.

9. Description of parts for substitution—not just manufacturer's part number.

10. Return mail card for comments on manual, for feedback.

The Calibration Procedures Committee requests comments on calibration procedures problems and possible solutions, also for guidelines in formulating a program which would benefit NCSL Members and all metrology and calibration agencies in the Nation. One calibration technician indicated that he felt the instrument manufacturers might take a lesson from "Sam's Photo-Facts" and "Heathkit" as examples of a procedure which is simple and easy to follow. It has been suggested that a series of seminars or work shops be established in order to foster the communication between manufacturers and calibration agencies. By one means or another, effort must be made to achieve meaningful and honest calibration procedures which can be utilized to meet the customer's needs.

OBJECTIVES OF THE NCSL CALIBRATION PROCEDURES COMMITTEE

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Introduction

Why is there so much discussion on standardization of terminology and procedures? The science of measurement is supposed to be one of the most exacting of all sciences. However, it is easy to dispel this illusion simply by comparing similar documents from two or more different laboratories. The variations in document format and terminology frequently create difficulty and mutual misinterpretation of the very facts we are trying to understand. This lack of preciseness in the documentation of a science otherwise founded on precision has long been recognized and many individuals have tried to do something about it. These individuals have been handicapped, primarily, by their inability to reach a large segment of the very industry which would receive the most benefit and which could be of greatest assistance.

The NCSL now has solved the problem by providing the necessary access to all organizations which apply measurement techniques, and implemented a work program which will result in standardization of data presentation format and terminology. A library of documents has also been established to contain copies of standardized calibration procedures, techniques, and specifications. A Calibration Procedures Committee was selected and has been assigned objectives compatible with the long range NCSL goals. The objectives, as well as a brief description of the long range goals, are given in following paragraphs. A definition of the NCSL goals and the committee objectives demonstrates the benefits to be derived by the membership in NCSL and in the Procedures Library program.

Long Range Goals

Science is defined as a branch of knowledge dealing with a body of facts *systematically* arranged and *showing* the operation of general laws. The science of measurement must establish a systematic arrangement (format) for presenting facts (data) which can be used universally in the industry.

A standardized terminology must be established and used universally by those engaged in precision measurement activity. The best human endeavor is wasted if the information generated cannot be accurately transmitted and understood by others.

The long range goals for achieving intelligent and efficient communication among organizations involved in the science of measurement are as follows:

1. Establish and maintain contact with all organizations involved in the science of measurement with particular emphasis on measurement standards.
2. Establish recognition of NCSL as an authoritative source of information on all phases of standards laboratory activity.
3. Develop a universally acceptable format for all documents pertaining to standards laboratory activity.
4. Develop a well defined glossary of terms to be used in all standards laboratory documentation.
5. Develop and maintain a comprehensive library of information pertaining to standards laboratory operation, equipment calibration, equipment operational techniques, and equipment specification.

Current Objectives

Examination of the NCSL long range goals shows both immediate and long range benefits to participating members. The objectives of the committee have been selected to directly support efficient achievement of these goals, but continued progress is conditional on active NCSL membership participation.

A definition of objectives outlining the program to be followed by the committee is as follows:

1. A central library of calibration procedures, techniques, and specifications will be established. Copies of these documents will be furnished, on loan, to NCSL library members for inclusion in their organization files or for assistance in the generation of similar documents that are tailored to suit their own organizational needs. Calibration procedures, techniques, and specifications for the library will be obtained, on a voluntary basis, from NCSL members. These calibration procedures, techniques, and specifications will be listed in logical sequence and copies of the listing will be furnished to NCSL library members as the list is developed. When procedures, techniques, and/or specifications are not available for a particular item of test equipment, the Calibration Procedures Committee will provide coordinating efforts among

the requestees so that duplicated effort in writing the required new document does not result. A method of document evaluation will be included as a library service. Library members will be requested to list "use value" of each of several documents they may receive on the same item of test equipment. The library function will then retain documents known to be useful and will remove excess material which is demonstrated to have little or no use.

2. An active promotional campaign will be initiated to acquaint the membership on the contents and use of the library. Every effort will be made to provide the maximum benefit to members. It is expected that the library service will be an active force in expanding NCSL membership.

3. A standard format for calibration procedures and techniques will be developed, and its acceptance and use by all NCSL members will be promoted.

4. Equipment manufacturers will be encouraged to standardize equipment specifications and to participate in the development of a unified glossary of terms to be used in writing specifications.

5. Equipment manufacturers will be encouraged to generate calibration procedures and techniques which would be furnished with each item of test equipment as necessary supporting documentation. Such documents would be in acceptable format and copies would be furnished to the NCSL Library. Through membership participation, the committee will when requested provide assistance to such manufacturers for the development of such documents.

Present Status

A calibration procedures, techniques, and specifications library has been established under the auspices of the U.S. Air Force. This library has over 18,000 entries to date, and copies of the document list have been sent to library members. A library procedure has been established to permit library members to withdraw copies of desired documents and a document evaluation program is in operation. MIL–C–24133A is recommended for use as a standard format, although changes to this document will be suggested at a future date.

Realized Benefits

Many NCSL members have borrowed calibration procedures from the library and have used them to generate similar documents more suitable to their organizational requirements. This method of "writing" procedures results in a considerable reduction of the man-hours usually spent in this type of effort. In one case, this reduction resulted in estimated savings of $20,000, including the time of personnel freed for other jobs. This cost saving was justified in the following manner: It takes at least 100 man-hours on the average to write a good procedure, including item familiarization, laboratory check, and editing. An evaluation of NCSL library documents indicates a use factor of 30%, which means 30 of the 100 hours involved have been saved. At a burdened engineering man-hour cost of $12.00 this comes to $360.00/procedure or $18,000 for 50 procedures. If the use factor reaches 80% or 90% (one objective of this committee), the cost savings for 50 procedures would be $48,000.

Another immediate benefit is the availability of such documents on short notice. They may be used as interim procedures, so that standards laboratory personnel do not have to remain idle while the necessary instructions are generated.

One benefit of a more intangible nature is that standards laboratory personnel can make direct comparison of several procedures pertaining to one item of test equipment. This self-educational process can only result in an increased ability to more accurately evaluate the worth of a particular document. This, in turn, assists the calibration procedures library personnel in more accurately evaluating the worth of library calibration procedures and techniques.

It is the opinion of the Calibration Procedures Committee that the presentation of this information to the NCSL membership will acquaint them with the great benefits they can receive by active participation in the NCSL library effort. This participation will assist the committee in the achievement of its objectives and will in turn create greater benefits for the participating membership.

SESSION 6: THE MEASUREMENT SYSTEM OF THE UNITED STATES

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Today I should like to introduce to you a new way of looking at the measurement activities of the Nation. In this approach we consider all these activities as parts of a system. We shall talk about the National Bureau of Standards as a functional element of that system, and then we shall look at the role of the NBS Institute for Basic Standards within that functional element. Finally, once we have painted this picture for purpose of understanding, we shall turn to some of the policy questions that the picture raises.

I am sure that when I have finished many of you will say there is nothing really new in the systems approach to measurement. And in a sense that is true; the systems concept is simply a way of describing much that is going on, but it does provide a logical, systematic way of looking at measurement activities in this country.

A Society of Systems

Let us begin our discussion by considering the nature of the highly complex technological society now existing in the United States. How does life in this society differ from the life of the frontiersman 200 years ago? The essential difference, I believe, is that as individuals in our society we interact with a number of what might be called social systems, such as the communication system, the education system, the fiscal-monetary system, the legal-penal system, and the transportation system. I could go on and name more of these systems, but I shall mention only one more, and that is our National Measurement System which we shall discuss shortly.

In their interactions with one another through their interfaces, these systems, it seems to me, are characteristic of our society. They have a great influence on the lives and activities of individual citizens. In fact, one might think of our present American society as a sort of supersystem composed of all these systems.

Diverse as these systems are, they do have certain elements in common, and I think this should be emphasized. You recall that in English we use the word "standards" for two different concepts—standards of physical measurement, and standards of practice. In like manner we find ourselves using the term "system" to refer to two independent concepts involved in each of the systems comprising our society.

If we look up the term "system" in Webster we find that among the definitions given there are two very concise ones that relate to the present discussion. One of the definitions considers a system as "an aggregate of essential *principles* or facts arranged in a rational dependence to form a coherent whole." The other definition refers to "an assemblage of interdependent or interacting *functional elements* working together under guidance from some central source to accomplish a common mission." The first type of system, which we shall call the *intellectual system*, forms the basis for the design of the second type, which we may call the *operational system.*

If we now look at the social systems we are discussing, we find that in each case they comprise two interwoven systems. One is an intellectual system which in a sense does not operate—it consists of the set of rules and conventions that govern the operation of the system. This type of system is universally applicable, much like the laws of physics and chemistry. Then, for each intellectual system, there is an operational system consisting of a set of functional elements, a set of inputs, a set of outputs, and a spectrum of activities.

An example of an intellectual system is the International System of Units (abbreviated SI for Système International)—an intellectual concept, a set of rules regarding units. This system in universal; not only is it international, but it could be used on other planets if we ever succeed in communicating with them.

The operational systems, on the other hand, are national in scope. But they have interfaces with the corresponding systems of other nations, and of course they have interfaces with the other systems that make up our national society.

The National Measurement System

Let us now try to look at our National Measurement System in this way. The first thing we need to recognize is that we do in fact have such a system even though it may not have been formally recognized. It has grown up in this country and most of us have taken it for granted without really being aware of its existence. But its influence on our national life is tremendous. Let me give some figures that will indicate the magnitude of the system with which we are dealing.

If we stop to think about it, we realize that on the average every citizen is involved in some 15 to 50 measurements a day—reading his watch or speedometer, or buying gasoline by the gallon. If we add to these all the measurements that are made in science and industry, we arrive at a rough estimate—good perhaps to a factor of 2 in the first significant figure—of 20 billion measurements being made every day in this country. To be consistent and compatible, all such measurements must be traceable back to a set of national standards.

To get some idea of the amount of money invested in the Nation's total measurement activity, we estimate that we have some $25 billion invested in measuring instruments alone, and we are increasing this investment by some $4½ billion a year. We have some $20 billion invested in research to provide measurement data, and we are adding about $3 billion a year to this amount. Altogether our investment in the system is about $50 billion. The payment to personnel to operate the system is roughly $10 billion a year. It is important to note that the entire National System is 99 percent self-financed through its own internal system of charges and fees.

Table 1 shows the impact of this Measurement System on our national economy in figures taken from the 1963 census. Here we are looking at

	Final demand (GNP) $ billions	Cost of measurement $ billions	Man yrs. spent on measurement thousands
Manufacturing	225	7.8	845
Construction Mining and farming	21	1.1	120
Transportation communications and utilities	39	0.9	98
Medical and Educational services	28	1.4	103
Government and other services	83	2.7	139
Totals	396	13.9	1305

Table 1

totals for those industries and services that account for $396 billion of our gross national product. These industries invest $13.9 billion a year in measurement—in using the output of the Measurement System and working with it—and they devote 1.3 million man-years to measurement; so you can see that the National Measurement System is a very sizeable and important system in our economy. Looking at these figures we see that if we can improve the efficiency of the measurement process sufficiently to increase the GNP due to these industries by 0.1 percent, then we will have saved about 10 times the annual budget of the National Bureau of Standards.

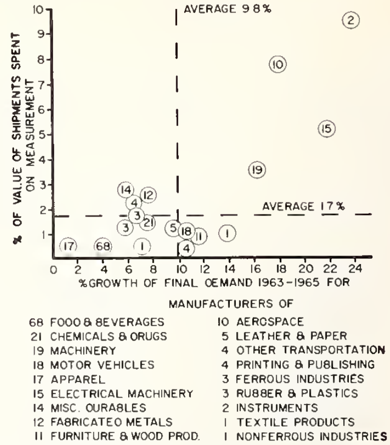


Figure 1 is also of interest here. The ordinate shows, for a number of industries, the percentages of the total value of all shipments that were spent on measurement; the abscissa shows the growth of these industries over the 1963–65 interval. Note that the fastest growing industries are those that have the greatest need for measurement. I do not say that measurement makes them grow faster, but I do say that the fastest growing industries are those that are most closely coupled to the output of the Measurement System, and that therefore our industrial growth is in fact tightly coupled to our measurement sophistication and capability.

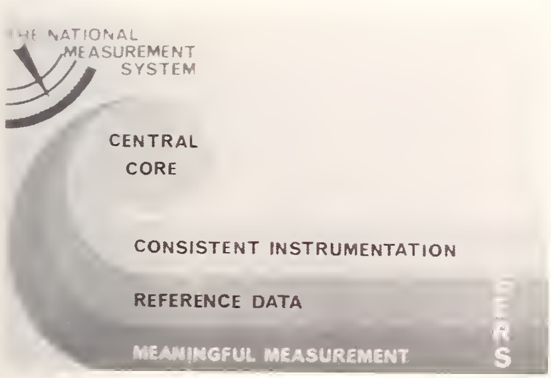
Now I should like to discuss the functions of our National Measurement System. The essential function of the system is to provide a quantitative measurement basis for interchangeability and decisions for action in all aspects of our daily life—public affairs, commerce and industry, science and engineering.

Interchangeability is of fundamental importance in modern society. Once we have a measurement system with a set of agreed-upon units and standards, we have a firm basis for the interchange of goods and services in the mass markets of modern commerce, of machine parts and devices in industry, and of scientific and technical information. Such a system makes it possible for any plant to mass-produce materials, parts, and systems that are interchangeable with those made in plants in other parts of the country. Without this basis for interchangeability, our industrial economy as we know it today could not exist. Likewise, if results obtained in one laboratory are to be useful in another, they must be expressed in a measurement system common to both laboratories; otherwise, each laboratory would have to operate on its own and confusion would result when they attempted to exchange information.

Modern society requires us to make numerous decisions throughout the day, and many of these decisions are based on measurement. For example, we are continually looking at a clock or watch to measure time so that we can decide whether to leave, stay, or stop what we are doing. An aircraft pilot must read a number of measurement output dials in order to make vital decisions during a flight.

To provide a basis for decisions throughout the Nation, all measurements must be compatible with each other. For example, the airplane pilot's decisions based on his instruments must be compatible with those of others who are making similar measurements if he is to stay on course, avoid collisions, and arrive on time. The key words here are *compatibility* and *consistency:* the Measurement System must make all sorts of diverse activity compatible and, at the interfaces, consistent; otherwise we should have a very chaotic situation.

Figure 2 shows the four outputs of the National Measurement System. First is the *central core*, consisting of the national standards, about which I

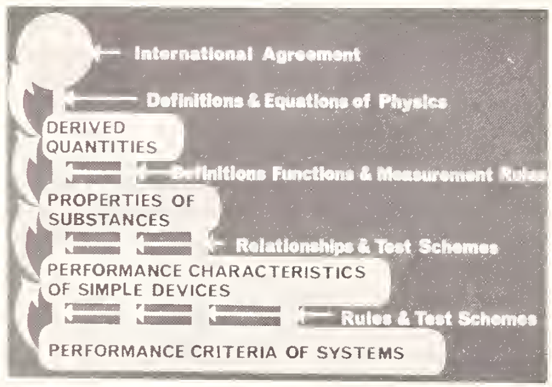


shall say more later. Next there is the provision of calibrated, *consistent instrumentation*, traceable to the national standards, to all the multitude of users whose measuring needs it serves. (Here, of course, I am thinking of the calibration activities of the whole system—not just the work of NBS.) Another output is a supply of *reference data* that provides all users with ready-made answers for measurements—these data can be used over and over again once they have been recorded and published. Finally, we have an important output that really involves the effective use of the other two—criteria for *meaningful measurement*. We might think of the Measurement System as having three spigots which the user can turn on. One spigot is labelled "instrumentation" and another is labelled "reference data." If the user does not know which of the first two spigots to try, he turns on the third spigot. This third spigot represents a part of the NMS through which people throughout the system can be told how to make use of the capability generated in the other two activities—how to measure what they set out to measure rather than something else.

Our system is made compatible with other national systems of measurement through its interface with the international system, set up through international agreement. The Convention of the Meter, established in 1875 through regular diplomatic channels, is made effectual through various technical agencies, beginning with the general Conference on Weights and Measures, which elects especially competent individuals to an International Committee. The latter supervises the work of the International Bureau of Weights and Measures, through seven committees dealing respectively with units, length, time, temperature, electricity, photometry, and ionizing radiations. The International Bureau provides the mechanism for intercomparison of the more important standards of the National Laboratories of the industrialized countries. Thus, compatibiltiy in world technology and trade is assured. The National System feeds back its extensions and comparisons to the international system, which in turn provides compatibility for the vast body of users around the world. Users in the National System establish their measurement capability and generate a pool of unmet needs which feeds back into other parts of the National System.

The Intellectual System

Figure 3 illustrates the "universe of measurables," the intellectual system that provides a basis for



the operational measurement system. This intellectual system is international in scope and everyone involved in modern science or industry is concerned with it. In the figure we start with four independent, arbitrarily defined units for the base quantities—length, mass, time, and temperature.* Adding another decimal place to the defined size of any one of them will have no effect on the size of any of the other three.

From these four "base units," we derive the units for all other physical quantities in accordance with the definitions and equations of physics. Take the quantity force for example; force equals mass times

*The International System of Units includes two additional basic units: the ampere and the candela. The ampere has been given this status as an aid to dimensional analysis, although it is defined in terms of length, mass, time, and a particular value of the magnetic constant Γ_m which is taken as $4\pi 10^{-7}$ henries per meter. The candela, which is used for measurements of visible light, is not purely physical since its definition involves an average human observer.

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acceleration, and acceleration is length over time squared. So once we have defined units of length, mass, and time, we can define a unit of force in such a way that the constant of proportionality in the equation

$$f = ma$$

is unity. Our unit of force is then a derived unit, dependent in size on the size of the units of length, mass, and time. In the same manner, the unit of density is derived from the units of mass and length. Continuing in this way, we eventually arrive at what is called a consistent system of units; that is, a system that is consistent with the equations of physics as we know them today. Once we have this consistent system for physical quantities we can proceed with a set of definitions, functions, and measurement rules to establish another category of measurables: the properties of substances (for example, density), relating their units back to the base and derived units. (The properties of substances are really functional relations among the physical quantities as these relations are characterized by a particular kind of matter. Density, for example, is the relationship between mass and volume that is characteristic of a specific substance, say lead or mercury.)

Similarly, by means of definitions, relationships, and test schemes, we can go from the properties of substances to the performance characteristics of simple devices—for example the amplification factor of a vacuum tube. Then proceeding on in the same way, we can go to the performance criteria of systems, feeding in test schemes and formulations to form a progressive, coherent set of measurable quantities.

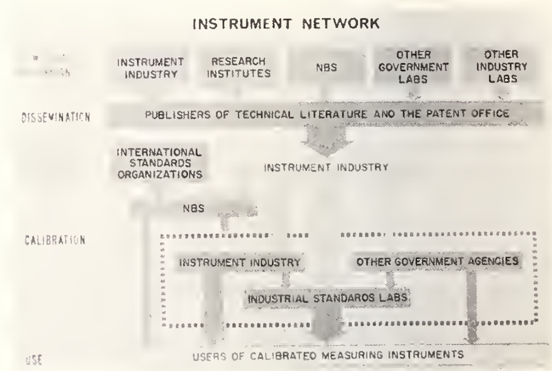
At each stage as we go down the chart, the degree of knowledge and sophistication involved decreases, not through want of effort but because we are still developing the system. At the top we are concerned primarily with very precise measurement; the important exact definitions have been agreed upon. As we go lower we find we are more concerned with the meanings of terms and definitions. In the lower stages we want to know what it is meaningful to measure, in order to specify firm understandable performance criteria.

The feedback up the chain that is shown in the figure takes place in two ways. First there is local feedback regarding the needs for refinement of the various kinds of measurables. Then there is the feedback of capability and knowledge developed in the rest of the system. For instance, information on properties is essential to the development of physically realizable standards for the four base units and to the measurement of the derived units. Likewise, information obtained by use of devices or systems enables us to improve the part of the system shown in the upper blocks, which can then be transmitted down to the lower blocks.

The Operational System

Now let us turn from the intellectual system to the operational system—consisting of people and organizations—which is national in scope and which interacts with the other systems of the Nation. One way of subdividing the system is to split it into three major networks. First there is the *instrument* network, which provides the calibrated instrumentation for making the measurements. Then there is the *data* network which gives ready-made answers to measurement problems. Finally, there is the *techniques* network which tells the user how to make meaningful measurement. In a very general way, this illustrates how the National Measurement System operates in this country.

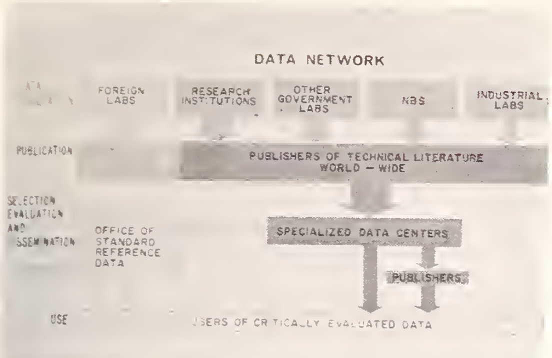
Figure 4 shows the details of the instrument network. At the top we have the development of new



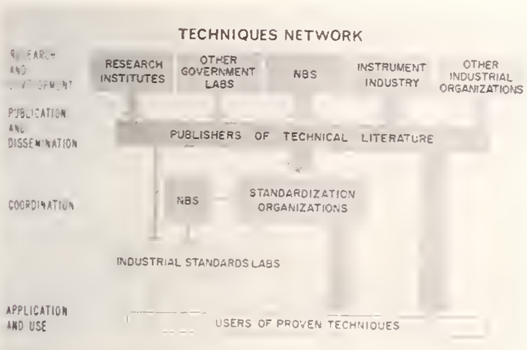
instrument ideas and designs by the instrument industry, research institutes, NBS, and other Government and industrial laboratories. These ideas and designs are disseminated by the publishers of technical literature and by the Patent Office. Ultimately they take the form of measurement hardware which must be accurately calibrated. This may be done by NBS directly, or by other standards laboratories whose master standards have been calibrated against the national standards maintained by NBS.

Figure 5 illustrates the data network. Here we have various laboratories contributing to a pool of technical literature which in turn feeds into a number of specialized data centers. The centers in turn funnel evaluated data into the NBS Office of Standard Reference Data. The users obtain their ready-made answers from the Office of Standard Reference Data and the publications of the specialized data centers.

Figure 6 shows the techniques network, which operates in a similar way, telling the user first how to measure, then what it is meaningful to measure. Many of the physical quantities in the universe of measureables are now so well defined that it is not difficult to determine how they should be measured in practical situations. This is presently true of the quantities expressed in SI units, although it was



not always so. But with performance characteristics and performance criteria, the situation is quite different; here we still want to know how to specify precisely what we want to measure.



The System as a Black Box

Now let us go back and look again at the general concept of a system. If we consider a system as a black box characterized by inputs, a statement of function, and outputs, then any segment within the black box may be thought of as a subsystem which we can in turn examine for inputs, function, and outputs. And we can continue this subdividing process until we get down to the smallest structural elements of the system. Each subsystem can be divided into interacting elements, and each of these elements into interacting components.

Now consider one segment of the system with its inputs and outputs. A satisfactory statement of function requires that we recognize interface filters on either side of the segment, because these are the points where policies are set up that characterize the activity of the segment. An input interface filter determines which of all possible inputs will be accepted, and an output interface filter determines which of many possible outputs the segment will deliver. If we know the inputs and outputs and some of the policies that govern the filters, we can characterize the system segment in a functional statement.

With that by way of background, let us return to the National Measurement System. This System has as its main function to provide the central basis in the United States for a complete, consistent system for physical measurement. What then is the role of NBS as a functional element in the National Measurement System? This role is one of central Federal leadership—to guide the System as it continues to operate through the voluntary cooperation of American science and industry. As we see it, the Bureau must maintain this leadership through general acceptance, based on proven capability—not on laws or regulations. So the Bureau exerts its leadership through its outputs—by developing and maintaining the national standards which serve as a central core for the three networks, by providing calibration services and standard reference materials for the instrument network, by generating and evaluating data for the data network, and by developing techniques of meaningful measurement for the techniques network.

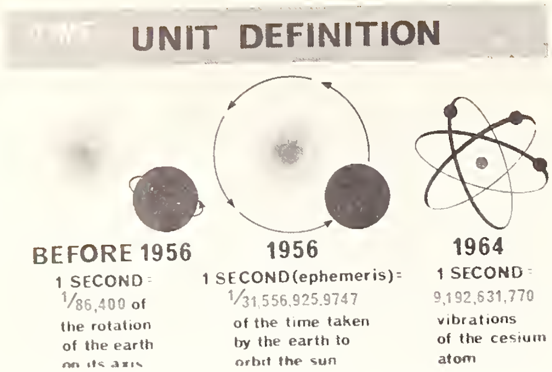
Now let us consider the Institute for Basic Standards as a functional subelement of the System. Its inputs come from the pool of unmet needs, from the international coordination to which it is tightly coupled, and from the various activities throughout the Nation which supply materials information—in particular from our own Institute for Materials Research. Its ourputs are the central core of national standards (essentially an in-house output), calibration services to disseminate this core, ready-made answers in the form of key reference data and a mechanism for disseminating them, a set of standard reference materials, consulting and advisory services, and publications on meaningful measurement.

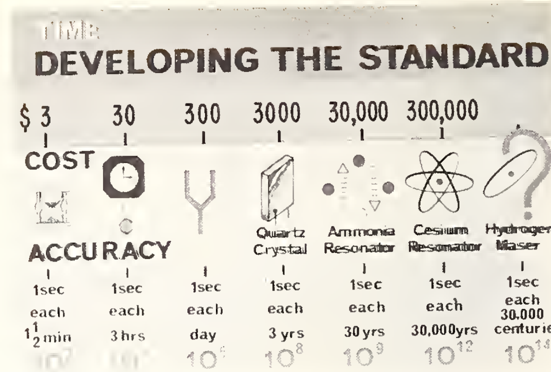
The Central Core

Let us begin with the central core, which consists of six base standards—national standards coordinated internationally—and thirty or forty derived standards. The six base units of the International System of Units are specified for the quantities mass, length, frequency or time, temperature, electric current, and luminous intensity. Four of these have been mentioned earlier. The central core is developed by starting with a knowledge of materials as a basis for conceiving and defining a unit, then proceeding to a material realization of this definition, and finally to the standard.

This process involves a feedback loop that operates continuously. While the units themselves are static—in that their values are changed only in the last few decimal places—there is a great deal of dynamics in the process of realizing these units with increasing accuracy and precision to meet the needs of science and industry.

A brief discussion of one of these units—the second—will illustrate the dynamic nature of measurement standards (Fig. 7). Before 1956 the second





was defined as 1/86,400 of a mean solar day. Thus its definition was based on the rotating earth as a clock. Of course, any periodic phenomenon can be used as a clock, and the more stable its period, the better clock it makes. We thought we had a pretty good clock in the rotating earth—it had been used for centuries. But by 1956 it had become evident that the rotation of the earth was subject to irregularities, and so the second was redefined as a fraction of the annual trip of the earth around the sun. (This redefinition did not change the *size* of the second, only the way in which it was defined.) The second thus defined is known as the ephemeris second, and it is possible to realize this second to about 2 parts in a billion, given some five years of astronomical measurements. But work with cesium-beam-controlled clocks had already surpassed this precision, so a new definition was needed. In October 1964, the 12th General Conference of Weights and Measures authorized an atomic definition of the second. The International Committee on Weights and Measures, acting for the Conference, temporarily based the definition on an invariant transition of the cesium-133 atom, in expectation of a more exact definition in the future. The value of 9,192,631,770 hertz was assigned to the cesium transition selected. It now appears that we can compare the second in terms of this definition to 1 or 2 parts in 10^{13} (equivalent to 1 sec in 30,000 years). These changes in the definition of the second are a good illustration of the way in which the units are continually being refined so that we can better say what it is we are trying to measure.

I might add that each time we replace an older unit with a new one of lesser uncertainty we are careful to define the new unit with the zone of confusion of the old. So long as we do it this way, the results obtained by previous measurements will still be valid within the range of indeterminacy associated with the older unit.

Figure 8 shows the progression in the development of standards for the second. We begin in ages past with the hour-glass which kept time to about a second in a minute and a half; it probably cost $3 and was accurate to about a part in 100. Next we have a pendulum clock, which costs about $30, and keeps time to a second in three hours or one part in 10^4. Next we have a well-made tuning fork, accurate to a part in 10^5 and costing perhaps $300; then the quartz frequency generator, accurate to a second in three years or a part in 10^8; the ammonia molecular clock, good to a second in 30 years, or a part in 10^9; then the new cesium resonator previously mentioned, accurate to a second in 30,000 years, or one part in 10^{12}; and finally the hydrogen maser, now under development, which may go to a part in 10^{14} at a cost as yet unknown.

Now note the progression in the cost of the standards. With each improvement in accuracy, the cost of research for further improvement spirals upward. Someone may ask, "Do we really need a clock that keeps time to a second in 30,000 years?" However, the need for timing accuracy in such fields as satellite tracking, rocket control, and astronomical observations is far from being met. We must remember that there are almost 10^{11} microseconds in a day and that a radio signal travels 300 meters in a microsecond. We use radio waves to measure distances and to track satellites which incidentally move at the rate of nearly a meter every microsecond. So we must have clocks that can keep in step to within a few microseconds over an extensive time interval. As a matter of fact, we are now under pressure to improve our present time-keeping accuracy of 1 part in 10^{12} by two more orders of magnitude. Still we must admit that the present accuracy in time measurement is fantastic. If two cesium clocks such as we have now had been started at the dawn of history, they would differ by no more than an eyeblink today.

The Instrumentation Network

Once a unit has been selected for a particular quantity and a national standard for this unit has been realized, we must establish techniques that will provide for measuring the entire range of magnitudes that must be dealt with. In mass, for example, the range extends from the mass of the earth, or even beyond, down to the mass of the electron, neutron, or subparticle (fig. 9). So we have a vast spectrum of some 50 orders of magnitude that must be connected through a measurement chain to the defined unit, the kilogram. Some of these magnitudes can be measured directly by taking multiples or submultiples of the standard, but as we leave the central part of the range we find it necessary to use indirect methods, with a corresponding reduction in accuracy.

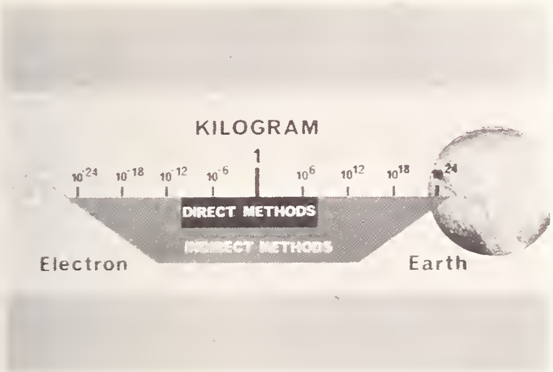
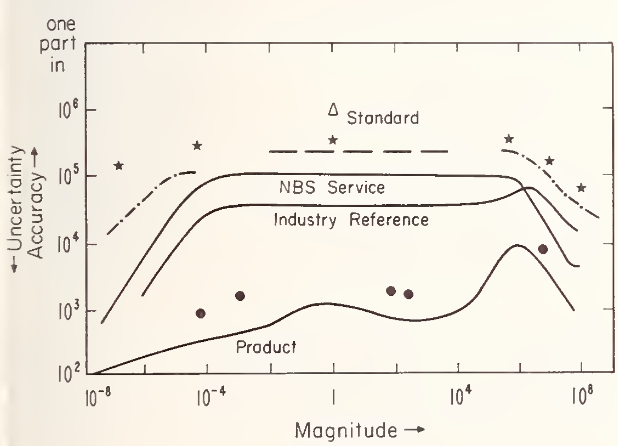
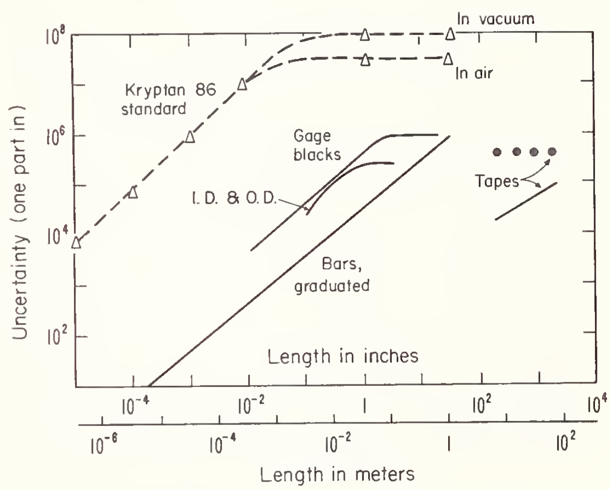


Figure 10 is a generalized version of the "accuracy charts" which the Bureau is using to assess its measurement capabilities over typical ranges of magnitude in various areas. The upper solid line indicates the accuracies presently available in regular NBS calibration service; the next lower one, what good industrial laboratories can do; the lowest one, the tolerances generally called for at the ultimate user's level—at the factory bench or in the finished product. The dots indicate the accuracies the factory's customers say they need, the horizontal dashes show what can be obtained by special arrangement with NBS, and the dash-dot lines show where NBS activities now under way will carry us. Finally, the stars represent the occasional demands expressed by important segments of our customers.



We can use this type of chart to show graphically where we are putting our major efforts, to indicate our goals, and to decide where to concentrate our further efforts. We need to resolve such questions as whether it is more important to raise the line representing NBS capability, and thereby bring up the line representing industrial capability, or whether to try to bring the latter up closer to the former by tightening up the system, perhaps by reducing the number of echelons between the NBS standard and the ultimate user.

Figure 11 is an up-to-date accuracy chart for length and diameter measurements, showing the different devices used in different ranges of magnitude and the accuracies achieved in NBS calibrations. Using recently developed equipment, and taking special pains, we can measure length to about a part in 10^8 for magnitudes from 1 to 0.01 meter.



Of course it is seldom possible for a single institution such as NBS to make calibrations over the complete range which might be needed in the National Measurement System. So we have to make basic decisions as to how far to go and how much to do. Our policy is to pick calibration points at appropriate intervals so that the measurement activities of the country can be coupled to NBS at these points by means of ratios, differences, and interpolations. In this way the national standards in the central core are disseminated over the calibration network.

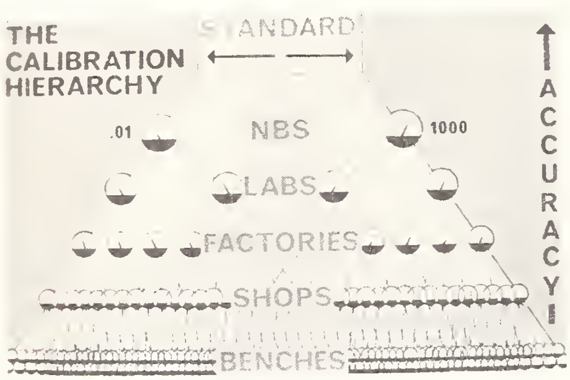
Calibration of an instrument involves comparing it directly with a standard so as to obtain corrections to the instrument readings.

Table 2—NBS CALIBRATION PROGRAM BUDGET
(In thousands of dollars)

	1965	1966	1967 est
Electrical	720	770	830
Mechanical	350	370	430
Radiation	750	820	880
Radio	710	770	830
Thermal	260	320	380
	2,790	3,100	3,400

Table 2 shows the magnitude of the Bureau's calibration program, which amounts to about $3 million per year. The customer pays the out-of-pocket NBS expense of making his calibrations, but he does not pay for the research and development that makes the calibration possible.

Compatibility requires that there must be a chain of measurement traceable from the base of the pyramid (Fig. 12) all the way up to a common reference standard. Unless each chain finally reaches the same apex, the system will lack compatibility. There is an interesting story about a man who set the town clock by the factory whistle. It turned out that the factory whistle was always in good agreement with the town clock. Upon investigating he found that the man at the factory was reading the town clock to find out when to blow the whistle. So they had set up a small feedback loop between themselves but they had no means of achieving compatibility with timekeepers elsewhere.

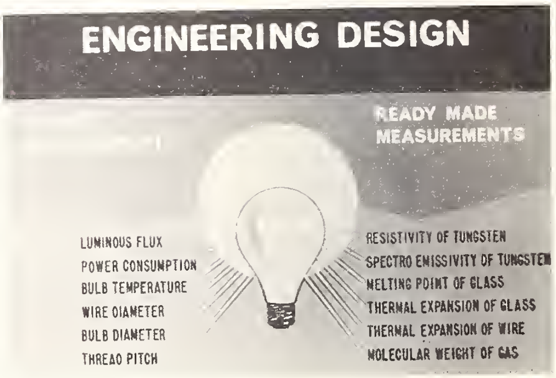


The standard reference materials program is unique to the United States, although some of the samples are sold to users in foreign countries. Standard reference materials are well characterized substances with accurately determined properties. The Bureau certifies them either for chemical composition or with respect to some specific physical or chemical property. They obviously provide a basis for equitable interchange of articles of commerce. Also, samples of these materials are sold to an individual so that he can calibrate his own measuring process. A great advantage of the program is that it enables the user to do self-calibration "on-site." Thus he ties his measurement to the National System and evaluates his results in terms of his own capability and his own instruments and procedures. If he sends his instrument to NBS for calibration, he does not obtain any knowledge of his own capability for using the instrument to the accuracy with which it has been calibrated.

We are now moving into self-calibration in other areas. Ways are being considered for tying standards laboratories into the National Measurement System on a self-calibration basis by means of measurement agreement comparisons, often called round-robins. The laboratories would do most of the work with their own instruments, their own staffs, and their own technologies. Having done so, they would have a measure of their own capabilities and would know how closely their accuracies are related back to the national standards.

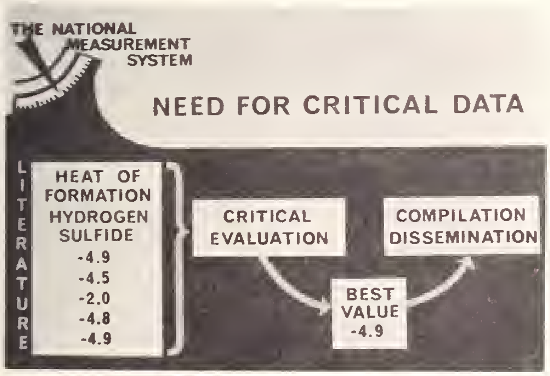
The Data Network

Now let us turn to the data network. Figure 13 is a good illustration of the fundamental importance of this type of activity. Consider an engineer who has set out to design a new competitive light bulb. What does he have to know? First of all, he has to be able to make direct measurements; he must have instruments to measure the diameter of the bulb, the pitch of the thread, the weight of the materials, the diameter of the wires, and so on. But even though he has the capability of making these measurements in production, he is still a long way from an adequate design. He needs information on the electrical resistivity and spectral emissivity of tungsten and other competitive materials, the melting point and thermal expansion of glass—in fact, maybe some 50 types of data of this kind—in order to make a competitive design. If he has to stop and measure all these properties, he will be investing several million dollars in a research program before he can start his design. On the other hand, if ready-made answers are already available for the data he needs, because someone else has already measured them, then he can save this vast investment. Once he has found the numbers, he can proceed with the design, provided that he can trust the numbers to be correct.



Another important point to consider here is that when sufficient data have been obtained to characterize a substance, then that substance can serve as a reference material for the calibration of instruments that measure the properties of substances. These properties are often temperature-dependent, and the International Practical Temperature Scale is based on fixed points at 1063, 960.8, 444.6, 100, 0.01, and minus 182.97 degrees Celsius, related to gold, silver, sulfur, steam, water, and oxygen respectively. If the substance is sufficiently well characterized, the reference sample can be purchased from the usual sources of supply and certified standard samples will not be necessary. Today practically all the instruments that are used to measure properties of substances are calibrated in-house by manufacturers or users, using standard data on the measured property. These calibrations are related to the national standards through the key data on properties which NBS provides. People outside NBS can work with these data, so the existence of ready-made answers takes a vast load off the instrument network of the Measurement System.

Figure 14 illustrates, perhaps even more graphically, the need for critical evaluation of such data. When an engineer turns to the scattered literature in search of design data, he is likely to get a wide range of values for each property he looks up. Suppose, for example, that he is designing an industrial process that involves the heat of formation of hydrogen sulfide. In the literature he may find an array of values ranging from 2.0 to 4.9. Uncertainty in such a measurement can have far-reaching economic effects. If he accepts the value "2.0" for the heat of formation of hydrogen sulfide, he might conclude that his planned process will not work, and that hence there is no point in going further. On the other hand, if he accepts the value "4.9" he may find that his process will be highly productive and should be pushed. Which value should he accept? In the absence of critically evaluated data on the heat of formation of hydrogen sulfide, he can only do what is usually done in industry today—seek expert advice if he can find it, make an educated guess, or measure it again himself, adding another value to the list. Unless he is an expert in the measurement of heats of formation, the value he obtains will probably be no better than those already in the literature, and may be much worse.



The solution is to get together a group of experts who know the field and can evaluate the various measurements from the literature so as to obtain a "best value"—the most acceptable and trustworthy value—and will make this value generally available. This is the process of critical data evaluation and compilation. To carry out this function on a nationwide basis, the President's Office of Science and Technology has established the National Standard Reference Data System (NSRDS), and NBS has been given the responsibility for planning and coordinating its projects. A central headquarters, known as the Office of Standard Reference Data, has been established at the Bureau under the Institute for Basic Standards, and contracts aimed at establishing coherent and comprehensive coverage are now being let to various data centers throughout the country. The NSRDS seeks to pull the best values from the literature and to get them into the hands of the users of the System through publication and other means of dissemination.

This is an enormous task, for the 10 technical journals of the year 1699 grew to 100 in 1799, to more than 1000 in 1899, and is expected to reach 10,000 by the year 1999. The papers appearing in these journals have also increased ten-fold in each century; there will probably be 1,000,000 by 1999. Data compilation and evaluation activities presently carried on can now take care of only about a fifth of the annual increment of papers; IBS activities account for about 7 percent, and the other data centers of the country handle about 14 percent. So the backlog of unevaluated data is growing, the situation is getting more confused, and it is becoming increasingly difficult for scientists and engineers to find the data they need.

There is thus a strong economic need to get all these data critically evaluated and then disseminated to users. If we can succeed somehow in getting the resources that will enable the NSRDS to do this job, we estimate it will pay back into the economy between $20 and $200 for every dollar invested.

A primary task of NBS in data generation is to put key data into the reservoir. Others can use these data for extending their work into related areas. Users who recognize the value of this effort then feed more raw data into the data centers scattered throughout the Nation. The data centers evaluate and compile these data, which are then fed back into the data reservoir for further use. The key definitive data supplied by NBS permit the National Measurement System to grow and expand. The Bureau gains competence through research, and links its findings to the system so that compatibility will be provided to resolve conflicts. These activities are important to the proper functioning of the Measurement System. For example, judicious duplication of measurements by several users shows whether or not the instrument network is performing in a consistent, compatible way. At the same time, the research on materials that is part of the data acquisition activity provides a firm basis for the development of measurement standards for the central core.

Inputs, Outputs, and Filters

In the few minutes remaining I should like to say a few words about some of the inputs, outputs, and policy filters that influence NBS activities. Obviously there are a great many inputs to NBS from the other social systems of the country as well as from other parts of the Measurement System; I shall mention only a few of these.

One important input is the research being done at other laboratories on the frontiers of science. This work is developing the knowledge needed to improve the measurement process within the System. A related important output takes the form of scientific contributions from NBS scientists who are working in frontier science to provide a base for the measurement activities.

A continuing input problem of major dimensions is our need for trained metrologists. Here there is tremendous suction in the input pipeline but very little input to flow through it.

Another input to NBS consists of the new measurement needs and new measurement problems with which we are constantly being bombarded. As our resources are necessarily limited, we are hoping that we can meet some of these needs and problems by use of what we call the Research Associate Plan. Under this Plan, which we have had for years but which we are now extending, an industrial group, a trade association, or even a private company can send an employee to work at NBS on a problem which is of special interest to the sponsor, which also has public significance. The sponsor pays the employee's salary, while the Bureau makes available its laboratory facilities and the advice of its specialists. In this way wider use may be made of NBS instrumentation and of the measurement competence of the NBS staff. When the employee returns to the laboratory from which he came, he should be a more effective worker because of the better understanding he will have of measurement techniques and their use in the solution of problems.

On the output side, there is always the problem of deciding what calibration services are required to feed the System properly. Taking the "systems" point of view, the Bureau's policy is to undertake those tasks that will make the Measurement System function most effectively and economically in serving the interests of the country and the economy as a whole. From time to time we get feedback which indicates that some people do not understand this policy. Apparently they think that the Bureau is withdrawing from calibration activity and retiring into an ivory tower. Nothing could be further from the truth. Our objective is to ensure the calibration of every instrument whose calibration has any meaning. If the calibration is within the Bureau's capabilities and if it can be done more effectively at the Bureau, then we should do it; if it can be done more effectively outside the Bureau in other parts of the System, then it should be done there. We feel that we should do enough calibration work to keep our existing facilities reasonably well utilized; at the same time we should not attempt to compete with the private standards laboratories which have the important role of taking over from NBS and disseminating the standards throughout the rest of the System.

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SESSION 7: NATIONAL CALIBRATION REQUIREMENTS

Charles Johnson
The Boeing Metrology Laboratory

The NCSL Committee on National Calibration Requirements was formed to assist the National Bureau of Standards in determining present and future calibration support that industry requires. Questionnaires (Budget Bureau No. 41–65101) were sent to 126 NCSL members. As of April 30, 1966, a total of 112 were returned from 50 of the recipients.

The information presented here is the result of the survey. Analysis of this information is in the preliminary stages and one should be cautioned against drawing rigid conclusions from the material presented here.

It should be noted that there is some difficulty in clearly drawing the line between problems relating to inadequate standards and those which are measurement problems.

Of equal importance is the difficulty in determining the extent that industry should rely on the National Bureau of Standards to provide calibration services. At this time, there appear to be diverse opinions within industry as to the amount of calibration support that industry should supply to itself vs. the amount of support that they should receive from NBS.

The general conclusions drawn from this survey are:

1. NCSL members are generally aware of the capabilities of the National Bureau of Standards.
2. There is very little commonality among member laboratories' needs in those areas that are not presently supported by the National Bureau of Standards.
3. Solid economic justifications are lacking to support the majority of the requested services.
4. There is need for a more clearly defined dividing line between the Bureau's responsibilities and industry's responsibilities in providing calibration services.

Question 1: WHAT IS THE PHYSICAL QUANTITY TO BE MEASURED?

Question 7: DATE SERVICE IS REQUIRED?

Quantities are ranked by total number of times reported. Note negligible duplication in problem areas; most-mentioned quantity was listed as present requirement by only 4 NCSL members, as future requirement by only 5.

RANK	PHYSICAL QUANTITY	REQUIRED BEFORE JUNE 1966	REQUIRED AFTER JUNE 1966
1	RF POWER	4	5
2	VACUUM	4	1
3	LEAK RATE	4	0
4	IMPULSE SPECTRAL INTENSITY	3	0
5	VIBRATION	3	0
6	VOLTAGE RATIO (LOW FREQUENCY)	3	0
7	REFLECTION COEFFICIENT	2	4
8	PHASE (LOW FREQUENCY)	2	3
9	VOLTAGE (LOW FREQUENCY)	2	1
10	INDUCTANCE	2	1
11	NOISE (HIGH FREQUENCY)	2	1
12	FLOW RATE (PULSE)	2	1
13	LUMINOUS INTENSITY	2	1
14	MASS	2	0
15	SHOCK	2	0
16	FIELD STRENGTH	2	0
17	PULSE RISE TIME	2	0
18	ATTENUATION	1	2
19	POWER (LOW FREQUENCY)	1	1
20	FREQUENCY	1	1
21	ANGULAR POSITIONING	1	1
22	CURRENT (LOW FREQUENCY)	1	1
23	RESISTANCE (DC)	1	1
24	CAPACITANCE	1	1
25	SPECTRAL TRANSMITTANCE (OF LENS SYSTEMS)	1	0
26	TRANSMITTANCE AT SPECIFIC WAVE LENGTHS	1	0
27	TRANSMITTANCE OF DIFFUSING SCREENS	1	0
28	SPECTRAL TRANSMITTANCE	1	0
29	DIFFUSE REFLECTANCE	1	0
30	PRESSURE	1	0

RANK	PHYSICAL QUANTITY	REQUIRED BEFORE JUNE 1966	REQUIRED AFTER JUNE 1966
31	VISCOSITY	1	0
32	SIZE AND QUANTITY OF DUST IN AIR	1	0
33	IMPULSE NOISE	1	0
34	NOISE (HIGH FREQUENCY)	1	0
35	PEAK VOLTAGE	1	0
36	RESISTANCE (LOW FREQUENCY)	1	0
37	PULSE VOLTAGE	1	0
38	IMMITTANCE	1	0
39	PITCH DIAMETER	1	0
40	CURRENT RATIO	0	1
41	RADIATION EXPOSURE	0	1
42	OPTICAL RESOLUTION	0	1
43	RULED GRIDS	0	1
44	RELATIVE HUMIDITY	0	1
45	TEMPERATURE	0	1
46	RESISTANCE (HIGH FREQUENCY)	0	1
47	LIQUID FLOW	0	2
48	LINEAR ACCELERATION	0	1
49	VOLTAGE (DIRECT)	0	1
50	CURRENT (DIRECT)	0	1
51	RADIATION FLUX INTENSITY	0	1
52	EMISSIVITY	0	1
53	SOUND PRESSURE LEVEL	0	1
54	VOLTAGE (HIGH FREQUENCY)	0	1

Question 2: OVER WHAT RANGES?
Question 3: WITHIN WHAT UNCERTAINTY?
Question 5: AT WHAT VALUES OF ASSOCIATED PARAMETERS?

Replies are given for only the quantities ranked 1 to 10. The higher uncertainty value would apply to the limits of the range. The lower uncertainty would generally be for an improved capability in the center of the range. The associated parameter, when given, would not apply to the entire range.

QUANTITY	RANGE	UNCERTAINTY	ASSOCIATED PARAMETER
RF POWER	10^{-6} to 10^{3} watt	0.1 to 1 %	3M to 10G Hz
VACUUM	1 to 10^{-12} torr	0.1 to 20%	- -
LEAK RATE	10^{-5} to 10^{-9} cc/sec	1 to 5%	- -
IMPULSE SPECTRAL INTENSITY	100M to 10G Hz	0.5 to 0.25 dB	- -
VIBRATION	10^{-5} to 100 g	1 to 2%	0.001 to $2X10^{4}$ Hz 50 to 500°F
VOLTAGE RATIO	0 to 1 -	- 10 PPM	0.1 to 100 KHz
REFLECTION COEFFICIENT	0 to 1 -	0.00005 to 1% -	2.6 to 50 GHz
PHASE (LOW FREQUENCY)	0 to 360 deg.	0.1 to 0.01 deg.	400 to 10^{5} Hz
VOLTAGE (LOW FREQUENCY)	10^{-6} to 10^{-3} volts	- 0.005%	5 to $5X10^{4}$ Hz
INDUCTANCE	10^{-6} to 2000 henry	0.01 to 5%	0.1 to 10^{9} Hz

Question 4: EQUIPMENT TO BE CALIBRATED?
Replies for quantities ranked 1 to 5

QUANTITY	ITEM
RF POWER	THERMISTOR MOUNT. NOT KNOWN. COAXIAL BOLOMETER MOUNT.
VACUUM	McLEOD, PIRANI, QUARTZ BOURDON GAUGES. BAYARD-ALPERT GAUGES. IONIZATION GAUGES. THERMAL CONDUCTIVITY GAUGES. ALL MODELS OF IONIZATION GAUGES. ALL HIGH VACUUM EQUIPMENT.
LEAK RATE	HALOGEN LEAK STANDARD. LEAK BOTTLES. LEAK RATE STANDARD.
IMPULSE SPECTRAL INTENSITY	EMPIRE TYPES 1G-115, 1G-120, 1G-118, STODDART TYPE 91263-1, POLARAD 1C-120.
VIBRATION	ACCELEROMETER AND AMPLIFIER. SPACE VEHICLE ACCELERATION.

Question 6: NUMBER OF SIMILAR DEVICES NEEDING CALIBRATION?

Replies on quantities ranked 1 to 10

RANK	QUANTITY	FIRST YEAR	THEREAFTER PER YEAR
1	RF POWER	8	9
2	VACUUM	65	98
3	LEAK RATE	11	9
4	IMPULSE SPECTRAL INTENSITY	5	3
5	VIBRATION	5	4
6	VOLTAGE RATIO	3	3
7	REFLECTION COEFFICIENT	45	24
8	PHASE (LOW FREQUENCY)	7	3
9	VOLTAGE (LOW FREQUENCY)	1	0
10	INDUCTANCE	18	18

Question 9: WHY IS THIS SERVICE NEEDED?

Reasons reported most frequently; more than one reason often given.

TO PROVIDE A STANDARD; TO PROVIDE OR IMPROVE A CAPABILITY. 36

TO PROVIDE TRACEABILITY; TO SATISFY A CONTRACTURAL REQUIREMENT. 36

TO IMPROVE QUALITY AND RELIABILITY. 17

FORECAST REQUIREMENT. 14

TO OBTAIN CORRELATION BETWEEN ORGANIZATIONS. 12

TO INCREASE CONFIDENCE. 7

FOR SECONDARY STANDARD CALIBRATION. 6

TO REDUCE MANUFACTURING EXPENSE. 5

TO REDUCE COST OF STANDARDS CALIBRATION. 4

Question 10: WHAT IS THE ECONOMIC OR OTHER IMPACT IF THIS SERVICE IS NOT AVAILABLE?

Total of all replies on 85 forms showing an entry.

INTANGIBLE; UNKNOWN	50
TO ELIMINATE CONFUSION OR UNCERTAINTY	25
CERTIFICATION MANDATORY	10
DEFINITE DOLLAR AMOUNT	5

Question 11: HAVE YOU TRIED TO OBTAIN THIS SERVICE BY SPECIAL ARRANGEMENT?

All replies listed; those in ( ) referenced correspondence.

QUANTITY	YES	NO
RF POWER	2 (1)	4
VACUUM	3 (2)	2
LEAK RATE	4 (2)	0
IMPULSE SPECTRAL INTENSITY	2 (1)	0
VIBRATION	1	1
VOLTAGE RATIO	2	0
REFLECTION COEFFICIENT	2	4
PHASE (LOW FREQUENCY)	0	1
VOLTAGE (LOW FREQUENCY)	0	1
INDUCTANCE	1	2
TOTAL ALL QUESTIONNAIRES	49	49

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SESSION 8. PERSONNEL DEVELOPMENT

R. M. Lady, Chairman
Lockheed-Georgia Company, Marietta, Ga.

Introduction

For those attending an NCSL Conference for the first time, it should be pointed out that the Personnel Development Committee is primarily interested in the evaluation, selection and training of standards laboratory personnel. Some previous activities and workshops stressed the "training" portion of this interest, but the present project of this committee is concerned with evaluation and selection. This session has been divided into two parts—the first half will deal with our present project, and the second half will deal with customer training programs by instrument manufacturers.

One of the items that has been discussed since 1962 has been the problem of not having enough trained technicians and engineers, or not being able to hire them. Quite a few people throughout the organization indicated that they were having this problem. However, since then at least two educational institutions have endeavored to assist industry in fulfilling this need. The George Washington University in the District of Columbia now offers a degree in Metrology at both the undergraduate and the graduate level. However, as indicated by the enrollment, interest has not been very high. In regard to technicians, this committee recently received a letter from the Steel Valley Technical School in West Mifflin, Pennsylvania, which secured around $100,000 under the Manpower and Training Act for training students as instrument technicians. They offer what appears to be a fairly complete course of approximately 1400 hours in industrial instrumentation including procedures, basic trouble shooting, safety, etc. They had 50 students graduate last January, and I pass this along just as information. We are not endorsing any school, but merely letting you know that there are organizations tyring to fill the gap that we said existed several years ago.

PART I—PANEL ON EVALUATION AND SELECTION TEST

R. M. Lady

We are going to discuss first an evaluation and selection test that we have been working on for some time. We know that many of you probably have the same problem—inherited personnel. When your lab first started up, your people might have been picked from inspection or production departments and told to calibrate instruments at the Standards Lab. Once you had them, in some companies at least you couldn't get rid of them, so the only solution was to train them.

The question still exists as to how to determine who needs what type of training or who would be a good prospect for employment. Our committee has been attempting to develop some examination or survey or questionnaire that could be used not only in hiring new people but also in evaluating the people that you already have. What training should they have? Do they have hidden characteristics and abilities that you know nothing of? This is a bigger problem than it appeared to the committee when we first started work, and it's taking more time than expected. You'll hear more about this a little later, and we will be soliciting your help. Although this evaluation will help you mostly in selecting new people, we believe it will also be an aid in determining whether they have the right attitude as well as the basic knowledge.

N. T. Grisamore
George Washington University, Washington, D.C.

Some of you may have picked up this little blurb that was prepared rather hurriedly to give the purpose and procedure on the evaluation and selection tests, and Mr. Lady has a few more that he's going to distribute. I think that there really are two purposes assumed here—two uses of the results. The first one would be—how do you select particular people for a particular job? Now I know that everyone who has a responsibility for this does it in a particular fashion. But how about getting the collective knowledge of everybody who does this? Secondly, once you select these people, how do you know at what level they can perform? They might be completely competent in a particular job, but at what level of this type of work should they be placed?

I think that the first go-round of any questionnaire that we send out would have the primary purpose of obtaining the collective knowledge and experience of supervisory personnel in the evaluation of the employees. Now, let's use this term evaluation a little guardedly; I don't want it to sound as formal as it does. It means merely that you have some idea of how well a man performs in the job he has. We're not asking you to determine the causes of why he performs well or poorly. Our results will be sent back as a guideline for you to use in your selection and evaluation of employees. There's no sense in merely collecting it and keeping it hidden someplace. Our job here is to get the information back to the individuals who can make use of it. The questionnaire will not be devised primarily to determine the method by which you evaluate employees, but to help us in preparing a test which will allow you to evaluate employees. We hope to obtain the information which will first of all divide the laboratory employees into specific groups, as listed here. These groups may not be the ultimate choice, but are the ones that I thought would be a natural division. In this proposed draft the grouping is by job function and education. The second purpose of the questionnaire is to define the characteristics by which employees may be evaluated, or selected for a particular type of job. We are not going to try to determine what is a good method, or a bad method. What we want is information on the method that you use. We can then compile the results, get this information back to you, and let you decide whether it is a good method or a bad method. With these two kinds of results in hand, we must generate a test on more specific topics. Again, let's guardedly use that word "test". I know that a majority of you are going to run into problems as soon as somebody says "test".

This questionnaire, whether it's the one you have in hand or a modified version, will be sent to all NCSL members. Some of these answers for one reason or another, or for particular laboratories, might be unsuitable to broadcast, so we will make every effort at keeping the answers anonymous, by coding laboratories so that only the committee knows the code. I would suggest that at the end of our effort, the individual replies be sent back to the originating laboratories, and they can destroy them. I think that most laboratories would feel better if the information was returned for their disposition. Later on, Mr. Lady will go over this questionnaire in detail to find out if you have any suggestions or comments. The results from the questionnaire will be collated and various employee characteristics will be noted. Then a second questionnaire will be sent to the participants, in which they will be asked to characterize their own employees, in specific types of jobs. In other words, each laboratory will categorize their employees against the characteristics that have been generated from all the laboratories.

When the second questionnaire is returned, we can correlate the answers and define or determine what might be called universal characteristics for particular jobs. The universality might not be 100 percent, so use the term advisedly, but I would hope that this information would serve as a guide in the selection of employees.

F. T. Kallet

General Precision Aerospace Corp., Little Falls, N.J.

My activity at this session is to discuss the intended use and interpretation of the results of this test. Since we haven't any results as yet, we can't really discuss them, but we can tell you a little bit about what we are going to do with them. Once the test is designed and accepted, it is our intent to include it in the Recommended Practices Handbook for Standards Laboratories. We hope that this can serve as an industry-wide guide for selecting personnel for standards work. A secondary purpose will be to assist educational institutions in establishing their curricula. NCSL has regularly advocated that formal training be made available in our colleges and universities. Some schools have responded to the call as already mentioned. The burden is upon us all to assist those schools who are interested in developing such programs. By submitting the requirements of our testing program to those interested schools, perhaps we may help motivate them to establish a curriculum. If nothing else, we will have made them aware of industrial and government requirements in the field of standards and calibration.

Next, the testing program is to be itself tested. When the test is submitted to NCSL member organizations, they will be asked to have their own personnel take the test, and to submit the results (without names) to the Committee. From this, we will be able to review the adequacy of the questions asked in the various classifications. If after analysis, the results show the test to be too demanding or too simple, then it will be amended as appropriate to the knowledge presently available in industry. So you see that your inputs to the committee are essential in evaluating the preliminary results and developing the final test.

When the test is complete, we plan to distribute it to NCSL members, and insert it in the Recommended Practices Handbook under Selection and Training of Laboratory Personnel, so that it may be used as a guide for individual companies. These may change the details if they see fit to do so, to satisfy their own needs. There are many details which have yet to be settled—such questions as: Will the test have the same requirements for personnel servicing military and/or commerical products? To what degree will mechanical and electrical portions be separated? What weight to give each part of the test? Should provision be made to prevent the test from getting wide distribution, to circumvent the few who may be dishonest? How will the test be up-dated, as new and better techniques are developed? These and other problems have prevented the Committee from coming up immediately with a full testing program. We are fortunate in having Dr. Grisamore to assist us with the general techniques of testing. As explained, you will be contacted on a number of occasions. The committee will be looking to the membership for direct assistance, and we hope that you will respond enthusiastically to our correspondence.

R. M. Lady

Now let's take a few minutes to look over the rough draft of the preliminary questionnaire. We are depending upon your comments at this time, in order that we may revise it before we come up with the final draft.

Q: What was the name of the trade school that you mentioned?

A: The Steel Valley Technical School in West Mifflin, Pennsylvania; if you'll see me after the session, I can give you a bit more information.

Q: I have one question on the psychological attributes which a good calibration technician should have. How much thought has been given to this, and is it possible to test this with the questionnaire? Are you going to cover this in the draft you send out to the companies, to see what their feeling is on this?

A: This test will be a kind of cross between a pseudo-preference test and a knowledgeability test, to see if we can determine the attributes and characteristics of a good technician. Yes, sir, we are attempting to do this.

Q: My feeling is that the average technician or engineer who works in a Standards Laboratory must have some rapport with the equipment, but I don't know any men like that at all. Apparently, the knowledge and the attitude required should be half technical and half artistic, if you want to use that word. Did you say that your tests would include a way of testing on attitude?

A: This is correct. On this first preliminary questionnaire we hope you folks will tell us what particular clues you look for regarding attitude. What are these characteristics that you want to know? There are standard ways of using vocational guidance tests to get this type of information, using a number of questions already made up. The profile of an individual is generated by his interest in mathematics, outdoor activities, science, art, music composition, or what have you. Each of these interests is arranged in a graph according to how the person answers the questions. Individuals in particular occupations known to be well suited to their jobs have been shown to have particular profiles. We wouldn't have to generate anything—if what we need is a vocational preference test. There's only one difficulty that worries me about this psychological testing, and that is that we should make sure that a psychologist is available to interpret the results.

Q: To me it would seem rather difficult. I have seen electronics engineers who are completely enraptured with electronics in general, and yet in the standards lab they have no appreciation at all for the equipment sitting on the bench. The point is, I think a man should have a bit of reverence for this equipment that is so well made. If he hasn't and doesn't treat it accordingly, then I don't want him around the lab. This is rather a difficult thing to test for and yet I think it is necessary.

A: The committee has had some discussion on this and has found that in some companies selection includes a practical test: the applicant is given a written procedure and the equipment and told to make a calibration. In some cases the procedure is intentionally vague in order to induce questions, and the type of question and handling of the equipment is considered by the person giving the test.

PART II—CUSTOMER TRAINING
The Need for Customer Training

Jack Woolridge

Ideal Aerosmith, Inc., Cheyenne, Wyoming

I'd like to change my topic to "The Need for Training". As a representative of a manufacturing firm, I am naturally biased to one side of the picture, but I do most certainly realize that there is need for education on both sides, both at present and increasingly so in the future. This need results from the necessity of measuring more and more accurately. In fact, there is a definite relationship between man's ability to measure accurately and the advancement of our civilization. But the more accurately a person attempts to measure, the more complex becomes the problem of measuring, and the more specialized must be the training and thinking required. This leads to specialization in some

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small area of the art; for instance, the measurement of temperature, pressure, mass, length, humidity, and so on. The need for finer and more accurate measurement creates the need for further specialization, perhaps even in a small range within the categories mentioned.

Knowledge of precision measurement is developed by years of intensive study in a relatively small area. Manufacturers of precision measuring instruments usually have such a background. Users of instruments are interested primarily in the results achieved, but not particularly interested in how they are achieved. This is where some of the problems arise. It has become evident that the results achieved by measuring instruments are no better than the ability of the operator. In fact, an operator in many instances must work with an instrument for a long period of time, must study operating techniques and the theory of operation, and must evaluate the results before he can achieve the desired accuracy. Users of precise measuring devices often do not have the time to study, or to test and develop the necessary techniques. The manufacturers of precision measuring instruments live with these problems day after day, year in and year out. To survive, they must attempt to develop the required instruments and techniques.

Since our firm's work is in precise measuring, actually using only two basic types of instruments, mercurial manometers and one type of precision tilt meter, you will have to forgive me for using for illustrative purposes some examples of what we encounter.

Not too many years ago, there was very little need for customer training. Manometers which were acceptable for general industrial use at that time required an accuracy from 0.025 to 0.050 of an inch of mercury per atmosphere. The instrument could simply be set up for operation and the required readings taken. The next few years required quite a number of refinements to gain the required accuracy with such devices. A knowledge of the basic concepts of manometry, as found in any good physics book, were definitely required. If you wanted to achieve accuracies on the order of 0.005 to 0.010 inch, you corrected for:

1. The density of mercury due to temperature changes.
2. Expansion of the scale due to changes in temperature.
3. Variation of gravity due to elevation and latitude.
4. Capillary depression.

At this time, the need for education became apparent, for users of this type of instrument began to have trouble. The most common sources of error were:

1. Incorrect zeroing of the scale.
2. Poor vacuum above the mercury.
3. Dirty or contaminated mercury.
4. Improper correction for changes in temperature for scale and mercury.
5. Glassware not clean.
6. Misunderstanding of accessories used for correcting or compensating for temperature and gravity.
7. Failure to level the instrument.
8. Failure to recognize the air head between the manometer and the instrument tested.
9. Not correcting for capillary depression.
10. Neglecting to use scale or calibration corrections.

At the present, manometers are available which can give accuracies in the neighborhood of 0.0001 to 0.0003 inch of mercury per atmosphere. The instruments are designed to eliminate the operator error as far as possible. However, the results achieved with this type of instrument are very dependent upon control of the environment, and even more on the knowledge and technique of the operator. Here, there is a definite need for customer education, and our approach is as follows:

1. The operation and maintenance manual furnished with each instrument includes:
   (a) Theory of the instrument.
   (b) A list of 44 known uncertainties which limit the performance of the instrument. This is affected by the state of the art in other areas of measuring; the most important being gravity, temperature, and length. Other uncertainties result from the environment of the installation. These uncertainties have always existed but the user did not have to recognize them because they were an insignificant part of the total error.
2. The initial set-up on the instrument is made by a trained factory representative at the user's site. At the same time, a short course of instruction is given to the operators, calibrators and any other personnel that the user wishes.

In addition, our company has two other approaches. We offer to any interested user an opportunity for a short familiarization and theory course at our home plant, scheduled to fit customer requirements. Also, a 3 to 5-day course is offered at the user's plant. These short courses do not turn out fully qualified operators. They do greatly shorten the training period, and arouse interest which leads to self-education and enthusiasm for the job at hand. They also aid a user in trouble-shooting, perhaps saving him many hours of down time and several hundred dollars for a service call.

Very seldom do we find an instrument not operating correctly. Erratic results can usually be traced to environmental conditions or operator technique. The factory servicemen have faith in what the instrument tells them, and they look for trouble in odd places elsewhere, such as:

1. An air-conditioning unit blowing directly on one side of the platform on which the instrument is mounted, causing it to contract enough to put the instrument out of level.

2. Machinery or personnel creating vibration or tilting the floor in an adjacent room.

3. The sun shining on one side of the building, the other side being in the shade, which caused a very perceptible tilt in the floor or platform.

4. Failure to recognize the heat of compression of mercury and mistaking it for a leak in the system or instability of the instrument.

These are just a few of the possible troubles which when recognized can be corrected by improving the installation or applying a mathematical formula.

Pressure measurement and calibration are only a small portion of the work being done in standards laboratories. The tolerances in other areas of measurement are becoming increasingly tight, and uncertainties which were overlooked because of their insignificance, become increasingly important. Specialists who devote their time and thought to these areas must be consulted. There is a definite need for training. Its benefits can be measured in lowered costs and in better performance.

A Teacher Training Program

Loebe Julie

Julie Research Laboratories, Inc.

I have ten pages of material, prepared some time ago, on a program for education and teacher training in precision measurements. However, I will restrict myself to the time that's available by going through the highlights only. I do have a few copies with me which I'd be glad to give to any of you who are interested.

I'm sure that you are aware of the serious need for a training and education program. We already have personnel, and the problem is what to do next. Perhaps because I'm more of an engineer than an educator, my own definitions for education and in-plant training are very much the same: an attempt to provide efficient transmission and reception of useful information. In the twelfth year of my company's history, we're trying to train operators, people who will service equipment, and people who will perhaps design software. I find that it is first necessary to learn things for ourselves.

In the last three years there have been something like 800 people in various lecture-demonstration seminars and something like 800 people in teaching lecture-laboratory courses on D-C instrumentation. The most effective training was in the 32-day lecture workshops, because the people were exposed to both the software, the design theory, procedures and techniques—and to the hardware—manipulating apparatus with reverence, taking data, and struggling to get scientifically valid answers.

The gap in DC measurement that we recognized in 1953 still exists. As a result, a new program was formulated. I describe it as a company-oriented precision measurement education and training program. Precision measurements are now to be found not only in the Standards Laboratory itself, but in calibration echelons, inspection echelons, and in manufacturing research and development activities. The gist of the proposed program is to expand the Standards Laboratory's mission to include the responsibility of teaching precision methods and techniques throughout the entire company. The extra work is more than compensated for by the extra importance and extra prestige accruing to the Standards Lab. If you take on the job of educating other personnel throughout the company, I think you can justify a larger budget for your own teaching program.

The program is intended to be a very practical one as opposed to a thoroughly academic one. Only those calibrations that are old hat in the Standards Laboratory would be taught at first, and certainly what ever calibrations are done outside the Standards Laboratory would be under Standards Laboratory supervision. Copies of calibration reports, data sheets, and certifications would be under the cognizance of the Standards Laboratory, and there would be periodic inspection audits made by Standards Laboratory personnel. A final feature of the company-oriented training program is the feedback, which provides that the departments involved periodically review the curriculum and evaluate course results. We are now talking about a figure of merit: calibrations per unit time as a function of the training effort and expense that is being devoted. In such a program, the Standards Laboratory personnel have their finger on all the calibration work being done. Thus we get traceability through an educational hierarchy, instead of through a standards hierarchy. There are some companies throughout the country that already function in the way I've described. However, there is no formal program to implement such a plan, and the purpose of writing it up is to see whether other companies will take advantage of this approach.

The teacher training program becomes logically necessary when we decide that the Standards Laboratories will undertake precision measurement training and education within the company. The obvious question is, how is the Standards Laboratory going to start teaching such a program. This now requires teaching teachers. I have an outline of the teacher training course, designed to cover the problems that the student teachers will have to cover. We are not trying to award degrees; we are trying to improve a company's calibration output. It is an attempt to examine the modern applications of precision measurements, but not everyone should get the same level of instruction. The most elementary material would be offered to the operators of the instruments, perhaps at a more advanced level of work to those who maintain the equipment. At a still higher level are the designers of hardware, and the designers of software, the procedures for calibrating, and finally the teachers in the training program. Our own teaching program was developed because, having fabricated a new tool, it became necessary to teach people to use it. You should concentrate on modern tools—not light beam galvanometers, but electronic null detectors, counters, and oscilloscopes. As to method, the emphasis on both theory and experiment is extremely important. The best potential teacher is normally a senior Standards Laboratory man, but he must have the ability to communicate. You have to motivate him, perhaps by financial rewards, status in management hierarchy, gratification in becoming associated with the job, the desire for self-improvement, or a better professional image.

To sum up, such a teacher training program and a company-oriented precision measurement program could achieve higher calibration accuracy, quality, and traceability. It could permit more efficient use of personnel, because the Standards Laboratory could delegate routine calibrations to other people. It could reduce down-time delay in calibration and standards. It could perhaps repair the breach that sometimes exists between the Standards Laboratory and other departments. Most importantly, it could give the Standards Laboratory its rightful role as a leader within the company, deserving both financial and moral support of management.

Training Services on Industrial Instruments

William Reynolds

Director of Training, Industrial Division of Honeywell, Inc., Fort Washington, Pa.

It would be unfair not to point out that most of the training services offered by Honeywell are also offered by other instrument companies, such as Leeds and Northup, Foxboro, Taylor, Bristol, and most of the other larger instrument manufacturers.

However, I am here to tell you about the Honeywell training services. The industrial Division (many of you will remember it as the Brown Instrument Company) gave formal training courses to customer personnel as early as 1935. The idea proved beneficial, both to them and to us. Last summer our Industrial Division moved to the outskirts of Philadelphia to a new plant which houses the new Education Center. This facility comprises six classrooms capable of handling up to 130 students, a modern process-instrument laboratory for up to 65 students, and a smaller lab complete with its own real-time process computer and peripheral equipment. An inventory of $400,000 worth of instruments and testing equipment and tools permits each student to have his own instrument to work on in the lab. We have 16 full-time instructors; in their 125 years of teaching experience they have trained over 12,000 people.

Our most popular courses are those on "Instrument Service and Maintenance." Four courses that differ somewhat in the scope of material covered are offered two or three times a year. Each class is made up of several different sections and students may register for any or all of the sections, depending upon their needs and interests, although all include two weeks of potentiometer training. The program is about equally divided between classroom lectures, demonstrations, and laboratory bench work. Liberal use is made of visual aids such as slides, films, diagrams and models. Students are encouraged to participate in class discussions. They are supplied with pertinent printed matter such as catalogs, service manuals, instruction books, conversion tables, etc.

Bench work consists of putting Honeywell equipment in operation, observing response and performance, and then completely disassembling it. Reassembly, adjustment, and calibration, and trouble shooting complete the exercise. This work is conducted under the close supervision of competent instructors, about one instructor for five students. There are no fees or charges of any kind.

A second course is entitled "Fundamentals of Instrumentation." It is a two-week class for men with little or no instrumentation experience in measurement and control, or for those who may wish a review of basic principles of operation and application. It covers basic measurements and primary elements; receivers and transmitters in the form of non-indicating, indicating and/or recording instruments; pneumatic and electric controls; and final control elements (valves). Since this is a general course, we charge a fee of $150.

A third course is "Introduction to Process Control Dynamics"—an intensive one-week program for experienced instrumentation and systems engineers. The aim is to teach non-mathematical techniques of evaluating process dynamics for the purpose of applying automatic control. Both transient-response and frequency-response methods are studied, including procedures for combining the frequency response characteristics of the modes of control with those of the process, to obtain optimum control performance. Graphical techniques of studying both the open and the closed loop behaviour of systems are employed.

Another course is "Computer Maintenance," a 12-week session on real-time computers, given several times a year for the past three years.

Regular courses in computer programming are also given to customers who have purchased our process computers.

In all, we are now training up to 1,000 customers' men each year for a total of 1,500 man-weeks at the Industrial Division Education Center. A point which should be of interest is that the effectiveness of instrument technicians is so improved by attendance at these courses that customers have estimated that the productivity of their men is increased three times—certainly a worthwhile result. We can believe this because our own field service representatives are five times more effective than the average customer's technician.

In the Aeronautical Division, a school has been in operation since 1941, offering training to 1) Air Force, Navy, Army, FAA, NASA; 2) All major airframe companies, e.g., Boeing, Lockheed, North American, Douglas, etc.; 3) other aircraft manufacturers and dealers, both domestic and foreign, e.g., Beech, Piper, Aero Commander, Cessna, DeHavilland; and 4) all major domestic and foreign airlines.

The course aims to meet engineering and technical training requirements on a systems and/or component level—including operation, maintenance, system interfacing, and overhaul/repair procedures. Laboratory-lecture/lab facilities are integrated with the classroom area. These include built-in power sources (400 cycle, 28 VDC, etc.), pneumatic sources, system operating mockups and demonstrators, and such training aids as color transparencies, charts, and projectors. Approximately 1,100 engineers and technicians are trained per year by a staff of 12, including on-site resident instructors.

Most of the Aero Division's major customers, including the military, require that we provide adequate factory training in support of our products. This is usually scheduled under contract. The costs include course preparation, training aids, training equipment (where specified) and course instruction. Classes vary in length from one to forty days, depending on complexity of the system being covered and the type of training required (familiarization, field maintenance, detailed mechanization, or overhaul). Both the Aero Division and its customers benefit directly from these special training programs. It is difficult to visualize how our equipment would fare in the hands of our aerospace customers without well-planned courses of instruction for their engineers and key technical personnel. On the other hand, where our products are installed, tested, and operated by competent, skilled personnel, we expect that our equipment will perform to its design capability.

Our Test Instrument Division in Denver provides customer training courses on request for users of Honeywell recording oscillographs, magnetic tape systems, and such precision laboratory instruments as resistance bridges and potentiometers.

The Honeywell EDP Division in Wellesley, Massachusetts provides extensive training on computers which process accounting data, as contrasted with the real-time industrial computers mentioned above. EDP has a staff of 30 instructors in Wellesley and in its education center in Los Angeles. This staff will grow to 50 by 1967. Additionally, 80 field-based instructors devote full time to training customers, as part of our support capability offered to users at no cost.

Installation of Attenuator Calibrators

Gunther U. Sorger
Director of Research, Weinschel Engineering, Gaithersburg, Maryland

If one talks about a standard at microwave frequencies, one has to describe with it a standard technique which is used to compare an unknown device, such as an attenuator, with that standard. Therefore, when our company offered an attenuator calibrator (VM–1) to standards laboratories to be used as a primary standard, we felt that it was necessary to describe a suitable technique, and to instruct the customer's personnel in the use of the equipment. Accordingly, we offered to purchasers as an option a training course of one week to train people to the point where they acquire confidence in the equipment. In addition, summer courses were given at GWU and UCLA.

An initial letter to the organization provided a layout of the installation and training course, and advised them what equipment they should have on hand. It also asked the nature of their specific measurement problems and a roster of the professional backgrounds of the technicians, engineers and supervisors who expected to attend the course.

Introductory material included slides showing block diagrams of the equipment, photographs of certain wave shapes, and a history of the instrument's development. In demonstrations, use was made of those frequencies, ranges, and transmission lines where measurements could be made accurately and effects could be shown impressively.

First day: Set up equipment; simple tests, like d-c measurements on mixers, continuity, insulation, proper indication for frequency locking, checking by symptoms at oscillation of phase to show wrong AFF.

Second day: Review of systems for attenuation measurements, frequency range, attenuation range, error analysis, ease of operation. Detailed description of parallel type IF substitution technique: mixer linearity, accuracy of waveguide-below-cutoff attenuator, error due to noise, erroneous signals, non-sufficient frequency locking, change in band center frequency of IF amplifier, RF leakage (X-band waveguide). Demonstrate these errors on actual set-up (overloading on mixer: crystal current change; non-linearity of piston attenuator, dropout of AFF; tuning of first IF stage to tune out IF reactance of mixer output. Difference in RF leakage between open flap coarse attenuator in X-band waveguide and rotary vane attenuator. Error due to signal frequency shift because RF input impedance into mixer to sharply tuned).

Applications of equipment other than attenuation measurements. General power ratio measurements. Measurement of reflection coefficient amount, measurement of directivity of directional couplers. Microwave filter response. Microwave multiplexer, side lobes of antenna measurements.

Third day: Demonstration of very accurate insertion loss measurement: tuning of generator output impedance and the load input impedance. Actual demonstration of mismatch uncertainty: Match load perfect, put slide screw tuner in front. Tune out for certain VSWR. Change position of probe, but not depth. VSWR stays same, but reflection coefficient angle changes. Match out generator: no change. Mismatch generator: show change and compare with calculations; calibrate item prepared by organization.

Fourth day: Change set-up for all frequencies for which equipment is intended and for which sources and mixers were bought. Verify specs (conversion loss, linearity, etc.). Perform performance test method on complete assembly according to instruction manual (use attenuator calibrated by NBS, measure at different power levels, show deviation of measured from nominal value).

Fifth day: Perform measurements suggested by organization: e.g., calibration of signal generator output attenuator. Calibration of 30 MHz substitution attenuator. Use of VM–1 as stable 30 MHz source with good output attenuator to calibrate another 30 MHz receiver. Comparison measurements using different systems: actual power measurements, audio substitution measurements.

SESSION 9: TRACEABILITY AND ACCURACY RATIOS

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The concepts of traceability and accuracy ratio and the government contractual regulations pertaining to these subjects continue to be sources of confusion. In this session these topics will be discussed by a speaker from industry, one from DOD, and one from NASA. Then the speakers and additional representatives of government and industry will convene for a panel discussion.

Our standards and calibration laboratories exist to make possible the measurement accuracy required on the production line, etc. "Traceability" implies that all such measurements are made in terms of the national standards, and that the uncertainty in these measurements is known and is adequate. The measurement accuracy in any echelon must be sufficient to pass the required accuracy to the next lower echelon, and there are means of determining the prevailing accuracy. One then may take the accuracy in two different echelons and form a ratio, but this ratio is not fundamental.

Introductory Remarks

This session grew out of discussions last summer when representatives of the U.S. Air Force, NASA, and NBS visited several of the large aerospace companies. At that time the concepts of traceability and accuracy ratio and the government contractual regulations pertaining to these subjects were found to be sources of confusion, and it was suggested that I inquire whether these subjects were of general concern in the aerospace industry. If so, it was felt that they should be discussed at this Conference. The almost universal answer to my inquiries was, "Yes, the problems are widespread and they should be discussed at the Conference." That is why we are here today.

The exact title of the session, "U.S. Government Policy for Traceability and Calibration Echelon Ration," was chosen by someone else—by the Program Chairman, I believe. I have interpreted the title to include not only statements of policy from government agencies but also statements from industry. Indeed, I have scheduled the industry representative as the first speaker. After the three scheduled speakers have been heard, they and five additional representatives of government and industry will convene as a panel for further discussion.

Before introducing the first speaker, I would like to offer the following thoughts as a background for the points to be made during the session.

The size of our "measurements community" is now large. It encompasses the entire nation and, indeed, extends into the international realm. Measurement agreement, uniformity, and compatibility must be achieved throughout this community. They can be achieved in principle by reference to commonly accepted prototypes (for example, to the standards of mass, length, and time). These may be based on a large aggregate of matter, as in the case of the standard kilogram, or on atomic constants as in the case of length and time.

It is obvious that when a single prototype like Kilogram No. 20 serves as the national standard, compatibility can be achieved only by a series of measurements originating in a comparison with the standard kilogram and extending to every grocery store, every production line, every launching site. For standards based on atomic processes, in principle anyone can establish his own standards without reference to a central standards laboratory, since atomic processes are invariant with time and location (provided, of course, that environmental factors such as magnetic fields are absent or are controlled). However, the realization of a meter or a second in terms of atomic constants is an experimental process—a measurement process involving complicated instrumentation and people. Measurement disagreements arise and errors occur even with the best of instrumentation and the best of measurement personnel. For example, the seconds derived from the cesium atom by various top-level laboratories are not all equal. Even if there were no technical problems in deriving such standards independently in each standards laboratory, the cost of doing so would be prohibitive. Thus, although an increasing number of practical standards will be based directly on atomic constants, the economic necessity will remain of obtaining most standards at most echelons from a central source, through a suitable measurement chain.

The fundamental reason for the existence of a national standards laboratory and for the other high- and intermediate-level laboratories in government and industry is to achieve the accuracy required on the production line, at the launching site, in the research laboratory, etc. When we make a measurement we wish, for example, to be able to find the length of a certain part *in terms of the national standard* of length and to know that the uncertainty in our measurement result is *within specific limits*. The purpose of our whole system of standards and calibration laboratories, and presumably the goal of "traceability," is simply to enable us to make such statements.

Let me comment further on the word "traceability." Some of my colleagues at NBS and elsewhere did not like the work when it was first coined. To me, however, the phrase "traceability to NBS" is a good and meaningful phrase. It implies that the user of the phrase recognizes the National Bureau of Standards as the source of the highest level of measurement accuracy available in the country (or at least as the source from which such accuracy should be available). It also implies, as I noted above, that all measurements on the production line are to be made in terms of the national standards and that the uncertainty in these measurements is to be known and is to be within acceptable limits.

I am concerned, however, because most of the discussions I have heard on the subject have dealt primarily with the mechanics of traceability and too little with the measurement accuracy being achieved.

In a press notice announcing the establishment of a British Calibration Service (dated 25th April, 1966), the following definition appears, which is pertinent to this discussion:

"Traceability to national standards means:

(a) that each standard used for calibration purposes has itself been calibrated against a standard of higher quality up to the level at which the higher quality instrument is the national standard itself.

(b) that the frequency of such calibration, which is dependent on the type, quality, stability, use and environment of the lower quality standards, is such as to establish reasonable confidence that between successive calibrations it will not move outside the limits of its specification.

(c) that the calibration of any instrument against a standard is valid in exact terms only at the time of calibration and its performance thereafter must be inferred from a knowledge of the factors mentioned in (b) above."

Having stated that a fundamental purpose of our measurement system is to achieve the required measurement accuracy on the production line or in the field, and having recognized that a hierarchy of standards laboratories or measurement echelons is necessary to achieve this, I now would like to comment on the accuracy required at the various echelons. The only requirement in any echelon is that its accuracy must be sufficient to permit it to pass the required accuracy to the next lower echelon. We must allow for some loss of accuracy in going from one echelon to the next lower one, but this loss can be kept very small (if we are willing to pay the cost).

How can we show that the accuracy of the echelons is adequate? A suitable way is to have a higher echelon, say, two echelons removed from the production line, measure the product on a sampling basis. If the product is within tolerances, then the echelon calibrates the production test equipment has adequate accuracy. This process can be extended to check the accuracy of other echelons. Round-robin interlaboratory comparisons can be used when different geographical locations are involved. When suitable national standards are not available, round-robins still can be used to find out the extent of measurement agreement and to improve it.

The important point is that the accuracy of each echelon must be sufficient, and there are means of determining that it is sufficient. Having established that the accuracy in each echelon is adequate, one may then take the prevailing accuracy in two different echelons and form a ratio. But this ratio is an auxiliary concept and not a fundamental one.

CURRENT DOD POLICIES AND PROBLEMS IN CALIBRATION

John J. Riordan and Charles J. Brzezinski

Office of the Assistant Secretary of Defense (Installations and Logistics)

1. Introduction

The purpose of this paper is to review overall Department of Defense policies pertaining to calibration requirements in procurement contracts, with particular reference to the problems of traceability and calibration accuracy ratios.

Accurate measurement and test equipment are essential elements of programs aimed at assuring product quality. Accordingly, provisions with respect to the accuracy of measuring and test equipment have been included in quality program requirements for material and services procured by the Department of Defense. Inasmuch as these provisions are based on what is commonly called the "contractor responsibility" concept, it may be well, at the outset, to sketch the essentials of this concept.

2. The Supplier Responsibility Concept

The following statements collectively constitute the substance and logic of the contractor responsibility concept:

1. The quality of manufactured products is dependent primarily on the effectiveness of the manufacturer's control over fabrication, inspection, and testing operations.

2. As a derivative of 1 above, manufacturers are responsible for instituting such controls of quality as are necessary to insure that manufactured products conform to consumer's quality requirements. Equally important, manufacturers are obligated to substantiate the quality of their product by objective, verifiable evidence.

3. As a derivative of 2 above, a producer ordinarily sells to a consumer not only supplies and services, but also proof that the product offered to the consumer was properly fabricated and tested.

4. Consumers usually cannot protect themselves against defective products except when those products are of relatively simple design (e.g., paper products). The reason for this is that many, if not most, characteristics of products cannot be measured and assessed at the point of purchase and at the moment of delivery. This is particularly true of products whose prime characteristic pertains to life and reliability. For example, the performance of a television set or an aircraft engine can be determined only by the passage of time or by simulated life and reliability tests.

5. The consumer is obligated to define clearly his quality requirements. Further, he must communicate these requirements in writing to the producer. These requirements are of two kinds: (1) those that pertain to the product itself and (2) those that pertain to the production environment. Thus two types specifications must be prepared by the consumer: (1) product specifications—documents that specify particular characteristics to which the product must conform (e.g., hardness) and the inspection and testing procedures, including sampling plans, by which such conformance is measured; and (2) systems specifications—documents which identify certain environmental prerequisites (e.g., adequate calibration capability) pertaining to inspection, testing, and the control of quality.

6. As a derivative of 5 above, it is incumbent on the consumer to exercise surveillance over the producer's controls, inspection, and testing in order to assure himself that the producer has, in fact, maintained effective controls in accordance with his contractural commitment. The amount (or severity) of consumer surveillance is appropriately a mathematical function of the effectiveness of the producer's controls and of the demonstrated quality and reliability of the producer's products. Minimum surveillance is adequate when a producer is demonstrably reliable.

3. Contract Calibration Requirements

The above described concepts are expressed in numerous documents with which the DoD has implemented the supplier responsibility approach to the problem of assuring the quality of purchased supplies. One example is the following statement which has been added to the quality assurance provisions of all material specifications:

"*Responsibility for Inspection:* Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements."

There is no direct reference to calibration in the above quoted specification provision. It permits the supplier to use his own facilities or any commerical laboratory provided these facilities are acceptable to the Government. For these facilities to be acceptable, some provision must be made for assuring the accuracy of measuring and test equipment used for performing the specified inspections.

The standard inspection clause in contracts does not include any direct reference to calibration requirements. Like the above quoted specification provision on responsibility for inspection, the following statements in standard inspection clauses invoke, indirectly, the requirement on the contractor to calibrate his measuring and test equipment:

1. If any inspection or test is made by the Government on the premises of the contractor or a subcontractor, the contractor without additional charge shall provide reasonable facilities and assistance for the safety and convenience of the Government inspectors in the performance of their duties.

2. The contractor shall provide and maintain an inspection system acceptable to the Government covering the supplies hereunder.

4. Quality Program Calibration Requirements

As previously indicated, the consumer is obligated to define clearly his quality requirements pertaining to such environmental prerequisites as control of the accuracy of measuring and testing equipment. Specific requirements pertaining to calibration were first established by the DoD in specification MIL–Q–9858, "Quality Program Requirements."[1] This specification identifies quality program requirements in terms of objectives. Among these requirements are the following controls pertaining to calibration:

Measuring and Testing Equipment. The contractor shall provide and maintain gages and other measuring and testing devices necessary to assure that supplies conform to technical requirements. These devices shall be calibrated against certified measurement standards which have known valid relationships to national standards at established periods to assure continued accuracy. The objective is to assure that inspection and test equipment is adjusted, replaced or repaired before it becomes inaccurate. The calibration of measuring and testing equipment shall be in conformity with military specification MIL–C–45662.[2] In addition, the contractor shall insure the use of only such subcontractor and vendor sources that depend upon calibration systems which effectively control the accuracy of measuring and testing equipment.

Production Tooling Used as Media of Inspection. When production jigs, fixtures, tooling masters, templates, patterns and such other devices are used as media of inspection, they shall be proved for accuracy prior to release for use. These devices shall be proved again for accuracy at intervals formally established in a manner to cause their timely adjustment, replacement or repair prior to becoming inaccurate.

Use of Contractor's Inspection Equipment. The contractor's gages, measuring and testing devices shall be made available for use by the Government when required to determine conformance with contract requirements. If conditions warrant, contractor's personnel shall be made available for operation of such devices and for verification of their accuracy and conditions.

Advanced Metrology Requirements. The quality program shall include timely identification and report to the Contracting Officer of any precision measurement need exceeding the known state of the art.

Control of the accuracy of measuring and testing equipment is such an important element of the contractor's quality program that the Department of Defense has considered it advisable to explain in greater detail that part of the above quoted requirement pertaining specifically to calibration. This additional detail has been provided in a separate specification, MIL–C–45662, Calibration System Requirements, which by reference is a part of MIL–Q–9858.

By referencing specification MIL–Q–9858 in contracts, the Department of Defense specifies clear and explicit requirements on contractors to establish calibration systems in accordance with MIL–C–45662. The requirements of MIL–Q–9858 are made a part of a contract by adding the following contract clause, as required by the Armed Services Procurement Regulation, to the standard inspection clause: "The Contractor shall provide and maintain a quality program acceptable to the Government for supplies and services covered by this contract. The quality program shall be in accordance with Military Specification MIL–Q–9858A."

5. Inspection System Calibration Requirements

Not all items purchased by the DoD are so complex as to warrant a requirement on the contractor to establish and maintain a quality program conforming to all requirements in MIL–Q–9858. For these items it may be sufficient, from the standpoint of quality assurance, to invoke the requirements of specification MIL–I–45208,[3] Inspection System Requirements. With respect to calibration, however, the requirement in MIL–I–45208 is similar to the requirement in MIL–Q–9858, as indicated in the following provision:

Measuring and Test Equipment. The contractor shall provide and maintain gages and other measuring and testing devices necessary to assure that supplies conform to the technical requirements. In order to assure continued accuracy, these devices shall be calibrated at established intervals against certified standards which have known valid relationships to national standards. If production tooling such as jigs, fixtures, templates, and patterns is used as a media of inspection, such devices shall also be proved for accuracy at established intervals. Calibration of inspection equipment shall be in accordance with MIL–C–45662. When required, the contractor's measuring and testing equipment shall be made available for use by the Government Representative to determine conformance of product with contract requirements. In addition, if conditions warrant, contractor's personnel shall be made available for operation of such devices and for verification of their accuracy and condition.

Like MIL–Q–9858, MIL–I–45208 is made applicable to contracts by adding the following clause to the standard inspection clause: "The inspection system shall be in accordance with Military Specification MIL–I–45208."

MIL–Q–9858, MIL–I–45208, and MIL–C–45662 express requirements that apply to a wide variety of conditions. Understandably, these requirements are not expressed in terms of detailed operating procedures. Quality programs must generally be tailored to contractors' plants, processes, and products. Thus the quality program requirements of MIL–Q–9858A are stated as objectives. This is also true with respect to calibration systems. A given gage, for example, may be subject either to occasional or to continuous intensive use. Thus the only practical requirement the consumer can specify is one that provides for the gage to be calibrated frequently enough to assure that it is accurate each time it is used.

6. Calibration System Requirements

The requirements in MIL–C–45662 are, like MIL–Q–9858A, expressed in terms of objectives because these requirements apply to a wide variety of measurements involving numerous accuracy levels. These requirements specify that the accuracy of a measuring or testing device used for inspection must be derived from a comparison to some basic standard—namely, a standard established by the National Bureau of Standards. In accordance with the supplier responsibility concept these requirements are incumbent on the contractor.

The provision of MIL–C–45662 pertaining to calibration intervals is a good example of a requirement stated as an objective:

Intervals of calibration. Measuring and test equipment and measurement standards shall be calibrated at periodic intervals established on the basis of stability, purpose, and degree of usage. Intervals shall be shortened as required to assure continued accuracy as evidence by the results of preceding calibrations and may be lengthened only when the results of previous calibrations provide definite indications that such action will not adversely affect the accuracy of the system.

The above quoted provision clearly specifies the required calibration interval without specifying the length of time between calibrations. It specifies the calibration interval in terms of those factors that must be taken into consideration in selecting a suitable time interval. A similar approach is quite practical for specifying accuracy requirements.

7. Traceability and Accuracy Ratios

As defined in MIL–C–45662, calibration is a comparison of a measurement standard or instrument of known accuracy with another standard or instrument to detect, correlate, report, or eliminate by adjustment, any variation in the accuracy of the item being compared. The measurement standard or instrument is to be "calibrated" against certified measurement standards which have known valid relationships to national standards. This valid relationship may be through a series of standards such as the following, which are defined in MIL–C–45662:

Measurement standard (reference). Standards of the highest accuracy order in a calibration system which establish the basic accuracy values for that system.

Measurement standard (transfer). Designated measuring equipment used in a calibration system as a medium for transferring the basic value of reference standards to lower echelon transfer standards or measuring and test equipment.

Interim standard. An instrument used as a standard until an authorized standard is established.

It is obvious that two instruments with known valid relationships to a national standard need not be equally accurate. Where the measurement to be made does not involve a high degree of accuracy there can be several calibration echelons between the measuring equipment and the national standard. But where the same measurement must be made with the highest obtainable accuracy, the next calibration echelon for the measuring equipment may have to be at the national standard level. There is no simple approach, then, to the problem of specifying either the number of calibration echelons or the accuracy ratios between echelons. Where a consumer purchases a great diversity of materiel involving a wide variety of measurements and measurement accuracy requirements, it is impractical to specify either the number of calibration echelons that must be used or the accuracy ratio that can be tolerated between calibration echelons. Accordingly, the Department of Defense does not specify an accuracy ratio between calibration echelons and does not prescribe the steps by which "traceability" to a national standard is to be accomplished. The requirement pertaining to calibration echelons, ratios, and traceability is specified in MIL–C–45662 as follows:

Domestic contracts. Measuring and test equipment shall be calibrated by the contractor or a commercial facility utilizing reference standards (or interim standards) whose calibration is certified as being traceable to the National Bureau of Standards, has been derived from accepted values of natural physical constants, or has been derived by the ratio type of self-calibration techniques. Reference standards requiring calibration by a higher level standards laboratory shall be calibrated by a commercial facility capable of providing the required service, a Government Laboratory under arrangements made by the Contracting Officer, or by the National Bureau of Standards. All reference standards used in the calibration system shall be supported by certificates, reports, or data sheets attesting to the date, accuracy, and conditions under which the results furnished were obtained. All subordinate standards and measuring and test equipment shall be supported by like data when such information is essential to achieving the accuracy control required by this specification. In those cases where no data are required, a suitably annotated calibration label on the item shall be sufficient to satisfy the support data requirements of this paragraph. Certificates or reports from other than the National Bureau of Standards or a Government Laboratory shall attest to the fact that the Standards used in obtaining the results have been compared at planned intervals with the National Standard either directly or through a controlled system utilizing the methods outlined above. The contractor shall be responsible for assuring that the sources providing calibration services, other than the National Bureau of Standards or a Government Laboratory, are in fact capable of performing the required service to the satisfaction of this specification. All certificates and reports shall be available for inspection by authorized Government representatives.

Foreign contracts. The provisions in 3.2.5.1. shall apply with the exception that the National Standards Laboratories of countries whose standards are compared with International or U.S. National Standards may be utilized in lieu of the U.S. National Bureau of Standards.

8. Conclusion

Traceability and calibration echelon accuracy ratios are elements of a broader problem, namely, the need for more precise delineation of the respective calibration responsibilities of Government and industry. Within Government there is also a need for more precise delineation of the roles of Government agencies in their relations to each other, particularly the relationship of the National Bureau of Standards to the Department of Defense.

Requirements pertaining to traceability and calibration echelon accuracy ratios are not specifically covered by Department of Defense policy statements or specifications. Such requirements, however, are broadly included in systems specifications and are ordinarily expressed as objectives rather than step-by-step procedures.

9. References

(1) MIL–Q–9858A, "Quality Program Requirements," December 16, 1963.

(2) MIL–C–45662A, "Calibration System Requirements," 9 February 1962.

(3) MIL–I–45208A, "Inspection System Requirements," December 16, 1963.

NASA CALIBRATION PRACTICES

John E. Condon

Director, Reliability and Quality Assurance, NASA Headquarters, Washington, D.C.

NASA policy requires contractors and suppliers to have and maintain a system for controlling test and inspection equipment in a manner to ensure that all accepted article parameters are within specified tolerances. Traceability to national standards is an integral part of this system requirement which is similar to that required by DoD agencies. Both of NASA's quality documents, NPC 200–2, *Quality Program Provisions for Space System Contractors* and NPC 200–3, *Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services* require that ". . . inspection, measuring, and test equipment shall be calibrated against certified standards which have known, valid relationships to national standards."

The size, complexity, and large number of parts required by the Apollo project has led to additional emphasis in metrology being placed upon Apollo contractors. This emphasis has resulted in the development and release of the Apollo Metrology Requirements Manual (NHB 5300.2). In addition to requiring that standards used have valid relationships to national reference standards, this manual specifically requires that the traceability be evidenced by valid reports and substantiated with flow charts.

A formal NASA policy directive requiring traceability to national reference standards has not been necessary relative to NASA installations equipment calibration. In accordance with normal good calibration practices, all NASA Installations have internal policies or directives with requirements, such as "each laboratory is responsible for assuring that all calibration services under its cognizance are traceable to the National Bureau of Standards."

Thus, *generally*, NASA is able to show traceability to an acceptable national standard on every parameter for which it has a requirement. I used the term "*generally*" because there are valid exceptions, which I am sure most of you are aware of. One such exception is in areas where no real standard exists or where the standards used represent the state-of-the-art, such as with vacuums, leaks, and light intensity relative to the color spectrum. Another example is where a physical constant is used as the standard, such as with temperature and frequency calibration where various melting points or the resonant frequency of the cesium atom are used as the stable reference.

Judgment sometimes becomes necessary in those areas where NASA's standards and equipment are comparable to those of the NBS. In such cases, *theoretically*, little is to be gained through traceability to the NBS; but, *practically*, the benefits of measurement reliability based on the history, stability, and experience of the NBS is important. In these cases, traceability to the NBS is maintained but usually at long calibration intervals.

This leads to another point—NASA does not indiscriminately send everything to the NBS. Calibration at the NBS requires expenditures and makes the equipment unavailable for a period of time. As NASA's capabilities improved, calibration procedures are revised to eliminate calibration of some equipment at the NBS.

An illustration brought to my attention as a cost reduction item is the 0.01 percent Rusko deadweight gage used to calibrate pressure gages. By developing high-level mass and dimensional standards, Kennedy Space Center is now able to perform its own calibration at a substantial savings. Even more important is the fact that the calibration time has been reduced from 3 or 4 months to one week. Traceability to the NBS is still maintained through the high level mass and dimensional standards utilized in the calibration.

As you are all aware, there is a lot more to traceability than just a policy requiring that the calibration of a unit be traceable to a national standard. The fact that such a calibration has been performed in itself is not totally sufficient. It is equally important that there be VALID TRACEABILITY FROM A NATIONAL STANDARD TO THE ACTUAL MEASUREMENT. This introduces a scope to traceability which I might call *valid traceability. In essence it is valid traceability that is desired.* However, outside of personnel specifically engaged in the field of metrology, valid traceability is not fully recognized and therefore often not achieved. As a result, the full scope involved with valid traceability is not always considered and thus contributes to the unreliability of the current systems.

What are the functions that should be considered in order to determine valid traceability? Generally, they would be anything that could in any way affect the accuracy of a measuring instrument. Being more specific, they can be summarized in six major functions, all of which are equally important in achieving the desired goal of valid traceability.

1. *The first function is equipment protection.* This function covers the use, handling, and storage of inspection and test equipment. In itself this function is very broad. Poor handling, improper containers for transportation, inadequate protection during storage, and other factors can easily destroy the value of accuracy obtained through the calibration to a national standard. *Yet how often are these factors fully considered?* As an example, NASA surveys indicate that some suppliers still store and issue frequently used thread, plug, and other gages thrown together, unprotected, in boxes.

2. *The second function is personnel competence.* This ties in somewhat with the function of equipment protection because competent personnel are necessary to preclude poor handling and misuse. Without competent and thoughtful personnel, there can be no complete assurance of valid traceability. This must extend beyond mere training to the motivation of all personnel to maintain the proper atmosphere within the plant.

3. *Motivation is also involved in the third function — maintenance control.* A system can establish checks and procedures to see that inoperative or inaccurate equipment is repaired. Motivation is necessary throughout the plant to ensure that these system functions are performed timely and adequately. A dropped mechanical gage that is not promptly submitted for checking and possible repair precludes valid traceability. This can cause problems before the control aspects of a system become operative and correct the condition.

4. *Environment control is the fourth function which must be considered both in calibration and use of the instrument.* Often plants have well controlled and air conditioned calibration areas; however, the calibrated equipment is then used in improper environments invalidating traceability.

5. *The proper use and control of calibration procedures is the fifth function which requires a great deal of attention.* In order to achieve valid traceability a calibration procedure must be implicitly followed in detail. An example of this was noted by a NASA representative following a recent survey of a calibration laboratory. It was found that a Rusko dead-weight gage was being used which had not been corrected for the effect of local gravity; this had a .005% effect on a .01% instrument.

To standardize and aid in eliminating the duplication of developing calibration techniques for the same equipment, NASA has recently established an inter-installation reference of calibration procedures for the Apollo program. Some of the NASA installations are also joining the National Conference of Standards Laboratories in order to participate in the benefits of the calibration procedures library.

6. *The last function is calibration interval.* The proper interval is important to prevent out-of-specification situations. Primarily in addition to controlling costs in this area, NASA's NPC 200–2 requires that calibration data be evaluated to note trends and to determine the calibration interval required to keep the instrument from going out of tolerance.

In summation valid traceability involves all of these functions, and reduction in the effectiveness of any one can nullify the benefits of all the rest.

NASA's policy on ratio-of-accuracy as stated in NPC 200–2 requires that "Within the-state-of-the-art limitations, the standards used for calibration of inspection, measuring, and test equipment shall have a tolerance no greater than 10% of the allowable tolerance for the equipment being calibrated." Unfortunately, there have been some difficulties encountered in the interpretation of this requirement. Generally the difficulties are similar to those already mentioned by Mr. Russell, in his comments, namely the interpretation of the term "within-the-state-of-the-art" and how to correctly apply the 10:1 ratio of accuracy requirement. These difficulties in interpretation result in inconsistencies and, to alleviate this, some NASA Installations have issued interpretive documents clarifying the intent of this requirement.

Use of the term "within-the-state-of-the-art" was intended to recognize that many measurement requirements are becoming so sophisticated that they approached the limits of the science of metrology. In such cases, it becomes impossible to maintain the 10 to 1 ratio of accuracy in the calibration of the instrument.

In this fast moving technology what is the "state-of-the-art" at any given moment? This is sometimes difficult to determine or interpret; especially at suppliers plants.

I fully appreciate Mr. Russell's comments relative to the desire for a single Government document on metrology. Mr. Riordan and I have discussed this matter and currently have the matter under serious consideration. With mutual cooperation both within the Government and with industry, we hope to alleviate many of our current problems and accomplish our goals in a more effective manner.

INDUSTRY'S VIEW OF THE 10:1 RATIO-OF-ACCURACY REQUIREMENT

F. C. Russell

North American Aviation, Inc., Space & Information Systems Division, Downey, California

1. Introduction

It is a pleasure to speak to you on a subject that is of great concern to all of us who are engaged in some phase of calibrating measurement standards or test equipment used for the acceptance of deliverable product.

Last June, the NBS/Air Force Working Group, while conducting a survey of contractor facilities and metrology programs, visited the North American Aviation Downey Facility, where we had an opportunity to explain our metrology program and to discuss mutual technical problems with the group.

One of our discussions centered around the accuracy ratio of standard to instrument during measurement and calibration operations. We did not necessarily arrive at a solution to this dilemma, but our discussions did point up the need for further exploration of this problem.

Mr. Harvey Lance, a member of the group, and I corresponded following the meeting with regard to this subject.

Inasmuch as the 1965 NCSL Workshop at Disneyland was almost upon us and the program had long since been established, it was decided that the 1966 Standards Laboratory Conference would be an opportune time to present the various views of industry (the contractors) and the various government agencies (the customers) and to attempt to arrive at an agreeable and realistic requirement.

Basically, the problem revolves around the actual or implied requirement that the accuracy of an instrument or standard used to measure a quantity, or to calibrate another instrument, shall be 10 times as accurate as the quantity or the instrument being calibrated.

There is also the implication that the 10-to-1 ratio of accuracy shall exist between every level or echelon in the traceability chain from product to National Standards.

This requirement could create an impossible situation in spite of the statement included in most specifications that limits this requirement to "within-the-state-of-the-art."

"Within-the-state-of-the-art," in many cases, is difficult to determine at any one point in time, and it may result in the customer, or his representative, insisting that the contractor procure and use an instrument or standard, regardless of cost, because it is available "within-the-state-of-the-art."

In order to prepare myself to better understand this problem on an industry-wide basis, I developed a questionnaire and sent copies to most of the major contractors represented here today. I would like to take this opportunity to thank all of you for your prompt and knowledgeable replies.

2. Development

Of the 24 questionnaires circulated, I received 12 of them back within 2 weeks. I reviewed the replies in detail and I found the following:

1. Of those who replied, all are engaged in Government contract work.
2. Most indicated that they are major contractors or a combination of major and subcontractor.
3. Documents or specifications that control or stipulate the required ratio of accuracy include the following:

MIL–C–45662A & B	MIL–Q–9858A
MIL–HDBK–52	NASA NPC 200–2
BU WEPS SLIM Manual	NASA NHB–5300–2
MIL–C–24133	

4. Most contractors indicated that the ratio-of-accuracy requirements imposed upon them ranged from 10:1 to 4:1, or "state-of-the-art."
5. In nearly every case, they stated that the 10-to-1 requirement was considered unrealistic from an economic as well as a practical point of view.

I will not go into detail on the answers to other questions that I asked; however, these answers have greatly influenced the conclusions I have reached and the recommendations that I will propose.

3. Observations

I am of the opinion that there are too many documents that basically state parallel requirements, the majority of which are, to a degree, unrealistic.

I an also of the opinion that the statement, "state-of-the-art," is a convenient but meaningless loophole that might as well be removed from the requirements.

You may, or may not, agree with this statement. However, my experience has been that it is a nebulous quantity that is too often used to avoid a direct answer with regard to the ratio-of-accuracy problem.

If there is any justification for a 10-to-1 ratio of accuracy, it should be restricted to *product* measurement, where in most cases environment is uncontrolled, operating personnel are not necessarily skilled, and historical data of instrument stability and accuracy is not available. However, where standards or calibration laboratory personnel are working in a controlled environment, where proven procedures are used, where data on variations are maintained to reflect instrument history, and where the technicians are skilled and dedicated individuals, as is true in nearly every case of my knowledge, under these circumstances the 10-to-1 requirement is unnecessary. Where 4-to-1 is maintained and adequate variable data are on file for reference and evaluation, the reliability of the calibrated instrument accuracy is assured.

I also believe that much of the confusion that exists relative to this ratio problem lies in the interpretation of the specification requirements. A concerted effort should be made by the contractors and customers alike to arrive at a common figure or definition of the tolerance or ratio of accuracy. This figure or definition should be so precise as to preclude any misinterpretation of its intent or purpose.

4. Recommendations

If accuracy of measurement is to be controlled by ratio, I would recommend that a 10-to-1 ratio be required at product measurement level only, and that a 4-to-1 ratio be required at the level of calibration where the measuring instruments are calibrated.

The accuracy ratio of Reference Standards to Working Standards and higher echelons of calibration should be controlled only to the extent that variable data and analysis cannot support reliability of measured accuracy.

Standards laboratory engineers should be capable of proving accuracies down to the 1-to-1 ratio when supported by the environments, skills, methods, and variable data that typifies an efficient standards laboratory.

In a number of the questionnaires that were returned, I noted that some of you feel that there should *not* be a specific value of ratio determining the accuracy of instruments used for measuring product for acceptance or for measuring instruments used for calibration.

In view of this feeling, I should like to propose an alternate plan or method of controlling the accuracy of measurements. This method would not require any specific ratio of accuracy, but rather would require a limited band of tolerance determined by the accuracy of the reference instrument used for the measurement. The absolute tolerance of a measured quantity would be reduced by the amount of tolerance of the test instrument.

For example: If a Process Specification requires a voltage measurement of 100 volts ±10%, the absolute tolerance or acceptable limits of that quantity would be established at from 90 to 110 volts.

If we should choose to use a 1% instrument to verify this quantity, then we would reduce our acceptable limits to from 91 to 109 volts.

If we should choose to use a 5% instrument to measure this quantity, then we would reduce our acceptable limits to from 95 to 105 volts.

It would be possible to use a 10% instrument, which in fact on a ratio basis would be 1:1, with the acceptable limits confined to a reading of exactly 100 volts. In all cases, the voltage is set (or determined to be) within the acceptable limits, with no ratio requirement left for interpretation or argument. Granted, this approach appears on the surface to be too simple, but why complicate measurement matters when it is not necessary?

Economically this approach can be a boon to the small contractor with limited test equipment or capital funds, for now he too can produce and deliver an acceptable product without regard for the mandatory ratio-of-accuracy requirement. His only restriction will be that his range of acceptable tolerance is limited by the accuracy of his available test equipment.

If he wishes to increase that range of acceptable tolerance, then it behooves him to arrange for the procurement of more accurate instrumentation.

This approach to controlling accuracy of measurement is not new. It is a basic method used throughout industry for years where there has been a definite desire to provide accurate measurements regardless of any contractual requirements.

I should like to acknowledge a proposed Measurement Standards Instruction bulletin prepared by the Aerojet General Corporation's Sacramento Plant, titled, "Accuracy Requirements of Calibration Standards," and forwarded to me by Mr. Van deHouten. This document is a discussion of the various echelons of standards, and although it does not pertain to test or inspection instruments, the principles established would certainly lend themselves to this area also.

This document is well written; it considers and provides for use of both the ratio and limited tolerance concepts, and I would recommend that its content be studied for consideration by any group attempting to establish internal controls.

5. Conclusions

I should like to conclude my observations with the following summation:

We (as contractors) are all engaged in similar projects, providing products for a customer.

I believe I am safe in saying that we are all in agreement that there are too many different specifications describing the accuracy of instruments required to control the acceptance of product.

We can leave things the way they are; we can negotiate for a more realistic ratio-of-accuracy requirement, or we can recommend that a *new* approach be taken by our customers in assuring accurate measurements in the process of producing and delivering data or product.

On numerous occasions, the National Bureau of Standards has been asked to establish policy regarding this ratio problem. I do not believe that they should be asked to take a position on it. This is a problem between the contractor and his customer.

The National Conference of Standards Laboratories is the logical group to resolve this issue. I recommend (1) that a committee be established to determine the most realistic approach to assuring accuracy of measurements, (2) that a model specification be prepared, and (3) that it be submitted to the various Government agencies (our customers) for their approval.

256-114 O-67—9

PANEL DISCUSSION

Participants:

John E. Condon, NASA Headquarters
George Gastineau, Air Force Contract Management Division
J. L. Hayes, Bureau of Naval Weapons
H. W. Lance, NBS Radio Standards Laboratory (Moderator)
Carl Morrison, Army Metrology and Calibration Center
John J. Riordan, DOD (Installations and Logistics)
Forrest C. Russell. North American Aviation, Inc.
W. A. Wildhack, NBS Institute for Basic Standards
L. B. Wilson, Sperry Gyroscope Co.

Question: Mr. Condon, there are procedures used in the NASA laboratories that involve accuracy ratios of 2:1 or smaller. We would like to use some of these but cannot because of the requirements of NPC–200–2. Can't this be worked out somehow?

Mr. Condon: As I understand your question, it is not a matter of conflicting contractual requirements. You merely want to use the same procedure used in a NASA laboratory, which does not happen to be compatible with a 10:1 ratio. Possibly that procedure is not applicable to the type of equipment you are concerned with. It might be suitable for laboratory developmental work as opposed to the building of flight-type hardware. The 10:1 again has to be further clarified as to what you're going to do on each particular item that you are going to be calibrating. You do have and you are required to submit a total quality program plan in accordance with 200–2. And certainly this is negotiable.

Mr. Russell: I have something to add here that might have a bearing on this problem. North American Space and Information Division has both Apollo and Saturn contracts and, as Mr. Condon has pointed out, NPC–200–2 is a guide only. We have no contractual requirements to live up to 200–2. We have an Apollo quality control plan. The requirements for calibration and for accuracy ratios are stated in this, and we have negotiated these with the customer. For a long time I for one was misled, and was under the belief that we did adhere strictly to 200–2, and I was the closest one to it at North American. But contractually, we were not required to follow it. I don't know whether you have this problem, but there is the possibility of some misinterpretation.

Question: Mr. Riordan, I was very much interested in your remarks on contractors' responsibilities in connection with ASPR–14. I wonder whether this is applicable to all contracts or whether there are some that do not contain this requirement.

Mr. Riordan: I imagine there are some contracts that do not contain the requirement, but I would expect these to be extremely few and probably in the small-purchase area. I also know that the earlier 9858A (if we use that number as a device for translating ASPR–14 into contractual language) was not applied in certain major areas such as Polaris. However, it is now being applied there. I would say that except for Polaris in the past and except for some small purchases, either 9858A or 45208A does apply. So I believe that, excepting construction, the contractor responsibility is now everywhere, even on Polaris. Incidentally, there was a very interesting meeting at the University of Virginia last week with the construction people, and I think there is a tendency to move in this direction in construction.

Question: Mr. Condon, you said that emphasis is being placed on Apollo calibrations. Does that mean that the restrictions are tighter?

Mr. Condon: What I meant was that in the Apollo program, particularly because of the size of the program and the tremendous number of prime contractors and subcontractors involved, the calibration problem has been of greater concern to that program office. As a result they have placed greater emphasis on calibration, particularly through the issuance of an Apollo program calibration handbook. There is no NASA-wide calibration handbook at this time.

Mr. Lance: I should like to break in here for something that I neglected in the hurry to make up lost time, and shall now ask some brief statements from those people on the Panel who could not be scheduled for a 15 minute talk.

Mr. Wildhack: I want to cast a little doubt on the point of view already expressed that there is nothing wrong with the terms "traceability" and "accuracy ratio" that a little explanation won't help. I suggest that the term "traceability," instead of needing amplification, perhaps needs obliteration. I certainly agree with Mr. Russell when he says that NBS should not rule on this matter. Yet NBS does have a very strong interest in it. When a large procurement agency tells a large number of contractors, "You shall be 'traceable' to the National Bureau of Standards," this is bound to generate correspondence with NBS saying, "How do I get traceability to you?" Formally, we can only reply, "That's your problem. That's a contractual term for which we find no definition in the dictionary."

I think the situation has come more nearly under control within the last few years as contractors and inspectors worked out their own interpretations. However, it remains a ridiculous situation for the measurements fraternity, who are avidly pursuing accuracy and precision, to be at the same time guilty of imprecise use of an undefined term. I certainly agree that it is high time for the various government agencies concerned to get together and write a treatise on the things that are essential for the contractor to do in order to convince the inspector that he does, in fact, have a good basis for delivering the promised accuracy in the final product. In the past, the government agencies have not worked closely enough together on these matters. I hope that in the next go-around we'll all do better.

Mr. Wilson: The Aerospace Industries Association has a Calibration and Measurements project with Frank McGinnis as Chairman. We have ten members on the project team, and I think about half of them are here at this conference. We have as one of our major tasks to review three of the calibration MIL specs, MIL Handbook 52, MIL C–45662A, and MIL C–24133. The last of these deals with calibration procedures and is of interest to NCSL and its calibration procedures library. The members of our project team have contributed their suggestions for revisions of these three MIL specs. These are going out now from AIA headquarters to the various AIA companies and divisions, and we expect to get comments back by about the middle of May. I was interested to hear Mr. Riordan mention the cost-benefit approach. I would like to quote from the preliminary comments of our project team: "The determination of accuracy for a reference standard (this pertains to the 4:1 or 10:1 accuracy ratios) should involve a cost-effectiveness approach with realistic trade-offs among such things as the cost, commercial availability, and accuracy of a standard, as well as the cost of using that standard. The selection of a reference standard based on accuracy-ratio considerations alone will rarely result in an optimum choice. Each case must be judged on its individual requirements." We also make some specific recommendations with regard to the wording. Basically these recommendations include several alternatives from which the contractor can choose. We feel that a guide such as MIL Handbook 52 should stress the alternative approaches. This is basic in the cost-effectiveness or systems-effectiveness outlook which currently is being advocated as a management concept. Hence we are suggesting the use of more alternative approaches, instead of merely making MIL Handbook 52 a direct extension, more or less mandatory, of MIL C–45662A.

Mr. Morrison: Army is the preparing activity for MIL–C–45662, which means that, in the long run, we assemble our opinions and everybody else's into a final draft for approval and comment. I have been sitting here trying to soak up all of the comments, and I think I soaked up quite a bit, including some lumps. I was most happy to hear Mr. Russell call for a concerted effort by the contractor and the customer for uniform statements. There are established channels for getting to me formally, and telling me the kind of criticism which I hear in meetings like this. Handbook 52 even gives our address. However, the amount of formal comments that it has generated has been very minute. I can recall maybe a half dozen letters, and these are generally of a very pleasing nature. So I am somewhat at a loss, having come to this meeting and heard all of the controversy. I suggest that, since we are about to revise this document, you get my address or that of Mr. Riordan's office, and forward your comments to us. AIA is taking great steps along these lines. We would like to hear from the rest of you, too, and not just from the floor at this meeting.

Mr. Gastineau: I heartily concur in Mr. Morrison's statement about getting to the source. The Air Force now is in the process of preparing a proposed revision of MIL C–45662A. We already have submitted a copy to NBS for comment, and have some comments back. We hope to get a revision which contains a suitable statement about accuracy ratios.

Mr. Hayes: Just one comment. Mr. Russell brought up an alternative to accuracy ratios which sounds appealing, but I would like to oppose it because I think it would increase the erroneous rejection rate of the product and having increased that, it would increase costs. I think if you really investigate it statistically, that's what his second alternative amounts to.

Mr. Lance: Gentlemen, time does not permit further discussion. Some very interesting points of view have been expressed here today. These, I believe, point the way toward a reconciliation of the differences of opinion on such subjects as traceability and accuracy ratio. In conclusion I would like to emphasize the suggestion made earlier for more thorough mutual discussions among the groups involved.

SESSION 10: WORLDWIDE UNIFICATION OF INDUSTRIAL STANDARDS

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Preface

Why are we concerned with metrology, its problems and short-comings, its lack of appreciation, its lag behind national economy growth throughout the world? Let me illustrate the international aspect of this increased concern with a few extracts from a recent issue of Izmeritel'naya Tekhnika.

"Hardly any problem of national economy can be dealt with successfully without basic information on a multitude of quantities required for its solution, such as the quantity of a given product, the composition and properties of various materials and substances, geometrical parameters and the working characteristics of articles and systems, time intervals between events, etc.

"The basic criterion to determine whether the measured information is suitable for solving a specific problem consists of the precision with which this information meets the requirements set by the problem. Take for instance, moisture content of grain—an important consideration in evaluation, buying, and selling. If, as happened in 1961, all hygrometers used in a country are calibrated with an error of 0.3% lower than actual value, there is a loss of $2500/1000 tons of grain to the industry.

"A large quantity of undiscovered and fictitious rejects creates great difficulties for coordinating production. The existence of undiscovered rejects in the deliveries of manufacturing plants forces consuming plants to establish a full acceptance inspection, and to retest all the delivered materials and component parts, which is a wasteful practice.

"In the relationship of quality to measured information, two things are clear:

"1. Measurements constitute an important part of all the work whose quality has a direct effect on the quality of products.

"2. The basic criterion of measuring processes, which shows their capacity for ensuring production quality, consists of their RELIABILITY, i.e., the probability that measurements will provide information whose accuracy corresponds to the requirements of the specific problem.

The inevitable conclusion is, the establishment of conditions which fully eliminate the possibilities of obtaining measurements which are either incorrect or insufficiently precise for the solution of specific problems of a national economy, is a task of first-rate national importance.

"The condition of the measuring equipment, which provides measurements with the precision required for a reliable solution of specific problems in a national economy, is said to provide uniform measurements. Therefore the main task of a unified national system is the provision of uniformity of all measurements carried out in a national economy.

"There is a need for continuous statistical control of the measurement quality of measurement instruments which are used in a national economy.

"There is a need for development and adoption of methods and means of testing which simulate the most important external effects which are characteristic of the environment to which an instrument is exposed in practice.

"There is a need for knowledge of the characteristics and conditions of use of measuring instruments, and for dissemination of this knowledge to all activities affected. This knowledge should include, not only the simplest measuring instruments, but all the complex systems, those related to high-speed quantity measurement, to analyses, to telemetry, to all types of transducers and converters comprised in automatic controls and processing equipment.

"A national measurement system should 1) systematize and classify typical measurement problems which arise in a national economy, 2) develop methods for investigating, recording and classifying the combined effects of environment upon the measurement characteristics of the measurement methods, 3) develop methods for investigating, recording and classifying the effect of the nature of measured quantities upon the methodology of the measurement efforts and 4) develop methods for investigating, recording and classifying the EFFECT of the measuring *equipment* upon the measured *quantity*.

"A national system of measurements must do a number of things:

"1. Raise the precision by which measurement units are transferred.

"2. Encourage new methods and develop high-precision reference equipment in all fields of measurement.

"3. Automate measurements, and establish a system for providing uniform measurements in automated production.

"4. Develop the theory of measurement science, paying particular attention to the precision and reliability of results obtained under complicated measuring conditions.

"5. Develop and improve statistical methods for controlling technological processes, and the quality of production.

"6. Encourage training of metrology experts.

"7. Encourage participation in international measurements efforts and standardization."

The United States is, of course, equally concerned with the same problems and the survey which follows is offered to the National Conference of Standards Laboratories, to its delegates, and to all the standardizing laboratories in this country, as information useful to establish the non-national characteristics of a problem which faces us all—that of establishing the critical need for full support of accurate measurements.

PART 1

INTRODUCTION

The timing of this particular survey would appear to be extremely fortuitous in view of the massive efforts being made in Australia, Britain, France, India, Russia and other countries to stabilize and to improve the measurement accuracies of their industries, as a major step toward improving product quality and reliability. Requests for support, in the form of data, and personal appearances of responsible persons representing their countries, have been most gratifying in the responses accorded the National Conference of Standards Laboratories.

As a preliminary approach to this study, it is worthwhile in my estimation, to glance at specific efforts in several countries in order to understand the increased significance and attention being paid to the Science of Measurements, and the direct effect and impact it imparts to product quality and reliability. The following statements of efforts in each country are based upon replies to inquiries addressed to responsible sources, or to published material regarded as highly pertinent. In the latter category, a collection of articles appearing in the September 1965 translation of the Soviet journal Izmeritel'naya Tekhnika, was most helpful in providing a multi-faceted approach to the problems faced by Russian industrial metrology and the proposed solutions. Much of the information appearing in this paper is excerpted from the journal.

Occasionally, fortuitous timing also may backfire! In an investigation of the efforts being made by Britain, to unify its industrial measurements, I became entangled in a problem of timing. A new systematic approach to the unification of industrial and scientific measurements had been evolved in Britain but not announced officially. For that reason, no prior information could be prepared for presentation to the International Session at Gaithersburg. However, the presence of British representatives at the Conference was scheduled, and news pertaining to the new system was divulged at the Session.

In making a study of the French program, attention was directed to an excellent article by J. B. Quinn in the November 15, 1965 issue of Science, which represented the culmination of a year's research by the author, in France. The article was quite enlightening in its analysis of the shortcomings to date, of the French effort to update its scientific and technological policies.

The close geographical proximity of Canada and the United States has exposed Canadian industrial firms to the standardizing efforts being promoted by the U.S. Government Procurement Agencies. This exposure has resulted, in no small degree, to encouragement of the formation of specific activities within the Canadian Government, whose interests in production quality parallel those of the U.S. Since measurement accuracy is a fundamental in all reliability and quality programs, it is only natural to discover the existence of measurement unifying efforts in Canada, such as those supervised by the Department of Defence, Quality Assurance Division.

The establishment of the National Association of Testing Authorities, Australia several years ago was a most constructive step toward up-grading of production quality and reliability in that country. Its concrete support by government and industry alike, is clear evidence of recognition of a significant need—unification of measurement and test techniques. The history of the Association indicates that Australia is firmly committed to a high-level program of increased quality of production, thereby enhancing its competitive position in the world market.

During a visit to Sweden in 1965, it was readily apparent that government and industry alike were concerned with a more rigid control of a wider field of measurements standards. For many years, the establishment of mechanical or dimensional standards has been accomplished satisfactorily by the existence of excellent measurement facilities at several industrial firms coordinated through the National Institute for Materials Testing. The growing importance of electronics focused attention upon the need to establish controls in this area. As a consequence, Standards Laboratories established at the Research Institute of National Defence, Chalmers Institute of Technology, and the ASEA Electrical Company supply precision measurements recognized as being reference-level accuracy for dc voltage, power, resistance, ac voltage to 30 MHz, ac and rf power to 75 GHz, capacitance, inductance, rf attenuation to 12 GHz, frequency to 12 GHz, noise to 40 GHz.

Work is done for Swedish customers upon request. In order to improve services and to extend measurement capabilities, a coordination committee of six prominent scientists/engineers has been established by the Royal Academy of Engineering Sciences to study the problems. The Secretary for this Swedish Committee for Measurement Techniques, Mr. Lars Frank will be present at the International Session to discuss the status of measurements and unification in Sweden.

In a country such as Norway, unification of industrial standards although desirable, is handicapped by lack of an instrumentation production industry. Since most specialized products are obtained from abroad, the Norwegians rely to a great extent on the integrity of foreign manufacturers and the warranties supplied with the products. For control of purchase specifications reliance for example is placed upon the ITU specifications for instrumentation in the telecommunications field, upon industrial handbooks for mechanical equipment, upon prototype standards specifications issued by the BIPM (International Bureau of Weights and Measures) or representative national standards activities such as the US National Bureau of Standards or the British National Physics Laboratory.

The Norwegians at the present time wisely try to strike a balance between national efforts to establish standardization practices and those already in effect in supplier-countries. To some extent, it is felt that sufficient emphasis still has not been placed upon the establishment of national control organizations, and that steps should be taken to provide internal controls for reliability and quality, to supplement the elementary legal concern which exists for the fundamental aspects of commerce.

Australia

Australia took a major step toward unification of measurements standards practices in industry about 6 years ago, when the National Association of Testing Authorities, Australia (NATA) was formed. NATA is the organization "for coordination of testing facilities through registration of testing laboratories operated by individuals, or organizations such as partnerships, companies, councils, shires, commissions and governments." It is a nonprofit organization governed by a Council consisting of:

1. Eight members elected directly by members of the Association.
2. Six members (the Chairman of each State Committee of the Association) elected indirectly by members of the Association.
3. Three members representing the Associated Chambers of Manufacturers of Australia.
4. Six members representing the Commonwealth, nominated by the Commonwealth Government.
5. Six members representing the States, one being nominated by each of the State Governments.
6. One member representing the Standards Association of Australia.
7. Three members representing professional interests, one being nominated by each of the Royal Australian Chemical Institute, the Institution of Engineers, Australia, and the Australian Institute of Physics.
8. Up to six members nominated by the other members of the Council.

This control by a widely representative Council assures a sound, commonsense approach to the requirements of industry, commerce, and government. Annual cost of administration of NATA is approximately $45,000, of which approximately 85% is provided by the Commonwealth and State Governments and the balance by laboratory registration fees. Slightly more than 300 laboratories are registered, thereby expediting acceptance of data by governmental agencies, and other industrial and commercial purchasers.

Membership in the Association enables laboratory management to determine the capabilities of the laboratories, and also provides a source of professional advice and competence. A unique advantage to management is the ability to determine from the Association, the extent of under- or over-staffing and implementation which may be in existence, thereby providing a useful economic control.

The Association, through cooperation with the Standards Association of Australia and similar organizations, is able to provide registrants with improved test methods and other related matters. Laboratories may be qualified in any, or all of, seven categories—1) Metrology, 2) Mechanical Testing, 3) Electrical Testing, 4) Photometry, 5) Heat and Temperature, 6) Industrial Radiography, 7) Chemical Testing. Qualification is performed by special examination teams of experts who assess the capabilities and experience of the laboratory personnel, and the laboratory facilities. After qualification, a laboratory is checked at regular intervals to assure continuing compliance with good practices.

France

The French nation during the past eight years has come to the realization that national policy is highly dependent upon science and technology. Accordingly, measures are being devised to bring science into the national policy, and to use and to guide scientific efforts for the betterment of the nation.

To head up the effort, three bodies were legally created in 1958 to formulate and direct scientific policy. These were the Secretary of State for Scientific Research, the Interministerial Committee for Scientific and Technical Research, and the General Planning Commissariat.

There has been a serious lack of training in applied research and management which hampers progress of the national program. There exists a wide gap between basic research and its application to technology. Insufficient data exist on R&D activities, technical education capabilities, and future technical requirements; on the effect of technology upon the economic well being of the state; on the equality of distribution of resources among R&D projects. The almost non-existence of large French industrial complexes capable of competing in R&D with German, British, or American corporative giants is a distinct handicap in establishing technological breakthrough and prestige.

Viewed from overseas, there appears to be another important gap in the national effort, judging from the complement of the quasi-legal bodies which are steering the new course. Although the Interministerial Committee for Scientific and Technical Research comprises many diversified efforts including Education, Agriculture, Industry, etc., it is interesting to note that the Industry associates do not include product reliability and quality assurance activities and do not emphasize or relate directly to unified measurements programs.

The Central Planning Commissariat, consisting of approximately 23 commissions, is responsible for planning each 4-year National Plan, to implement the long range National program. Each commission represents a segment of the economy and includes Building and Public Works, Chemistry, Commerce, Energy, etc., but again the overall body appears to be lacking in emphasis upon the need for productive quality and reliability, established by a unified measurement program.

India

Shortly after independence from Britain, the Indian Council of Scientific and Industrial Research (CSIR) established the National Physical Laboratory (1950). This Laboratory was given several responsibilities, among them

a) Establishment and maintenance of the Indian primary standards of mass, length, time, temperature, and electromagnetism.

b) Testing and certification of industrial products.

c) Basic and applied research in Physics.

d) Coordination of the change of Indian measurements systems to the Metric System in collaboration with the Commerce & Industry Ministry.

Dr. S. H. Zaheer, Director General of the CSIR, in 1965 stated ". . . it is important that the developing countries gradually build up their own knowhow so as not to be completely dependent on knowledge from abroad".

Scientific research in the Laboratory has been conducted in 19 Divisions which include the following fields (1) Acoustics, (2) Analytical Chemistry, (3) Applied Mechanics, (4) Electricity, (5) Electronics, (6) Glass Technology, (7) Heat and Power, (8) Industrial Physics, (9) Infrared Spectroscopy, (10) Low Temperature Physics, (11) Optics, (12) Radio Components, (13) Radio Propagation, (14) Rain & Cloud Physics, (15) Solid State Physics, (16) Theoretical Physics, (17) Time and Frequency, (18) Weights & Measures, (19) X-Ray Crystallography.

The existence of the Laboratory has permitted large savings of foreign exchange to be realized through the making and supplying of carbon products and electronic components to industry, and complicated glass apparatus to scientific institutions. Because of advice and assistance from NPL a number of Indian firms have been encouraged to produce scientific and analytical balances and weights, and railway signal glasses. Development testing of industrial products has encouraged production in quantity (NPL does not do routine testing normally). New industries have been created by development at NPL of industrial processes which have been licensed to industrial firms for productive development.

NPL has a strong group working in the field of ultrasonics and has made significant contributions in this field at the international level. Exhaustive work on the hydro-carbon flame bands has received international recognition. Much work is being done on the physics of the upper atmosphere and ionosphere. A regular transmission service of time and frequency standards is maintained continuously.

Divisions of NPL participate in the work of the Indian Standards Institute in the work of prescribing suitable standards for products and in carrying out experimental investigations where necessary in the drafting of such standards. As an aid to industrial quality control, test methods have been developed to assist industry in conducting more basic (but less time-consuming) tests during production. Such tests investigate material properties for example, rather than dimensional tolerances, and the relationship to ultimate reliability. The effect of tropical climate environment upon electronic and radio components is a primary concern in India and much work has been conducted by NPL to establish suitable standard criteria for materials and packaging.

During the life of the Weights & Measures Division of NPL more than 300 technical personnel, selected by the several Indian State Governments, have received training in the techniques of measurement, and methods of enforcing the provisions of the Weight & Measures Act. In addition over 100 representatives from industrial, scientific, and educational institutions have received specialized training in precision measurements.

The NPL Library operates as the primary literature center for the Laboratory and for the Indian National Scientific Documentation Center. It holds a complete set of Indian patents and has been declared by the Indian Government to be the Inspection Center for the public. In addition the Library has complete files of the Indian Standard and the British Standard specifications.

The Indian Standards Institution (ISI) is charged with responsibility for drawing up specifications for materials, performance criteria for machine and small tools, chemical, electrical or engineering products, consumer goods, etc.

At the State level is established a Legal Metrology Department (Weights and Measures Enforcement Department). The head laboratory in each Department maintains the various secondary standards, certified by NPL. The head of the Department (controller of Weights and Measures) is responsible for a network of laboratories which verify the accuracy of commercial weights and measures, and weighing and measuring instruments employed within the State. In order to ensure uniform practices in the State Departments, the Indian Ministry of Commerce has set up a Directorate of Weights and Measures. Periodically, the Ministry arranges to hold Conferences of Controllers of Weights and Measures, which are attended by representatives of the NPL and the ISI. These Conferences bring out the troubles encountered by the various Controllers, and assistance in solving the problems is given by the experts assembled.

Russia

On January 21–22, 1965, members of the State Committee of Standards, Measures and Measuring Instruments of the USSR held a conference to deal with the improvement of standardization and the development of work in the field of metrology and precision measurement techniques. At this meeting V. V. Boitsov, Chairman of the Committee, noted the need to raise the quality of production in Russia. V. V. Tkachenko, Deputy Chairman, stressed that standardization plans are a vital part of the USSR economic plan. Radical changes in the trends, scale and content of standardization are noted and high quality production requires higher-quality components and materiel. Within the next three years existing specifications and standards must be raised to the level of the best world standards.

I. I. Novikov, first Vice Chairman of the Committee, stated that modern conditions of successful scientific research require instrumentation equal to the world's best, noting that standardization is not possible without exceptional efforts in metrology and precision measurement techniques. He then specified a number of tasks in these fields. These would be implemented by the establishment of large measurements standards laboratories in the capitals of the Republics and in the large industrial centers, controlling enforcement of standards of measurement and quality of production. In addition, the All-Union Scientific Research Institute of Standardization would be established as the principal organization in the USSR for enforcement of standards and inspection of measuring equipment.

Previously, laboratories established in the industrial plants looked to the State Inspection Laboratories for certification of measuring instruments. The State Laboratories in turn, must utilize the services of laboratories under the jurisdiction of the All-Union Scientific-Research Institute for certification of precision standards instrumentation and the standard units, which may have been allotted the State Laboratories. Typical examples are the All-Union Scientific-Research Institute of Physicotechnical and Radio-Technical Measurements (VNIIFTRI), which has responsibility for research and development of standards at the microwave and higher frequency ranges, and the All-Union Mendeleev Metrology Research Institute (VNIIMM), having responsibility for electrical standards to 1 GHz and also for other fields of measurement.

The State Inspection Laboratories for measuring equipment presently:

a. Do not in most cases, possess their own working reference standards and therefore

b. Cannot provide verification, calibration, or technical assistance services.

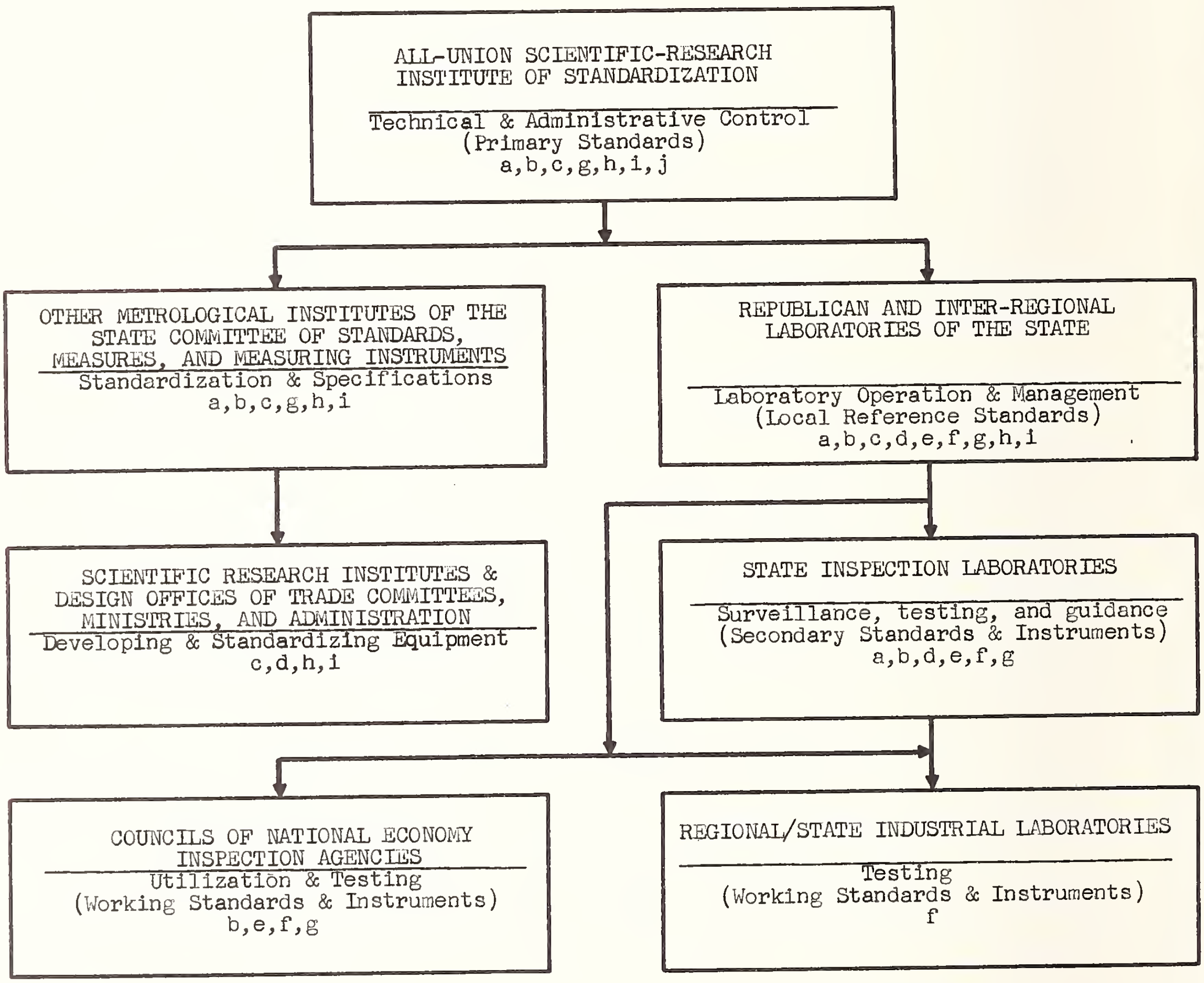
The duties of the Laboratories would be:

1. Enforcement of standards and technical specifications.
2. Storing and maintenance of working reference standards/measures.
3. Transfer of measuring unit values from working standards to basic reference measuring instruments.
4. Certification of reference materials.
5. Supervision of the work, and condition of measuring instrumentation of the State Inspection Laboratories assigned to their control.
6. Self-establishment as centers of organizational and methodology standardization in the assigned geographical areas.
7. Encouraging use of State standards by the Councils of National Economy.
8. To conduct research and experiments in order to organize scientifically-oriented and proven methods for testing machines, equipment, and materials for reliability, and methods for evaluating quality; promote adoption and use of such methods by industry.
9. To disseminate technical information related to standards and specifications.
10. To collect and process information pertaining to the quality of measuring equipment employed by industry.

Provision would be made to supply the Republican Laboratories with working reference standards for measuring lengths and angles, mass, resistance, voltage, capacitance, inductance, temperature, pressure, density and concentration of solutions, viscosity, pH values, surface roughness, hardness, force, time and frequency, optical properties, illumination, gas composition and quality, and motion. Distribution of the standards to each Laboratory would be made in accordance with the needs derived from the local economy.

Standardized designs for the Laboratories have been developed which take into account the recent planning of similar laboratories throughout the world. Each laboratory would contain spaces for specialized measurements, general measurements, repair shops, and provision would be made to supply numerous mobile reference assemblies for economy of instrumentation.

The proposed echelon of responsibilities is illustrated in the figure following. It should be noted that the definite responsibilities for operation of the System for State Inspection of Measuring Equipment are coded within the functional blocks for the sake of brevity, and the accompanying table translates the code numbers.



PROPOSED SYSTEM FOR STATE INSPECTION OF MEASURING EQUIPMENT

Coding for Functional Duties

a. Study and appraisal of methods of measurement utilized for quality inspection, derivation of Standard Reference Data, economic accounting, design engineering, scientific, research, and electrical surveillance systems.

b. Control over utilization of USSR measuring equipment.

c. Acceptance testing prerequisites for measuring equipment.

d. Initial testing requirements for measuring equipment.

e. Periodic-control-testing requirements for measuring equipment.

f. Calibration of measuring equipment.

g. Maintenance and storage of reference standards, units, and measuring instruments.

h. Develop standard measurement techniques, and performance characteristics and criteria for measurement equipment.

i. Recommending discontinuance of production of obsolete equipment, develop new measuring equipment.

j. Exercise surveillance and control for the USSR in the measurement field as related to the activities of the International Organization for Legal Metrology (MOZM) and the Council for Mutual Economic Aid (Comecon).

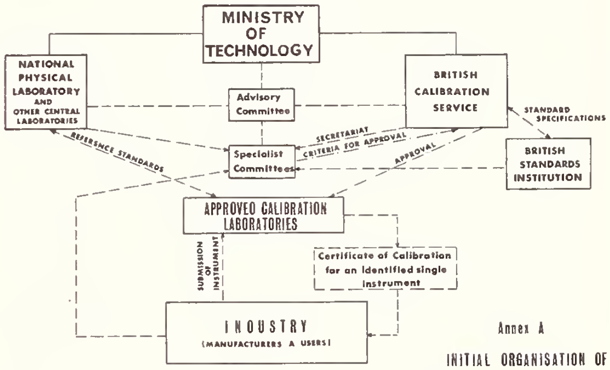
United Kingdom

On April 25, 1966 the establishment of the British Calibration Service was announced to Parliament by Mr. Frank Cousins, Minister of Technology. He indicated that the service was felt to be essentially necessary in order to supply national standards in a number of important fields, and to rationalize and augment the British calibration facilities. It was felt that such actions were necessary in order to (1) expand the range of exports, (2) increase exports of types of industrial equipment which depend upon precise measurements, (3) speed up technological advance throughout the entire domestic industry.

Planning and regulation of the Service remains with the Ministry of Technology; actual calibration would be carried out by existing laboratories which would be certified for such work by an investigating committee. The National Physical Laboratory would remain as the custodian of the national standards. An Advisory Council on Calibration and Measurement, headed by Mr. M. Banks, was formed to establish operational procedures and performance criteria for participating laboratories. A fee charge for each participating laboratory was expected to make the System self-supporting to a large extent.

Mr. Cousins announced plans to encourage universities and colleges to emphasize measurements science in the curricula. He intends to encourage revision of many British standards, bringing them into line with international metric practices. The British Standards Institution was to receive increased support to further this aim. Industry is to be encouraged to employ the higher standards of performance which will be monitored by the Electrical Inspection Directorate of the Ministry of Aviation.

During the first year of the new Service it is expected that some 50 laboratories will be certified. Headquarters staff in the Ministry of Technology will undertake the duties of (1) inspection of laboratories, (2) provision of a central information service, (3) promotion of development of new methods of measurement, (4) technical advice to approved laboratories, (5) promotion of education and training in measurement science. Certified laboratories will be required to have best standards checked against those of the National Physical Laboratory. NPL remains responsible for the basic international standards of length, mass, time, electrical current, temperature, and luminous intensity, as well as approximately 50 other derived standards. General organization of the Service is shown in the following diagram.



Annex A

INITIAL ORGANISATION OF CALIBRATION SERVICE

Director of the British Calibration Service is H. E. Barnett, formerly Assistant Director of the Electrical Inspection Directorate of the Ministry of Aviation. Among Mr. Barnett's tasks for the immediate future will be the necessity to strengthen and expand the measurement capabilities at the National Physical Laboratory, to encourage a rise in the status of measurements science at the technical college level, and to develop national measurements facilities and capabilities to become more self-sufficient.

Acknowledgements

It will be noted that this revised report is limited to a comparatively few countries. Contact was attempted with Columbia, Egypt, Mexico, but no replies were forth-coming. At a later date, it is hoped that these nations will be represented in an addendum to the survey.

With respect to the nations which did reply, I wish to acknowledge with deepest sincerity the work of the following individuals, who so graciously participated in the collection of these data:

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PART 2

1966 CONFERENCE
INTERNATIONAL SESSION QUESTIONNAIRE

A. Within the United States, the only legal source of measurement accuracy is established by the U.S. Congress as the responsibility of the National Bureau of Standards. Does your country have such a program, namely, a single legal source of measurement accuracy?

Answers

AUSTRALIA—Yes—A National Standards Commission, established by the National Standards Weights and Measures Act of the Federal Government, is responsible for establishment and administration of sources of all measurements, at appropriate levels of accuracy.

CANADA—National Research Council of Canada is the legal source for the establishment and maintenance of basic units of measurement—length, mass, electrical and luminous intensity. Although there is no legal prescription for the establishment of a temperature scale, the National Research Council adheres to the Thermodynamic Scale and utilizes the International Practical Temperature Scale. Time is legally the responsibility of the Department of Mines and Technical Surveys viz. Dominion Observatory. However, National Research Council has established the atomic resonators which establish atomic time for the Dominion Observatory and National Research Council.

To discharge their responsibility, certain Canadian Government Departments, Public Corporations, Boards and Commissions operate or establish measurement laboratories. Cooperation between these bodies and the National Research Council has been excellent.

All measurements used for "Billing" purposes are the responsibility of the Canadian Department of Trade and Commerce. This is a Federal responsibility.

In general, the National Research Council has exercised the powers provided by "The Research Council Act (RSC 239)" Section 13 (c) (iv)—"For the investigation and determination of standards and methods of measurements, including length, volume, weight, mass, capacity, time, heat, light, electricity, magnetism and other forms of energy, and the determination of physical constants and the fundamental properties of matter."

In comparisons between National Laboratories, which are carried out by the International Bureau of Weights and Measures at Sevres, France, the National Research Council represents Canada for primary quantities.

CHILE—There is no legal source of measurement accuracy.

FRANCE—The legal system of measurements in France is established by the government. It is actually the Metric System based on six units, established by the General Conference of Weights and Measures, as the International System of Units (decreed on May 3, 1961).

By agreement with the National Conservatory (Association) of Arts and Trades the Central Laboratory of Electrical Industries (LCIE) is in charge of the French electrical measurements; it preserves the standards which represent the units of resistance, inductance, and electromotive force and carry out all the work of comparison measurements, including those based upon the international system of the International Bureau of Weights and Measures (BIPM). It extends, in this way, its activity in classical measurements as well as in the high or microwave frequencies, and the measurements of ionizing radiation which require, as a basis, the putting to work of highly precise electrical measurements.

Taking into account of the situation defined below, the information given further on, in answer to the questionnaire, applies only to the electrical domain.

GERMANY—Legislation passed by the German Bundesregierung has noted the Physikalisch-Technische Bundesanstalt (PTB) as the legal source of physical and technical units of measurement in Germany. The PTB has technical jurisdiction over the state calibration or verification boards which operate as independent entities within their own geographical area.

INDIA—Yes—the National Physical Laboratory (NPL) at Delhi was established as the custodian of the primary standards of India. Standards belonging to the Legal Metrology Departments (Weights and Measures Enforcement Departments) of the various Indian States, have been established and certified by the NPL. These standards are periodically checked in accordance with the national Enforcement Rules.

ISRAEL—Yes, the Israel Standards Institute (ISI).

ITALY—In Italy the C.N.R. (National Research Council) has been given, at the present time, the task of preparing specifications for standards, units of measurement, and symbols by the Ministry of Industry and Commerce, and the appropriate channel for this is the CNR–UNI Commission known as CGUS.

This Commission has prepared a specific standard, containing among other things, the fundamental definitions of quantities and units.

As far as the preservation of the national standards is concerned, this responsibility has been given to a different Bureau.

The traditional standards of length and mass are respectively, copy No. 9 of the Standards Meter and copy No. 5 of the Standard Kilogram at Sevres, and are in the custody of the Central Metric Bureau and of the Assayer of Precious Metals, in Rome.

The standards for the interval of time, the intensity of electrical current, the luminous intensity are maintained at the IENGF (Galileo Ferraris National Electrotechnical Institute) of Turin; this Institute does not depend directly upon the CNR, but maintains close working relationships.

Finally, the preservation of the temperature scale is the responsibility of the ITI (Italian Thermometric Institute) at Turin. These last two Institutes, namely the IENGF and the ITI have appropriate laboratories for the maintenance and comparison of the standards entrusted to them, with the maximum of precision attainable.

JAPAN—Yes, there is a legal source of measurement standards. The Japanese Law of Metrology assigns responsibility for the standards to several government research laboratories. Standards of weight, length, and temperature are the responsibility of the National Research Laboratory of Metrology (NRLM) located in Itabashi-ku, Tokyo. Standards of time are the responsibility of the Tokyo Astronomical Laboratory (TAL). Standards of electrical quantities, electromagnetic propagation, light, color, sound, radioactivity, and radiation are the responsibility of the Electrotechnical Laboratory (ETL) at Chiyoda-ku, Tokyo.

NETHERLANDS—Legal measurement accuracy in the Netherlands is covered by the "IJkwet 1937" (Calibration Act 1937), which deals solely with the accuracy of equipment for measuring length, mass, area and volume used in trade and commerce. The Calibration Act 1937 can be seen as a law for the benefit of an orderly economic intercourse and as such is an instrument of economic policy. The "Dienst van het IJkwezen" (Service of Weights and Measures), which is in charge of the activities resulting from the legal regulations, is under the competency of the Ministry of Economic Affairs.

Thus far the only basic units legally defined are the meter and the kilogram. A revision of the Calibration Act 1937 is in course of preparation in order to make it fit the modern social intercourse. This revision will probably result in an expansion of the activities of the Service of Weights and Measures. An important modification will be the introduction of the six basic units of the SI in the revised law.

NORWAY—Legal measurement accuracy is covered in Norway by the law of Weights and Measures. Thus far the law deals solely with the accuracy of equipment for measuring weight, length, area and volume used in commerce and trade. The law provides for the amendment of other quantities—for instance electrical quantities—by a resolution from the king. Thus far, no such amendment has been made. The obligatory verification of weight, length, area, and volume measuring equipment—and subsidiary equipment such as flow meters—is the responsibility of Det norske Justervesen (Norwegian Bureau of Weights and Measures) which also maintains the Norwegian prototypes for the Meter and the Kilogram. Det norske Justervesen is the only institution having legal power, but other organizations may be certified by Justervesenet for making calibrations.

RUSSIA—Yes, the All-Union Scientific-Research Institute of Standardization in coordination with the republic and interregional laboratories.

SWEDEN—The Royal Mint controls some commercial standards related to length, mass, and density.

U.K.—Within the U.K. the National Physical Laboratory (NPL) is in general the custodian of standards of measurement to which other measurements are referred. The day-by-day administration of weights and measures for trade is currently the responsibility of the Board of Trade.

B. In the procurement of supplies for the government agencies in the United States, the requirement is established that the accuracy of all measurements and measuring equipment be verified by the National Bureau of Standards, or that the accuracy of the measurements agency performing calibration services for the supplier, be traceable or verified by the Bureau. Does a similar program exist in your country, to require certification of the source of measurement accuracy within your organization?

Answers

AUSTRALIA—The requirement "certification of measurement accuracy by the legally-established source" does not specify exactly the situation in Australia, as applied to procurement of materiel by government agencies. However, it is a fairly common practice for government agencies to require endorsement of supplier's measurement test documents, by the National Association of Testing Authorities, Australia (NATA). Refer to Part 1 of this report for a description of NATA.

CANADA—In Canada, various Government Departments, Public Corporations, Boards and Agencies have certain responsibilities for the acceptance of material and equipment being supplied to the Federal Government. All the Departments and Agencies have not been contacted to determine policy or practice concerning traceability to or verification by the National Research Council, however those contacted do relate their measurements to the National Laboratory. The National Research Council will perform basic measurements upon request.

In the Department of National Defence various quality-programme and inspection-system requirements for contractors require traceability to National Standards. Traceability to other National Laboratories such as the National Bureau of Standards or the National Physical Laboratory is also acceptable to the Department.

Several documents issued by governmental agencies determine the significance of, and the degree of compliance with, controls established for measurement accuracies concerned with the verification of quality of delivered products to the government. These are:

1. "Specifications For Quality Requirements For Standards Laboratories" Proc. 101–13, Department of National Defence, Royal Canadian Air Force. (Similar in content to US MIL–C–45662A "Military Specification—Calibration System Requirements").

2. "Quality Program Requirements For Contractors" Specification DND 1015, Department of National Defence. (Similar in content and intent to US MIL–Q–9858A "Military Specification—Quality Program Requirements").

3. Policies, Implementation Responsibilities, and Calibration Supervision of Military Calibration Facilities—CFP129, Canadian Forces. (Similar in intent to USAF Technical Order Manual T.O. 33.1.14 "Repair, Calibration And Certification Of Precision Measurement Equipment", and to the USN Bureau of Ordnance Program Manual "Standards Laboratories Information Manual—Calibration Program").

Defense contracts placed in Canada by other Countries are subject to that Country's contractual quality programme objectives and requirements. The contractor is responsible for demonstrating that all contractual conditions have been fulfilled.

There has been in the past and still exists, various contractual conditions for materiel consigned for use within Canada or by Canadian Forces which do not specifically call up traceability to National Standards. Utilization of standard materials offered by the National Bureau of Standards is fairly common in operations within the Quality Assurance Branch of the Materiel Command, DND.

CHILE—No such program exists. Compliance with specifications contained in contracts with foreign suppliers normally is established at the supplier's plant location.

FRANCE—Industrial firms, furnishing materiel to the military administration, must produce proof at the time of delivery of these items, that the electrical measuring equipment, used for quality control, have been first of all:

a. either calibrated by the LCIE,

b. or compared with secondary standards which belong to the contractor and are verified periodically by the LCIE.

This control does not apply, as yet, to items furnished to the civilian agencies.

GERMANY—Strictly speaking, this program requirement does not exist.

INDIA—The Government Purchasing Agency makes use of certified weights, measures, and weighing and measuring instruments in the inspection of materiel supplied under contract to the government. The Supplier, in turn, is under legal obligation to observe the Weights and Measures Act. This law requires all vendors employing weights, measures, or weighing and measuring instrumentation, to have such units certified for accuracy if employed in "Trade". This term applies not only to normal commercial business but also transactions with the Posts and Telegraph Departments, the Railways, and in the payment of wages to workers based on quantity of output. An example of the last-mentioned category is the tests of accuracy of the volume of coal tubs used in coal mines—utilized by coal miners in delivering output.

ISRAEL—No

ITALY—This requirement is not absolutely enforced but usually in most important instances, the Government requires certification from the National Institute or the Universities, or else the supplier must produce verification from a Ministry Laboratory. In Italy the numerous faculties of engineering form part of the University, together with the other scientific and humanistic faculties. There is an exception in Milan and Turin; the faculties of engineering and architecture are separated from the others and together form an engineering institute which is considered as a separate University. However, by an old tradition they have their own President, Administrative Council, and organizing mechanism.

JAPAN—Legal verification of measurement accuracy is not a requirement for vendors. However, government agencies often require factual evidence of inspection measurement data related to the items being supplied by a vendor. It is presumed that government inspection may involve an investigation of the vendor's source of measurement accuracy.

NETHERLANDS—No such program exists on a mandatory basis. However, on a voluntary basis there is quite an activity of "Het Meetinstituut BEMETEL–TNO" in the field of industrial metrology and pressure measurements. This is a combined activity of BEMETEL (Organization of Employers in the Mechanical and Electrical Industries) and TNO (Organization for Applied Scientific Research).

As to the procurement of supplies for the army, the navy and the airforce in some cases the requirement is established that the vendor's measuring equipment be traceable to primary standards.

NORWAY—When the quantity involved is weight, length, area, or volume, Det norske Justervesen can assume responsibility. When other measurements than of these four quantities are involved, acceptance tests are usually made by the agency in question, often in cooperation with the delivering firm. The instruments used normally have certificates from foreign establishments like NBS, NPL etc. The Norwegian Air Force maintains a "traceable" electronic standards laboratory at their Air Material Command base near Oslo. Traceability is to NPL in England. A few measurements are traced to Laboratoire Nationale des Electronique in France. The Air Force maintains traceable standards for all the conventional electric quantities plus power and frequency. Plans have been made to establish a system of traceable meterological standards.

RUSSIA—The State Committee of Standards, Measures, and Measuring Instruments of the USSR revealed a national movement to establish an orderly national system for ensuring high quality of production, at a meeting held in Moscow January 21–22, 1965, at the Exhibition of National Economic Achievements of the USSR. During the discussions, much attention was directed to the need for assuring the reliability, quality, and useful life of products. It was agreed that establishment of a unified State System for supervising the adoption and enforcement of measurement standards would be a necessity. Under modern production conditions, it was pointed out, reliable measurements are obtained only through standard methods and techniques.

SWEDEN—No

UK—Supplies for defence agencies are controlled by Government Inspectorates which, as part of their function, supervise measurements and base these on national standards mostly held by NPL.

C. If there is no single source of measurement accuracy legally established in your country, how are questions of measurement accuracy arbitrated or resolved?

Answers

AUSTRALIA—There is no federal agency which performs this service. However, NATA was established to educate test and management groups relative to the supply of products having highest quality and reliability, to civilian consumers. Because of this effort, many industrial, commercial, and government procurement activities insist upon NATA-endorsed test documents, as a confirmation of adherence to minimum requirements of good practices.

CANADA—In keeping with our reply to question A, questions of measurement accuracy are generally resolved within the responsible Government Department or Agency. Inter-laboratory correlation tests are used to resolve measurement disputes in some cases.

CHILE—Questions involving disagreements in measurements, concerning supplier and customer, are resolved through arbitration. Each contract specifies, as deemed necessary, the terms of arbitration.

FRANCE—This question does not apply to France

GERMANY—Not applicable.

INDIA—Questions of measurement accuracy in commercial transactions are relegated to and are the responsibility of the State in which the controversy arises. Each State has sovereignty over its own cases, but it must be remembered that all State standards are certified by the NPL.

ISRAEL—Not applicable.

ITALY—In line with the principle of limitation in primary metrology the question is not of interest in Italy, inasmuch as there is usually only one fundamental institute legally recognized for each quantity. However, for measurements of non-primary character (Lower accuracy) in particular instances, pilot laboratories have been designated to whom the other laboratories were obliged to refer their measurements.

JAPAN—Not applicable

NETHERLANDS—Questions of measurement accuracy in transactions which are not covered by the Calibration Act are arbitrated incidentally. In most cases the judge asks for a report of TNO (Organization for Applied Scientific Research).

The greater number of questions of measurement accuracy between customer and supplier are arbitrated by scientific institutes as the institute mentioned under B, the organization TNO or, in some cases, technical universities, without the interference of judicial power.

NORWAY—Covered by answers to A and B

RUSSIA—Not applicable

SWEDEN—The Royal Swedish Academy of Engineering Sciences has formed the Swedish Committee for Measurement Techniques. At the present time the Committee is making an inquiry of universities, research institutions, and industries in Sweden to investigate the requirements for and resources of standards and calibration facilities.

In addition, the Swedish government has appointed a committee to investigate metrological units and standards. The two committees have cooperated in recommendations, and in consideration of the adoption of the International System (SI) of units.

As a practical approach, four standards laboratories in Sweden provide services for special measurements problems. The standards laboratory at the Chalmers University of Technology in Gothenburg has leading capabilities for dc voltage measurements to 1000 volts, and ac voltage, capacitance, and resistance measurements. The laboratory located at the ASEA Electrical Company in Stockholm is a leader in dc and ac high-voltage measurements.

The Swedish defence organizations and the defence industry has recognized the need for calibrating facilities and standards laboratories, particularly in the field of radio frequency measurements. To implement the recognized need, the Research Institute for National Defence in Stockholm organized a standards laboratory group about ten years ago. This group acts as the Swedish Defence Ministry's primary standards laboratories, serving both military and industry needs. The laboratories also take part in international intercomparisons of radio frequency quantities, working closely with the International Scientific Radio Union (URSI).

The National Institute for Materials Testing has established leading capabilities in ac-dc transfer measurements, and in some of the physical standards areas, including acoustics.

From sources such as these could come heavy support for a national standards center, if the Swedish government should take such a step. Meanwhile, industrial centers requiring certified measurements are able to make use of commercial services offered by these laboratories.

UK—For Government defence procurement the verdict of the responsible Inspectorate is usually accepted.

D. Within industrial plants in the United States, a close working relationship exists between the organization which establishes the measurements accuracy of the company's test, research, and inspection programs, and the activity which is responsible for the assurance of quality in the final product. Does your country's government have any agencies which enforce minimum requirements of good operation upon either or both the measurements standards and the quality organizations of an industry which supplies goods solely to civilian consumers, or solely to government consumers?

Answers

AUSTRALIA—Not applicable

CANADA—Various Federal and Provincial Governmental Departments and Agencies enforce to varying degrees, requirements for good operation. The Department of National Defence performs this function in keeping with its own responsibilities, and other Departments such as Trade and Commerce carry out this function by direct or indirect controlling action. The Canadian Department of Trade and Commerce has responsibilities for commercial measurements used for "billing" purposes. In Canada, this is a Federal responsibility; Departmental standards are certified by the National Research Council to validate these standards. Controlled measurements apply to Government consumers and to a certain extent for civilian consumers. Civilian consumers have courses of action available through the responsible Government Department or Agency for the investigation of complaints they may have which could be related to "requirements of good operation".

CHILE—There are no recognized agencies with such powers. However, the larger industries in Chile have general understandings concerning good industrial practices and usually impose these practices upon national or foreign vendors.

FRANCE—In addition to the specifications or regulations established for their own needs by some agencies or nationalized enterprises, the characteristics and the performance of electrical equipment are defined by criteria (or norms) which are prepared by organizations whose standardizing function is officially recognized (AFNOR, Electrical Technical Union, Telecommunication Coordination Committee, National Center for Telecommunication Studies).

Compliance with the requirements of the documents prepared by these organizations is mandatory only in certain cases such as:

(1) In the case of certified quality brands which are utilized in house-hold electrical appliances, electrical equipment for buildings and homes, electrical conduits and electrical cables (Similar to US Underwriters Laboratory coding).

(2) In the case of industrial grade electronic components intended for supply to the armed forces and other governmental civilian agencies for which certain characteristics are specified (Similar to US JAN specs).

The technical control (inspection supervision) necessary to provide for this quality certification or branding—from receiving of materials through the manufacturing processes—is a function of LCIE.

GERMANY—No formal program is known to exist.

INDIA—There is no activity or agency which is responsible for such procedures. Also, no industry is

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compelled to have inspection or research equipment certified for accuracy. However a purchasing agency (industrial or governmental) often inserts into the purchase contract, the requirement/s that the delivered materiel shall conform to particular Indian Standard Specification/s, and that conformance shall be established by the NPL.

ISRAEL—The ISI has industrial technical laboratories which are attached to the factories. These laboratories may draw upon the local industrial technologists or scientists for assistance, as required.

ITALY—There is no specific government agency which performs this service, however civilian and military administrations and certain major industries have a certain number of specialists who are assigned the specific task of following production and assuring proper calibration.

Furthermore there are some very active committees of the CEI (Italian Electrotechnical Committee, a section of the IEC) that in collaboration with the CNR, draw up official Italian Standards specifications for all electrical, electronic, and radio instrumentation.

As for the civilian production, there exist institutes, such as the IIMQ (Italian Institute for Quality Brands), non-government but legally recognized, who participate on a voluntary basis in establishing voluntary quality standards, which verify the quality of the final product and various components such as cables, and issue appropriate certificates.

JAPAN—There is no single agency which has been established for such a purpose. In the field of electrical standards, a semi-governmental organization—Japan Electric Meters Inspection Corporation (JEMIC) was established in January 1965. This is a specialized activity which performs inspection and type approval of electrical meters, calibration of working standards, and special tests upon general electrical meters and other measurement instruments which depend upon transfer standards rotated between JEMIC and the Electrotechnical Lab.

The Japan Telegraph and Telephone Corporation, a number of measurement instrument manufacturers, and other related industries are establishing unified quality programs through technical-cooperation programs with the JEMIC and ETL. Government agencies procuring certain types of equipment such as basic standards, optical lenses, airplanes, and radio and radar instrumentation, provide legal regulations in the purchase contracts specifying good operation practices.

NETHERLANDS—Our government has no agencies for this purpose. There is however an organization called "Stichting Kwaliteitsdienst voor de Industrie" (Foundation Quality Service to the Industry) subsidized by the Ministry of Economic Affairs and by subscription of industry.

NORWAY—Rudiments of such an organization exist, but it is not yet built up. There is no "agency which enforces minimum requirements", but the larger firms have their own test departments or laboratories. Accuracy is ensured by instruments usually calibrated abroad. The legal aspect is taken care of by an underwriters guarantee. For electrical equipment, Norsk Elektrisk Materiellkontroll (NEMKO) establishes safety standards.

RUSSIA—All industry is nationalized. Within each plant is stationed one or more representatives of the State Inspection Laboratories who serve as inspectors of the end products. Presently, there are no uniform procedures for quality assurance but the proposed national system sponsored, in part by the State Committee of Standards, is expected to establish improved methods for testing and controlling production.

SWEDEN—No.

UNITED KINGDOM—For Government defence consumers the official Inspectorates discharge this function. For civilian consumers there is no enforcement but increasing use is being made of the British Standard Specifications, and in respect of some of these a form of quality supervision is operated by the British Standards Institution under its "Kite-mark" scheme.

E. In the United States, the National Conference of Standards Laboratories conducts a measurements accuracy survey of Standards Laboratories who voluntarily participate, but in a manner which prohibits revealing of the results to any participant other than the original laboratory. In other words, each participating laboratory is able to perform a self-evaluation without the possibility of embarrassment. The National Bureau of Standards monitors the program and correlates the results of the program. A written, tabulated report at the completion of each survey enables all participating laboratories to determine their own capabilities in the measurement of the test standards which comprise the package interchanged between the laboratories and the Bureau. Does your country have any organization which offers such a means of establishing the measurements capabilities of any measurements laboratory? If so, how does it perform the function?

Answers

AUSTRALIA—In Australia the laboratory-evaluation scheme is extended to cover all aspects of laboratory organization and operation. Participation is completely voluntary, and results of evaluations are completely confidential. Assessment is carried out by small teams of specialists, familiar with the type of work performed in the laboratory.

Assessment covers qualification and experience of each member of the laboratory staff, adequacy of laboratory equipment for the work performed, adequacy of techniques used, adequacy of laboratory administration and procedures. Practical tests are used as assessment techniques, but to supplement rather than to substitute for other procedures.

CANADA—Within the Department of National Defence a series of Inter-Laboratory Comparison Measurements has been conducted under the auspices of the Canadian Military Electronic Standards Agency Correlation Panel. Both Government and Defence Industrial Laboratories participated in this project which followed the principles of NCSL's "Experimental Measurement Agreement Comparison on a Nation Wide Basis". It was conducted on a voluntary basis and in a manner whereby numbers were assigned to participants and known only to the coordinator of the tests and the individual laboratory.

The tests undertaken in Canada were carried out in the Testing Laboratories by *Test* Personnel rather than by *Laboratory* Personnel in *Standards* Laboratories. This approach was taken to assure:

a) Correlation or repeatability of Test Measurements.

b) Provide some indication of the confidence in the Individual Participant's Standards and Transfer Capabilities.

The Canadian Military Electronic Standards Agency has been most effective in promoting evaluation tests employing electrical parameters such as resistance and capacitance and deserves much credit for its work. The Quality Assurance Division of Materiel Command participates in a number of other Inter-Laboratory comparison measurement or round-robins and exchanges on Petroleum products and organic protective coatings, and in Canadian Government Specification Board exchanges on petroleum products, paints, textiles and many other commodities. Informal exchanges with Government Departments and various segments of Canadian Industry have taken place. Other Government Departments, Agencies and Commercial Establishments may have undertaken such tests, however we are only aware of the projects outlined. We are aware of several Canadian Industrial Laboratories which have participated in "Laboratory-Inter-comparison Tests" with their parent companies in other countries. It is hoped that NCSL will not overlook parameters in certain fields, particularly in Chemistry where many significant determinations are being made.

CHILE—Several Universities are capable of performing this function, but there is no recognized formal procedure to encourage such interchange of standards.

FRANCE—In France there is not available any system, at the national level, for making intercomparisons of measurement abilities on a specific parameter (round-robin intercomparisons). Compatibility of measurement accuracy capabilities is effected only through the services of LCIE, by comparison with the national standards.

However, France periodically intercompares standards of equal accuracies, or has standards calibrated against higher internationally-recognized standards maintained by the International Bureau of Weights and Measures (BIPM). As indicated in the reply to question "A", LCIE represents France at the BIPM.

GERMANY—No formal program of inter-comparisons is known at this time. However PTB has established a verification system which coordinates with the twelve verification boards established in the eleven states of the Federal Republic, and in West Berlin. Each board is administratively subordinate to each local government, and is under the technical supervision of the PTB.

INDIA—No such program exists for intercomparison of measurement capabilities of industrial laboratories. However, installation of such a program applied to civilian laboratories would immediately involve the NPL as the official arbiter. In the meantime, there does exist a continuing requirement for the State Legal Metrology Departments to have their legal standards periodically checked by the NPL, which permits the conscientious laboratories to perform a self-evaluation.

ISRAEL—Such a program is not specified as being in existence.

ITALY—In Italy, the AEI (Italian Electrical and Electronic Association*) was the sponsor for many years before the war, of circular measurement intercomparisons between laboratories but only in the electrical field. The intercomparison has been extended to many Italian measurement laboratories. The final results are usually published in the AEI Journals ("Electrical Techniques" and "High Frequencies"), replacing in the appropriate tables, the names of laboratories with symbols known only to the participating parties, thereby assuring ánonymity.

*This Association has changed its name in the last few years, adding Electronic but has kept its original initials AEI, standing for Italian Electrical Association.

JAPAN—There is no formal organization or activity for intercomparison of measurement accuracy capabilities. However, it is evident that some manufacturers perform intra-laboratory comparisons within their own corporations for self-evaluation purposes.

NETHERLANDS—Such an organization exists in the field of length measurement. The institute mentioned under B can appoint agencies on the basis of minimum capabilities as shown in the measurement of a package of test standards interchanged between the institute and the agency. These agencies, approved and certified by the institute sub B, are combined in "De Meetkern", which can be seen as a Conference of Metrology Laboratories. Members of "De Meetkern" are also the Technical Universities in Holland.

NORWAY—For commerce, control exists as answered in "A". Some electronic control is done on a voluntary basis between industry and the Air Force lab described in "B". Otherwise, nothing exists.

RUSSIA—No formal program including industrial laboratories is in existence.

SWEDEN—Such measurement capability intercomparisons are conducted at fairly regular intervals among the laboratories previously described, and to a limited extent, with several industrial plants. There is no formal handling of the intercomparisons which are probably limited to standard cells and resistors, ac-dc transfer units, bolometers, and gage blocks.

UNITED KINGDOM—Government inspectorates in general monitor the measurement capabilities of supplying organizations, mainly by the use of test pieces, the checking of measuring equipment against Inspectorate standards, and the use of the "audit package" system of circulating items for measurement through a succession of suppliers' standards laboratories.

F. In your country does any organization evaluate the claims made by manufacturers, concerning the accuracy and/or the performance of instrumentation produced by civilian manufacturers? If so, are these reports available only to the government? only to the manufacturer? to the general public?

Answers

AUSTRALIA—There is no such organization.

CANADA—Upon request by Governmental or Industrial Bodies the National Research Council tests, on a fee basis, certain instruments for performance against specification requirements. The reports become the property of the requestor. To further disseminate this information, written authorization must be obtained from the National Research Council. Several Government Departments and Agencies carry out this function, however the reports are only available to the Government Department or Agency concerned and usually the manufacturer, and the public, in general, does not have access to the reports.

A number of industrial firms conduct their own vendor quality assurance programs, similar to practices in the U.S.

CHILE—No such formal program exists. An organization known as "Industry and Business Direction" is interested in this phase of industrial activity, but apparently its activities are limited to industries forming the organization's membership.

FRANCE—LCIE conducts tests of materials and electrical apparatus upon requests by agencies, industries, or private individuals. Certificates issued by LCIE are official and are the property of the requestor. With the permission of LCIE, the results of the tests may be publicized, provided that the entire report is made available to the public.

It is of interest to point out, in addition, the particular case of electrical and electronic measurement equipment, which is the concern of the Interdepartmental Commission of Electrical Measuring Apparatus. This is the activity which acts as liaison between manufacturers of measuring instruments, analyzes the needs of users and promotes the future development of measuring instruments. It also registers all comments or criticisms on manufactured equipment.

In certain cases, it has had comparison tests performed—by LCIE—on instruments of the same nature, in order to compare their respective qualities. To avoid abusive use or errors of interpretation, test results have been reported only to the cognizant technical personnel of the agencies, large civilian users and the manufacturers of the measuring equipment.

GERMANY—Impartial tests are conducted by the State Testing Boards. No mention is made of the disposition of test results.

INDIA—Yes—the Indian Standards Institution (ISI). Any manufacturer may request verification of performance to specifications by this organization, in order to receive the IS Certification Mark. If the ISI is satisfied that performance is in accordance with claims by the manufacturer, he may mark his product as conforming to the Indian Standard Specification. Such tests are conducted on a fee basis and periodic checks are made of the product to establish continuing conformance to specifications, under penalty of withdrawal of the official approval if discrepancies in performance are found.

ISRAEL—The ISI has cognizance over production claims and performance. Reports are distributed between government and factory.

ITALY—Such evaluations are not made by any particular institute, but on occasion, upon request by interested parties, necessary verifications are made by referring to appropriate institutes or organizations designated for this purpose.

JAPAN—There is no formal organization. However there exist, apparently, several trade organizations, which encourage examination of claims by members of the organization, and agreement on disposition of dubious or disputable claims of performance. Disputes usually are resolved by referring to special tests performed by ETL, NLRM, or TAL.

NETHERLANDS—Yes. This is an organization called "Werkgroep Instrument Beoordeling" (WIB; Working Party on Instrument Behaviour). Members are manufacturers as well as users. The WIB evaluates the instruments. The reports, written in English, are available to the members only.

NORWAY—Norway has no instrument industry.

RUSSIA—There are no "civilian" manufacturers since all industry is nationalized. Specifications mentioned for a product's performance are in coordination with specifications established by a governmental agency prior to production tooling-up.

SWEDEN—Not publicly.

UK—This is done to some extent by Government organizations and also by the Scientific Instrument Research Association. The reports of Government bodies are usually restricted to the departments and manufacturers immediately concerned while in the case of SIRA, the reports are confined to those members who contribute to the cost of the evaluation.

G. Does any organization in your country establish Standards of Practice in Operation of Measurements Standards Laboratories? Are any Standards available to you?

Answers

AUSTRALIA—Yes, the National Association of Testing Authorities, Australia.

CANADA—Specification PROC 101–13 has been developed by the Department of National Defence to "define the general requirements for a laboratory quality control system to assure that calibration and calibration services meet the quality standards stipulated by the Government contract. The requirements shall be met by procedures established by the contractor to the satisfaction of the Department of National Defence, Royal Canadian Air Force, or its authorized representative, herein referred to as the RCAF and the Inspector".

This standard was developed by the R.C.A.F., however with the integration process now underway in the Department, this document may be modified in certain respects. At the present time the Environmental Requirements, particularly for Dust Control and Temperature, are under study.

CHILE—No such organization exists.

FRANCE—This action is presently under development. LCIE, at the request of certain military agencies, establishes calibration procedures. General publication of these procedures is not being considered presently.

It should also be noted that LCIE publishes papers in the technical press on the techniques of measurements it has developed. Such publication is not systematic, however.

GERMANY—The PTB, acting as supreme technical authority in the national calibration service, establishes or advises on any Standards of Practice required by the State Laboratories.

INDIA—Standards of Practice involving high-precision measurements are established by the NPL and conform in general, with those practiced by other National Laboratories. Industrial Standards of Practice are prescribed by the ISI, but are voluntary.

ISRAEL—This is the responsibility of the ISI. The Institute maintains liaison with other national laboratories, e.g. the National Physical Laboratory in England.

ITALY—Generally, each Measurement Laboratory establishes and uses appropriate internal procedures, but frequently there are exchanges of information among the various laboratories either directly or via the CEI and the AEI.

JAPAN—There is no specific organization performing such a function. Instrumentation manufacturers draw up individual, practical standards of operation.

NETHERLANDS—Yes. In the field of length measurement "De Meetkern" is active. This work is still in the infancy but results will be available in the course of next year. Contact will be established with the American committee B–89.

NORWAY—To some extent material is available through a Norwegian Industrial Quality Control Association affiliated with the European Organization for Quality Control. Foreign publications are most used. The Air Force follows US practice through an established Technical Order system from the US Air Force.

RUSSIA—It is expected that the new All-Union Scientific-Research Institute of Standardization will deal with standards of practice and operation.

SWEDEN—Not within Sweden.

UNITED KINGDOM—A start has been made on preparing standards of practice but none is yet available.

H. Does any organization in your country promote dissemination of information pertaining to measurements standards, or techniques of precision and accurate measurements?

Answers

AUSTRALIA—There is no one-particular organization. Professional institutes such as the Institution of Engineers, Australia or the Institution of Production Engineers publish journals, bulletins, and the like. National Standards Laboratory, Defence Standards Laboratories, and some others publish bulletins and monographs. There is a steady flow of technical literature, in all languages, from Europe, America, and Japan.

CANADA—Several Federal and Provincial Governmental Departments and Agencies, as well as other associations and societies produce papers, technical notes and sponsor Seminars, however there is no single organization presently undertaking the dissemination of all information pertaining to measurement standards, techniques of precision and accurate measurements. The Canadian Standards Association has produced some material in this field, in particular a written standard covering "Gauging Threaded Products (B36)". Various Canadian technical periodicals and the commercial press inform readers of published papers and other technical developments in this field. Interested parties can write to the Department or Agency concerned to obtain a particular document or information on the particular subject.

CHILE—No such organization exists.

FRANCE—This action is presently under development. LCIE, at the request of certain military agencies, establishes calibration procedures. General publication of these procedures is not being considered presently.

It should also be noted that LCIE publishes papers in the technical press on the techniques of measurements it has developed. Such publication is not systematic, however.

GERMANY—This function is performed by the PTB.

INDIA—Such information is obtainable from the NPL when requested. NPL also undertakes to give practical and theoretical training in precision measurements to selected personnel of scientific institutions, industry, and the various State Legal Metrology Departments. During the past few years, over 400 people have received such training.

ISRAEL—Only through the ISI.

ITALY—In addition to specific information contained in scientific publications, there are periodic bulletins or monographs from the various Institutes which maintain the standards.

JAPAN—There does not exist any formal, continuing program for information dissemination. Such information is obtained at technical conferences, and symposiums, from coordinating committees representing Universities, Laboratories, Manufacturers, and ETL, and from liaison conferences held with ETL and industrial associations.

NETHERLANDS—Some industries have their own organization, but generally speaking there is an incidental dissemination of information through the medium of periodicals published by the organizations already mentioned.

NORWAY—The Norwegian Quality Control Association and national branches of organizations like the ISO distribute information. The military have their own organization which is influenced by NATA and/or US military specifications.

RUSSIA—It is expected that the new All-Union Scientific-Research Institute of Standardization will deal with standards of practice and operation.

SWEDEN—Yes—in radio frequency measurements the Swedish Commission I of URSI is quite active. Also active is the Committee for Measurement Techniques of the Royal Swedish Academy of Engineering Sciences, in the wider approach to metrological problems. The National Institute for Materials Testing has compiled many reports of test methods, which are available to industry.

UNITED KINGDOM—Limited dissemination of such information has gone on for many years but it is not systematized, and needs expansion.

I. How is your country made aware of the needs of industry for measurements standards to promote improved quality in products?

Answers

AUSTRALIA—There is no formal assessment of needs by any organization.

CANADA—The benefits of improved measurement standards to create improved products would be realized by individual companies or persons. The Canadian Standards Association, as the National Standards body for Canada, endeavours to incorporate quality requirements in their written standards to an increasing extent. The CSA participates in work undertaken by:

The International Electro Technica Commission
The International Standards Organization, and
The International Committee for Approval of Electrical Equipment (CEE).

Note—Industrial firms remark upon the impact of the US military program needs and the difficulties encountered by Canadian firms in obtaining production-sharing contracts under NORAD agreements. Aggressive steps are being taken to promote information dissemination by participation in the National Conference of Standards Laboratories and the Institute of Electrical and Electronic Engineers.

CHILE—There is no formal method of approaching this problem.

FRANCE—By participation in the study of the government's Equipment Plan*, industry and user-agencies are able to make known their needs (for measuring equipment not existing).

Incidentally, participation by LCIE engineers in many committees wherein they meet representatives of the electrical industry and agency heads concerned with electrical or electronic technology—Armed Forces, Broadcasting, Telecommunications, etc.—results in contacts which have constituted for many years, one of the principal means of making known the needs of industry in metrology.

*Part of a national civil science and technology S&T plan now underway.

GERMANY—By feedback to PTB via the State laboratories or through the efforts of the industrial technical associations, such as the Verband Deutscher Elektrotechniker (VDE, Verein Deutscher Ingenieure (VDI) and the Deutscher Normenausschuss (DNA).

INDIA—No formal means exist for establishing measurements standards needs.

ISRAEL—By feedback to the central ISI organization via the local factory laboratories.

ITALY—The knowledge of industrial needs arises mostly from direct contact between the industries and the Institutes or Laboratories during joint meetings sponsored by the regulatory agencies, both national and international. Among the typical agencies active in the electrical field in general, CEI and IEC and other well-known organizations could be mentioned.

The CNR has furthermore established a "Consultative Commission on the activities and types of interfaces between the CNR and the various interested industries for the solution of research problems."

JAPAN—There does not exist any formal, continuing program for information dissemination. Such information is obtained at technical conferences, and symposiums, from coordinating committees representing Universities, Laboratories, Manufacturers, and ETL, and from liaison conferences held with ETL and industrial associations.

NETHERLANDS—In the Netherlands a "Kwaliteitsdienst voor de Industrie" (Foundation Quality Service to Industry) exists. In the field of length measurement "De Meetkern" is active.

NORWAY—Articles in technical press and the Norwegian Quality Control Association and national branches of organizations like the ISO distribute information. The military have their own organization which is influenced by NATA and/or US military specifications.

RUSSIA—By coordinated committee work involving the institutes of the USSR Academy of Sciences, the State trade committees and ministries having cognizance over such matters, and the new All-Union Scientific-Research Institute of Standardization.

SWEDEN—By studies conducted by the Swedish Commission I of URSI, the Royal Academy Committee for Measurement Techniques, and the government committee on measurement standards and units.

UNITED KINGDOM—It is anticipated that an orderly feedback of information relevant to industrial needs for measurement standards will be accomplished via the Specialist Committees and Advisory Council to British Calibration Services headquarters.

J. Does any organization in your country develop and/or disseminate methods for the compilation and analysis of measurements and calibration data by statistical methods?

Answers

AUSTRALIA—No organization or activity is engaged in this activity.

CANADA—No Canadian organization appears to be disseminating such methods, although some may be under development. Existing methods such as those of ASTM are utilized to some extent in Canada. However, the National Research Council will assist, upon request, in the solution of particular problems.

CHILE—Several Universities are interested in the problem but are dealing with it only in a rudimentary manner.

FRANCE—No.

GERMANY—Same as answer to I.

INDIA—The Indian Statistical Institute handles research statistical problems, and the ISI has a Division which is engaged in a study of statistical methods for quality control. Such information however, normally is not being disseminated to industry at the present time.

ISRAEL—Such a program is not specified as being in existence.

ITALY—There exists within the CEI an appropriate subcommittee No. 109 named "Statistical

Quality Control", which publishes procedures or methods of this type (see "Rules for Sampling in the Testing of Quality" 1st Edition 109–2, edition VIII 1963).

JAPAN—No formal organization performs this task.

NETHERLANDS—This is one of the aims of the "Kwaliteitsdienst voor de Industrie" (Foundation Quality Service to Industry) and "De Nederlandse Verenizing voor Statistiek" (The Dutch Society for Statistics).

NORWAY—Norsk forening for kvalitetskontroll (Norwegian Quality Control Association).

RUSSIA—The State Committee of Standards, Measures, and Measuring Instruments of the USSR is aware of the need to develop theoretical metrology, particularly in developing criteria for evaluating the reliability and precision of data obtained from complex measuring systems. Through the working of the new All-Union Institute, it is hoped progress in establishing and disseminating such statistical information will be accelerated.

SWEDEN—Not formally.

UNITED KINGDOM—The Specialist Committees are a natural source for encouraging development and dissemination of statistical controls of data. Formal procedures could be assimilated and distributed through the British Standards Institution with the technical assistance of the Services Electrical Standards Centre, for example.

K. Does any organization in your country coordinate and encourage methods for control of measurements standards laboratory work loads, storage of data, training of measurements personnel, interchange of calibration procedures?

Answers

AUSTRALIA—The National Standards Laboratory in Sydney, and the Defence Standards Laboratories in Melbourne cooperate closely in storage of data, training of personnel, and standardization of calibration procedures. However, these activities are internal, and information distribution pertaining to the activities is minimized externally unless specific requests are directed to the laboratories.

CANADA—Various organizations are responsible for planning and controlling these aspects of their own operations. Beyond this, we are not aware of any organization attempting to perform these functions on an independent basis. Commercial standards laboratories are required to meet certain criteria for storage of data and capability of personnel.

CHILE—There is no formal organization concerned with these problems—each activity meets its problems independently.

FRANCE—Two scientific societies (SFE and SFER) have, among others, initiated actions which improve precision measurement procedures.

LCIE has, under its direction, the function of training technicians who, after being employed at LCIE, go into industry and apply the methods they were taught at LCIE.

GERMANY—Except through the normal technical supervisory activities of PTB, there is no formal program.

INDIA—In general, no. The ISI does train some personnel in measurements techniques and theory, but the other factors are in general handled by the respective laboratories independently.

ISRAEL—Only as an incidental matter related to the work loads at each factory laboratory.

ITALY—Some of the responsibilities indicated in the question are performed by the AEI which as an example, sponsors the above-mentioned circular inter-comparisons.

JAPAN—No formal organization performs this task.

NETHERLANDS—In general, no. However, an inquiry set up by the Dutch Service for Weights and Measures has revealed the desirability of coordination in our country. The matter is under investigation. In the field of length measurement "De Meetkern" stimulates and coordinates the above mentioned activities. There is close contact with educational bodies on different levels.

NORWAY—No.

RUSSIA—There is no specific single control organization at present. Again, the new All-Union Institute is expected to cope with such problems as:

The development and assimilation of measuring methods based on new principles, and of automatic devices for obtaining and analyzing, by means of electronic computers, the information on the course of production and technological processes, and combining measuring and control functions.

Developing the basis and means for automation of measurements, and the establishment of a system for providing uniform measurements in automated processes.

Developing methods and equipment for precision measurements of radio technical quantities, for testing and controlling radio technical, quantum-mechanical and acoustical systems and their components, for measuring high and low temperatures and the properties of materials under these conditions, for measuring ionizing radiations of all types and for evaluating the characteristics of nuclear processes.

Further development and improvement of statistical methods for controlling technological processes and the quality of production, and development of a rational organization for testing control instruments according to their production conditions.

Encouraging highly-qualified personnel to join metrological institutes.

Meeting the requirements of the metrological service in personnel of most varied qualifications by providing the required training in the higher educational and technical institutions of the USSR. Also the providing of standardization and measuring-equipment facilities to the institutions, and encouragement of correspondence courses.

The need for production of portable installations and instruments for testing commercial measuring instruments on the spot, for publication of catalogues of measuring instruments, and for incorporation in the new standards of the requirement for an aesthetic finish of articles.

SWEDEN—No.

UNITED KINGDOM—It is anticipated that British Calibration Services headquarters will become deeply involved in questions related to operational-management problems of certified laboratories.

L. Does any organization in your country establish definitions, classifications, test methods, and performance requirements for reference (highest level of accuracy) standards which are sold commercially?

Answers

AUSTRALIA—No organization has been established for this purpose. Most measurement reference standards are custom built or purchased abroad to customer specifications.

CANADA—Through participation in various International, National, Interdepartmental and Departmental committees many individuals in Governmental and Industrial positions assist in establishing these definitions. There is no single, identifiable organization which coordinates such actions.

CHILE—There is no such organization.

FRANCE—No

GERMANY—No answer—presumably this responsibility rests with each manufacturer.

INDIA—The Indian Government has established the National Physical Laboratory as the Prototype Approving Authority for measurement standard units at the reference standard level. NPL, in turn, bases its actions upon international practices.

ISRAEL—This is under the jurisdiction of the ISI.

ITALY—Inasmuch as there is limited production of high precision standards, when such a case occurs each Institute or Laboratory which acquires the standards, provides the necessary specifications in each case, and the final inspection.

JAPAN—Some work of this sort is provided by the association known as Japanese Industrial Standards (JIS).

NORWAY—No, apart from participation in international organizations.

RUSSIA—The All-Union Institute is expected to coordinate problems related to instrumentation and highest-level standards by attention to the following:

The development and production of new, improved reference standards for measuring units and their maintenance in a condition meeting the requirements of modern science and technology.

The establishment of reference standards on the basis of interatomic processes, which are characterized by strictly defined patterns, are not affected by external conditions and are relatively easy to reproduce.

The development of objective methods for evaluating measurement errors under complex conditions in order to obtain precise and reliable measurement results, and the development of mathematical statistics and of the theory of probability with respect to the problems of measurements and statistical control of production, including the statistical control and testing of the measuring equipment proper.

The establishment of a state service for providing the USSR national economy with reliable data concerning the physiochemical properties of materials and substances used in production, as well as numerical data on fundamental physical constants.

The establishment of a State service for providing the USSR national economy with reference materials and substances required for controlling technological processes, testing measuring equipment and evaluating the quality of indexes of all types of products.

Raising the precision in transferring measuring units by producing and improving reference standards and reference equipment.

Search for new methods and the development of new high-precision reference equipment in various fields of measurement.

Substantially improving the precision of chemical-analytical measurements and developing new methods and equipment to meet the requirements of the chemical industry.

Developing the precise-measurement techniques in the fields of biology, medicine and biophysics.

Developing theoretical metrology, in particular the working out of criteria for evaluating the precision and reliability of results obtained under complicated measuring conditions.

The improvement of information available in the field of metrology and high-precision instruments. For this purpose, it is necessary to establish closer contacts between the metrological institutes and all the scientific organizations of the USSR, and to raise the level of the State Committee of Standards' journal to that of exceedingly well-informed and authoritative scientific and technical publications.

The organization of compulsory State testing of all the newly-developed measuring, control and testing equipment, and the inspection of similar equipment imported from abroad.

The penetration into the national economy of the State-Controlled System of Instruments whose main task is to modularize and unitize instruments and devices, encourage common operation and interchangeability on the basis of uniform input and output signals, supply parameters and means of interconnection.

Speeding up the development of technical specifications for manufacturing and testing reference substances.

SWEDEN—No

UNITED KINGDOM—The Standards Instrument Manufacturers Association, in close collaboration with the Standards Instrument Research Association, is interested in this phase of work.

SESSION 11: TEST EQUIPMENT PERFORMANCE REQUIREMENTS

Chairman: Dario Antonucci
Grumman Aircraft Engineering Corp., Bethpage, L.I., New York

Committee Reports

C1, ELECTRICAL STANDARDS

Chairman: Jim Hadley
Bendix Corporation, Kansas City, Missouri

The following objectives were listed for C1:

1. To establish a list of terms, definitions and classifications for reference standards for dc and frequencies up to 1.0 MHz.

2. To establish test methods and performance requirements for reference standards from dc to frequencies up to 1.0 MHz.

3. To establish a list of persons, including representatives of organizations, who can provide technical information and advice relating to electrical reference standards.

4. To participate in the activities of other committees which have interests similar to our own, such as the ASA Committee C–100.

The membership status of the C–1 Committee as of the time of this report stands at three members. Additional members are desired, and any NCSL–66 attendees and/or members wishing to become members of this Committee should contact Jim Hadley or the NCSL Recording Secretary.

Planned activities of the C61 Committee, besides the already stated objectives:

1. Preparation of a list of standards and specifications which have been provided by other organizations that are directly applicable to the field of the committee's activities.

2. To prepare a list of terms and definitions pertinent to dc and low frequency reference standards. These terms will be coordinated with other NCSL committees.

3. To continue the work which has been started through the C–100 committee, and to make the results of this work available to the NCSL membership.

Ken Koep of Weston Instruments, Newark, N.J. reported for C1 on the C–100 Committee of the ASA:

1. The C–100 Committee is sponsored by SAMA.
2. Scope of C–100 Committee: Definitions, classifications, ratings, methods of test, performance requirements, and constructional details where necessary, for various types of the electrical reference and measuring devices covering the dc range and up to frequency range of 1.0 MHz, as used in electrical standardizing laboratories.
3. There was an investigation whether or not overlapping existed with other ASA committees, and this indicated that there was no overlapping.
4. C–100 is comprised of 4 subcommittees: ac-ratios, dc-ratio devices, ac-dc transfer devices, and definitions.
5. Organizations represented in the ASA C–100 Committee include: NCSL, NBS, U.S. Navy, U.S. Air Force, American Ordnance Ass'n., U.S. Army, NASA, SAMA, American Council of Independent Laboratories, ISA, Precision Measurement Association, Liaison Representative of the Canadian Standards Association, ASA B–88 and B–89, Telephone Industries.

C2, HIGH FREQUENCY STANDARDS

Chairman: Dario Antonucci
Grumman Aircraft Engineering Corp.

OBJECTIVE 1: To establish a reliable and realistic list of definitions and classifications applicable to standards and measurement instruments in the frequency range of 1.0 MHz and above.

a. Definitions:

1. As to application: standards, interlaboratory standards, transfer standards, working standards, etc.

2. As to purpose of standards: reference standards, measurement instruments, etc.

b. Classification of standards and instruments:

1. Classify standards and instruments by category, function, application, etc.

2. By type—such as R.F. Coaxial, Microwave Coaxial, Waveguide—what makes each a standard or test instrument, etc.

3. By levels of quality and echelons, etc.

OBJECTIVE 2: To define, as to application and function, test methods, and performance requirements, for electrical and electronic reference standards and measurement instruments.

a. Define test methods for:

1. Determining and measuring characteristics of high frequency and microwave standards as to function to which they will be utilized.

2. Determine test methods for determining quality characteristics as to function which the standards will be performing, such as reference standards, interlaboratory standards, permanently used as a system standard (built-in-standard), or component level reference.

3. Determining test methods and function characteristics of instruments used for general precision measurements other than as standards.

OBJECTIVE 3: To develop a list of reliable laboratory standards and measurement instruments by classification, name and function, excluding manufacturer's names and model numbers.

a. Listing standards according to frequency bands, type (coaxial or waveguide), minimum accuracy and precision, workmanship, special considerations.

b. Listing measurement instruments (besides standards):

1. By minimum desired characteristics.
2. By frequency bands (coaxial or WR sizes).
3. By measurement flexibility and adaptability.
4. By reliability (workmanship, stability, etc.).
5. By commercial or non-commercial availability.

OBJECTIVE 4: Develop a bibliography of standards publications and information sources.

a. Coaxial area:

1. Professional magazines and publications (speeches, reports, professional papers, etc.) in the coaxial field of high frequency standards.

2. List of references of institutions and/or industries where information on standards instruments is available or can be found. (Examples: IEEE, ISA, NBS, etc.)

3. Reference handbooks, texts, experiments, NBS publications, etc.

b. Waveguide and special areas:

1. NBS, military, professional or industrial publications on standards and standards measurements.

2. Commercial, government or military facilities where standards and measurements information can be found, and/or is available.

C3, DIMENSIONAL STANDARDS

Chairman: Mrs. Mary Hoskins
Honeywell, Inc., Minneapolis, Minnesota

The following comments were reported:

1. Regarding the performance criteria of test instruments and standards, who is responsible for what? It will be noted that the ASA B–89 Committee on Dimension Standards has been working for some time on defining and classifying dimensional standards.

2. A guide list of terms should be established which the user and the manufacturer will recognize. These criteria to be followed when buying or using the test equipment under consideration.

3. The criteria of test instruments and standards should be applied in two ways:

a. Through formal or universal definitions, as per the ASA B–89 classification

b. Through method of test, as recommended by Standards Committee.

4. The C–3 Committee member representation includes the Navy, the Sheffield Corporation, General Electric and Sandia Corporation. Additional members for this committee are desirable.

5. The proposed criteria of the C–3 Committee are based on three considerations:

a. Design Considerations
b. Functional Capabilities
c. Economics of Operation

C4, PHYSICAL STANDARDS

Chairman: Richard M. Herman
Hercules Powder Company, Magna, Utah

I. OBJECTIVES

1. Develop a list of important instrument characteristics for instruments in the physical field (accuracy, stability, precision, environmental coefficients, etc.) and a method of rating instruments using those characteristics.

2. Develop a directory of people who are knowledgeable in the various areas of the physical field and who may be called upon to provide technical information and advice in their various disciplines.

3. Develop a listing of standardized nomenclature, terms, and definitions to be used in the physical field. This listing is to be coordinated with the ISA, ASA, ASME, and other technical societies.

II. ACCOMPLISHMENTS TO DATE

1. Objective (2): A directory of people

Accomplished: There were 87 inquiries sent out, 34 answers received (40 percent response). Of those 87, 52 inquiries were sent to NCSL members, 20 answers received (38 percent response). As a result of the above action, 76 names are now categorized.

2. Objective (3): Standardized nomenclature, terms, and definitions.

Accomplished for Vibration Acceleration: Recommend ASA Standard S1.1-1960, Acoustical Terminology, be adopted.

Accomplished for Viscosity: Mr. Jacox had to resign due to pressing business. We need someone to take his place. Volunteers will be received; no reasonable offer refused.

Accomplished for Mass: Mr. White has compiled a bibliography of books, reports, articles, etc. from the U.S., Germany, and England. These will be cross-read and a brief synopsis written.

Accomplished for Force: The list of terms and definitions will include several definitions of each term and the source. This will allow some choice of the definition to be adopted. Sources will include NASA SP–7, "Dictionary of Technical Terms for Aerospace", "American Institute of Physics Handbook", and "The International Dictionary of Physics and Electronics".

Accomplished for Temperature: A partial list has been accumulated. Close liaison with the ASTM E–8 Committee will be maintained. They are preparing the same type of list.

III. THINGS YET TO BE DONE

All Objectives: Continue on the present course in all areas. The end result will be a committee report showing total accomplishments. That report, plus the efforts of the Ad Hoc Committee to be mentioned below, will eventually be published in accordance with the recommendations of the Recommended Practices Committee. Suggestions and recommendations from the Conference are solicited.

IV. AD HOC COMMITTEE ON NOMENCLATURE

1. At the request of J. Van de Houten, an Ad Hoc Committee, consisting of the chairmen of the four Test Equipment Performance Committees, has been established to compile a list of terms pertinent to the test equipment field, especially equipment normally found in standards laboratories. This list would be compatible with those issued by other technical societies, and would ultimately be issued as an NCSL Standard Practice, Committee Report, or Monograph.

SIGNIFICANCE OF HIGH FREQUENCY STANDARDS TO AEROSPACE INDUSTRY

Dario Antonucci

To an aerospace company, reliability is its most important product. This reliability can be theoretically represented by figures, but practically it can be achieved only through proven facts. Figures do not always result in facts, but facts always result in realistic figures. These facts in reliability can only be achieved by applying the science of measurements correctly. For achieving the desired results in measurements, the services of a well-established standards laboratory becomes of paramount significance. The quality of the aerospace product can be demonstrated only to the extent it can be measured.

I suspect that the reason for all of us being here today is the desire to achieve success in our endeavors in the scientific exploration of aerospace. In the old days many people had many ideas on how to achieve success. Some looked at the stars, others carried lucky charms, and still others waited for the right dream to come along to spur them into success-achieving action. Today, we who work in the industrial and aerospace sciences, being of a scientifically logical bent, are looking upon NCSL and NBS and similar organizations as our lucky talisman to success. Before we do that, however, we should know what to look for to achieve success; and that is reliability! Yet the word has hardly been mentioned at this conference.

Now, then what is the true significance of this word reliability? Speaking logically and realistically, if we have reliability we will have a successful mission; if we don't have it we will have failure. To achieve this reliability in any scientific undertaking, we must establish a dependable measurement program, because we can be sure of the reliability of our product only to the extent that it can be measured. A product can be designed, calculated and analyzed to be better, but it cannot be proven to be any better than the established references to which it can be compared. Hence, the application of this measurement program to achieve reliability is its most important function.

First however, we must differentiate between the figures and the facts which demonstrate reliability.

Reliability is a fact when success in the performance of a mission has been achieved. If the calculated figures of statistical analysis and analytical research have failed to give us a successful mission, we have only a fiction. In searching for success we must evaluate figures in terms of facts. Statistical analysis and design-figure analysis supply guidelines toward reliability, but not reliability itself. Figures, then, do not always result in facts, but facts most certainly always result in figures.

One method towards achieving reliability is the coordination of measurement programs through national channels, such as the National Bureau of Standards, the NCSL, and the many national professional societies. This method encourages industry, individually and in aggregate efforts, to work together with NBS and NCSL to propagating a more reliable, more uniform, and more exact standards measurement program. The effect should be to turn figures into positive facts, which can then be used by industry to obtain the highest degree of reliability in the national product.

To establish dependable measurement programs, the rules of uniformity must be faithfully observed. This can be accomplished by referencing measurements to the national references of NBS. The reference standards which exist within NBS can be used as a means to achieve reliability and uniformity of all measurement units and parameters, and should not be limited to any one particular industrial measurand.

In utilizing this national reference effectively, industry-oriented measurements programs and standards measurements systems must be efficiently established within corporations, and compared directly to the national reference. Because of the rapid increase in the volume of test instruments, the variety and sophistication of them, and the lack of adequate external resources, many aerospace, scientific and educational institutions are developing their own measurement capability, with accuracies which can be traced to the National Reference Standards.

The coordinated effort of the whole aerospace and scientific population must be effectively developed in cooperation with NBS, in order that competence and consistence throughout industry be realized. This means that individual corporations must put additional effort in establishing standards systems and/or programs with a high degree of reliability and integrity. The emphasis on measurement systems which can be referenced to the National Reference Standards with precision and confidence and precision is essential to the reliability of a corporation's standards effort.

The chain of responsibility for performing reliable evaluations, component tests and systems checkouts must be proven to be competent in such aspects as verified reliability, adequate and competent manpower with integrity, loyalty and interest, and continuous referencing to standards which are standards throughout the National Aerospace Program. Some indication effort expanded by Grumman Aircraft Engineering Corporation will be evident from Fig. 1*.

There are many important programs in an aerospace company that are dependent on traceable, precise, and reliable measurements for their success: Advanced Development, Research and Development, Vendor-Contractor Evaluation and Verification, Field Test and Evaluation, and New Product Development, to name just a few.

Metrologists in the last decade have made considerable advances, and broken through many barriers in propagating the importance of measurement science, but there still exists a very frustrating situation which those of us stumbling along at the working engineering level have not been able to improve. Industry's top management has not placed sufficient emphasis on adequate measurement programs, as needed to keep up with the rapid technological advance in the aerospace industry. Many managements have not yet come to realize the important role that a reliable measurements and standards program plays in the final determination of success or failure of a mission. Therefore, we still have a problem, and with the rapid increase in test equipment sophistication and more stringent requirements for higher accuracy and precision, this problem is getting worse. What is then the solution? If more top management personnel were to attend conferences and meetings like this one, perhaps they would understand the situation more clearly and thus give greater support to both the in-house and the national measurements programs.

In conclusion, let me quote a few words from the banquet speech of Mr. E. G. Hill of GD/Convair. He said that one of the most important points that we must consider in a good measurement program is "the return on the investment". What better return on an aerospace investment can we have than success of the mission?

*Editor's note: Space does not permit reproduction of the other excellent photos of the Grumman standards facilities and applications, as shown by the author at NCSL 66.

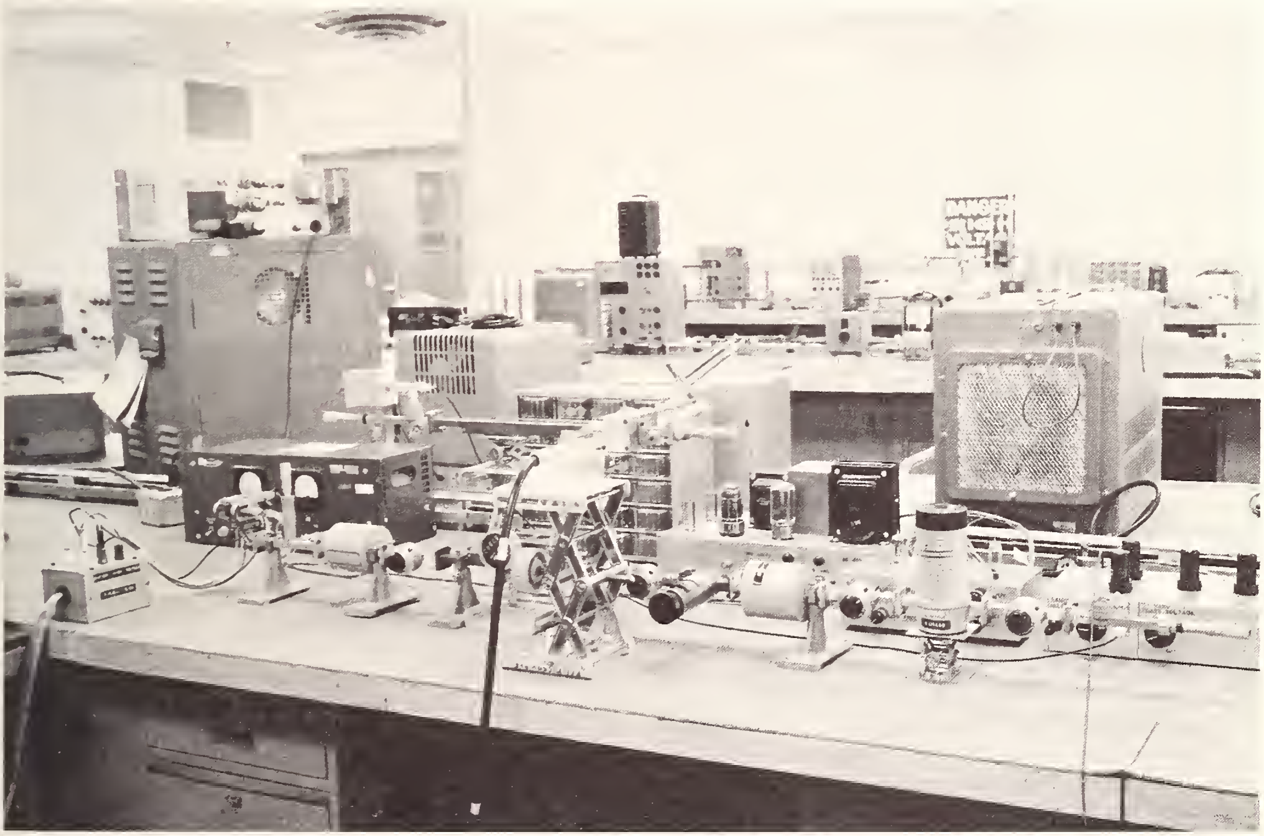

FIGURE 1. *Partial view of Grumman's primary microwave standards facility. In the foreground is the frequency meter calibration system, employing an NBS design of harmonic generator for the 12.4 to 18.0 GHz band.*

SESSION 12: STANDARDS LABORATORY ORGANIZATION AND MANAGEMENT

CHAIRMAN:
Mort Angelo
Lockheed-California Company
Burbank, California

COMMITTEE CHAIRMEN:
Corporate Standards Laboratories
L. R. Wallace
International Business Machines
Kingston, New York

Large Production Facility Laboratories
Mort Angelo
Lockheed-California Company
Burbank, California

Commercial Standards Laboratories
J. D. Ghesquiere
SSCO Standards Laboratory, Inc.
Southfield, Michigan

Universities and R & D Facilities Laboratories
W. H. McPhee
Massachusetts Institute of Technology
Cambridge, Massachusetts

PANEL MEMBERS:
R. G. Rosco
General Dynamics—Convair Division
San Diego, California

R. L. Schneider
Sandia Corporation
Albuquerque, New Mexico

N. A. Grisamore
George Washington University
Washington, D.C.

Mort Angelo, Committee Chairman: Our presentation is made up of reports from the four Standing Committee Chairmen concerning the organization and operation of a Standards Laboratory, each in its own environment. These gentlemen will present a brief resume of their committee activities. The other participating members will be introduced later when the panel session opens. Now, Lew Wallace will report on the activities of his committee, "Organization and Operation of a Corporate Standards Laboratory".

Mr. Wallace: Your program indicates that I should talk about the organization and operation of a Corporate Standards Laboratory and, as many of you know, it doesn't take much to get me started on that particular subject. However, my purpose here this morning is to give a status report of the operation of this committee. What we have been hoping to do is to hear about your ideas and experience, and to compile and analyze these things in order that they may be put into a report to you saying, "these are the things we think constitute good organization and good operation". Herein lies the problem. There have been a number of surveys of NCSL participants and these surveys invariably tell us several things. Most of you are under the administration of a Quality Assurance Division or Operation. Most laboratories work to a Laboratory Manager, and are more technical than professional. Instrument repair is a part of the Standards Laboratory function. Automatic equipment accountability is not a part of the Standards Laboratory function. Automatic recall systems are utilized and these recall systems are not combined with other recall systems. Further analysis of these various surveys does not indicate much more than that we have a high degree of togetherness, but this isn't really helping us.

Our real concern in making this study is to discover whether Standards Laboratories are merely lending a higher degree of sophistication to existing measurements techniques, and perhaps automating some of these techniques, or if they are truly concerned with development of new measuring techniques and the development of new standards. Sometimes one gets the feeling that, as the man says, we're so busy mopping up the floor that we can't reach up to turn off the faucet. Now here is what this committee is doing and has done. We found that most of the surveys we were exposed to, or had conducted, were considerably biased because we were dealing with NCSL participants and, naturally, we are all influenced by what this organization is doing. So, we used Standard and Poor's Register of Corporations and took a random sample of about 30 percent of the corporations listed under six separate standard industrial classifications. This sample resulted in selecting 183 corporations from these six SIC's. Very briefly, the classifications were as follows: engineering, laboratory, scientific research instruments and associated equipment; automatic temperature controls; optical instruments and lenses; electrical measuring instruments and test equipment; industrial controls; mechanical measuring and controlling instruments. These six SIC's were chosen because

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together they seemed to cover most of the manufacturers of instruments or scientific apparatus. To find out something about these organizations, we resorted to surveys. The results are too incomplete to render at a session at this time; however, we discovered a few things. We found that of the corporations surveyed, about 60 percent of them had between 100 and 1,000 employees; the range goes up to about 10,000, I believe. About 60 percent had an annual dollar value of business between one million and ten million dollars and about 6 percent are in the Eastern part of the nation.

Our next task will be to categorize the laboratories of the responding corporations. Let me emphasize that we are not evaluating laboratories; we shall categorize for the purpose of the study, in terms of the dependence upon, or independence from National standardizing service, primarily rendered by NBS. Having established this correspondence, we will then plot these categorizations against other variables, and determine which factors seem conducive to the development of an attitude of self-sufficiency and which factors might mitigate against achieving such self-sufficiency. By "self-sufficiency" we do not mean that people are going to go out and be completely independent of the National Bureau of Standards. We must recognize that we bear distinctive relationships to the National Bureau of Standards. What we are trying to find out is: what is the degree of self-sufficiency that the laboratories are developing to take them out of the category of "just doing well" what NBS has already been doing? What are we doing to help ourselves advance above the level of what we are doing now? What are we doing to reduce obsolescence of our own operations? This is what I mean by self-sufficiency.

We anticipate at least a preliminary report by August 1st of this year. To assist us in this venture, we will immediately begin reviewing applications for one management-type person and one statistical-type person to work with us on this committee. Now, if you plan to apply and happen not to recognize me in this august assemblage, I am sure that you will indicate your wish to work with us to either John Van de Houten or Andy Woodington. They will be very glad to pass the information on to me.

In summation, what this committee intends to do will be to report on and make recommendations concerning those functions and organizational structures which are pertinent to the organization and operation of corporate standards laboratories. We will determine to what degree self-sufficiency exists or is sought after by the respondents. We will analyze in depth those factors which mitigate against such self-sufficiency and will give you at least a preliminary report by August of this year.

Mort Angelo: Wes McPhee of the Massachusetts Institute of Technology heads the committee covering universities and R&D operations. In true chairmanlike manner, he has asked Dean Grisamore of George Washington University to give the committee report.

N. A. Grisamore: I am something of an interloper in this program, since the charge to the committee doesn't actually include laboratories for academic purposes. If you will look, it says Research Laboratories and then out of context I read, "which serve Research and Development Operations in Universities". Well R&D is only half the story. As for the organization and operation, the academic laboratory obviously reports to parents of students, so that settles those questions right then and there.

In a calibration laboratory in a university, there really are two types of laboratories. The first type of calibration laboratory in a university is one associated with a university having large R&D hardware contracts. They can afford an installation such as this as an overhead cost if nothing else. It is nice if you can get the funds from somewhere else, but you can always charge at least part of the lab costs to the government, just as you can charge a library to the government. Now if this is a facility whose primary use is to support contract work, with a secondary use as an academic laboratory, there are a considerable number of hazards in this. I don't know that I would want to take the responsibility for such an operation unless almost unlimited sums were available. I have seen what students can do in a laboratory, either by their own design or by the design of some poor instructor who just doesn't bother to tell them what to do.

The second type of laboratory—there aren't many of them; in fact, I don't know of any—falls into the category of schools without hardware contracts. Our university has a respectable amount of R&D funds, but this is mainly for paper work. This involves very little hardware other than pencils, paper, and some calculating machines. It always includes a computer; of course, you can't operate without a computer. Such a calibration laboratory, then, is primarily for academic purposes and its funds come out of the academic budget. Needless to say, the academic budget is like anybody else's, the ends never meet. In our case, we have been getting away with "grand larceny" because we have been able to send students to the NBS laboratories, to work under direct supervision of Bureau personnel, of course.

Now, with NBS moving to these sumptuous quarters, we have to equip our own laboratory and this is a *serious problem.* We consider the cost of equipping a laboratory from scratch which might be a little more than adequate, but less than desirable. This is only for a mechanical measurements laboratory and an electrical measurements laboratory, including some environmental controls for temperature and humidity. We would need a gage and an interferometer, a gage-block comparator and collimator, surface plates, facilities for internal measurements, a tool makers microscope, with an electrical standards laboratory, but without any microwave measuring equipment it will cost $40,000 to $110,000. This sum is just barely adequate. The lower figure is the amount we would need if we had only demonstration equipment. Students could not get their hands on it, and it would need supplementing by field trips out here to the Bureau of Standards. The figures I gave you cover only equipment, and not depreciation, replacement (which I would figure approximately 20 percent a year), or wages or salaries of technicians, custodians, etc. It doesn't include the recruiting of faculty, or more important, the recruiting of students.

Now, this might not sound like much to you people, but we have different kinds of money problems. These requests are competing with requests from other branches of the university. For example, how can you tell an English department that teaches more than 150 students that they can't have the money, because we need $100,000 or so to run a laboratory for 20 students over here. This doesn't set very well, I can assure you, and these people who produce tuition income for universities are quite vocal about the fact that they do it. These problems are not peculiar to our school alone, but to all schools having programs which necessitate expensive laboratories. How do we propose to overcome these problems? First of all, cooperation with Government laboratories and agencies within their statutory limitations is an obvious partial out. We can't say enough in appreciation for what the Bureau of Standards has done for us. We have also had some considerable help from portions of DOD. We need support from the industries that employ our graduates. We have considerable help from the manufacturers of precision measuring equipment, but we do not have it from the users. The users, I would say, are more vocal in demanding students than the manufacturers, perhaps because there are more of them.

Another way that things can be done to solve these problems is to support schools which want to undertake a program such as ours, in their appeals to Government agencies who have grant funds for laboratory equipment. There are a large number of these: NSF, HEW, DOD, NASA, Department of Commerce, etc.

The next thing is a touchy subject; it has been proposed, and one school is considering it, although we are not — and that is the operation of a commercial calibration laboratory by a school. This is fraught with all sorts of dangers because universities are non-profit organizations. It can be done, but the headaches that come along with it are not to be trifled with. Certainly this type of operation should not be in competition with local facilities. There is a possibility of cooperative effort between a commercial laboratory and a school in some sort of an educational program. We shy away from the operation of commercial calibration laboratories because there is one in this area. What, then, can the individuals in this meeting do? I would suspect that you people here are not the ones who make the decisions to offer funds, etc. You probably can make recommendations. We are really all brothers under the skin inviting funds and facilities, so I am sympathetic with your problems and I hope you are sympathetic with mine. I would say that one of the important things that you can do is to communicate to the pertinent committees of NCSL information concerning academic programs or courses in instrumentation or measurement science in schools in your local areas. This is one of the things that this committee specifically does not have information on. We pick it up here and there that someone offers a course, and we hear of this or that, but you people can save us a tremendous amount of time. We could always go through all the catalogs but going through that number of catalogs is no easy task.

The second thing that you could do is offer to help academic programs in your local area in whatever manner you deem it advisable. I know everyone has more work to do than there is time to do it, but I throw this out as something you can weigh against your other activities.

The third thing to do is to communicate to these schools the needs of employers and the opportunities for employment in measurement science. Schools depend upon outside sources for this sort of information. Everybody says, "that's fine and good", but when students are graduated in a particular area, you don't really know whether these students are going to have jobs. This employment situation certainly is important to the students, there is no question about it.

In closing, I remind you that all of us here are somewhat of the same opinion about the importance of measurement science, and even about the needs of government and industry for schools in this area of technology. We don't need to convince each other, but we must convince others of the importance of these matters.

Mort Angelo: Jim Ghesquiere is unique in our present day society — he believes that there is a place for the small, private enterprise. As such, he heads a committee which covers the Commercial Standards Laboratory.

J. D. Ghesquiere: This is a report of the Commercial Laboratory Committee. Mort says this is unique, and actually there are a number of calibration and standards laboratories across the country without any commercial activities. There will probably be many more, particularly because of the encouragement given by NBS to turn to a commercial laboratory for routine calibration work. Our committee consists of Bill Herrington with Veritek Corporation-West Coast, and Don MacFadgen with Sheffield Corporation. We are always looking for additional members for our committee so our work can be more comprehensive.

We first reported two years ago in New York on the problem of where to start and stop this recommended organization and practices for Commercial Laboratories. We did decide, after review, that there was no use trying to re-invent the wheel, that many of the practices and procedures are common to the Corporate, Production and Military Laboratories, and that we would stay out of these areas and use the work of the other committees. This reduced the workload to the point that we could select only those items that are unique to Commercial Standards Laboratory operations and try to develop a list of problems. Then, those of you who may decide to go into "business for yourself" can see what you are going to have to consider—consider strongly, perhaps even generate unique solutions of a proprietary nature. This effort may never offer solutions, but it will give you more of a picture of what you may be up against. Mr. Hill last night hit on several of our items, such as the cost of investment for the type of things over and above the requirements of your own in-house laboratories.

We have at this point developed a list of seventeen items. I am not going to go into detail, I would just like to read the titles very rapidly. First, we have Military Acceptance, second is Cost of Service, then Traceability to NBS, Ethics and Integrity, Quality Control, Quality Control Workmanship, Workload in Sennets Service, Calibration Procedures, Calibration Procedures for Customer's Equipment, Calibration Certification versus Test Work, Turn-Around Time, Employee Training, Record Management, Financing, Marketing, and Transportation.

These will sound like the problems other laboratories have, but if there are special considerations, it is possible that the solution may be quite different. We have listed this as an important item to be considered. For example, the first one on the list, Military Acceptance, sounds like everyone else's problem, but if you try to obtain military approval on a laboratory without having the direct military contract in the house, you are in for a lot of fun in a hurry. First, the Military will advise you that if you are being considered for a secondary contract, your prime contractor can request that they review your facilities. Of course, when you go back to the potential customer, he says, "I'm not even going to talk to you unless you're approved by the Military", and you run into an impasse. This is the type of thing you can run into and I cite it because it happened to be first on the list.

In addition to this list of problem areas for which we may or may not be able to publish solutions, we would also hope to set up, in conjunction with the other committee, some means of reference for those of you wishing to utilize an outside commercial laboratory; some means by which you can evaluate the laboratory short of having to take the whole organization apart piece by piece. We feel that many of the normal Standards Laboratory practices that you are familiar with will be a very important guideline in this type of evaluation. Our committee would like to know if such a check list would be desirable for the membership at large.

Mort Angelo: As Chairman for the Committee on Production Laboratories, I would like to report that we had a real whing-ding workshop at Disneyland last Fall. It was probably one of the best workshops that NCSL has had so far. On inputs obtained from that meeting, our committee is developing a new survey which will be mailed this summer. We are still hoping that we can put together a single plan or recommendation on how to organize and operate a large production facility laboratory. There seem to be many different ways to arrive at the same objective. After we have obtained the results of the newest survey, we will decide whether we have sufficient information to come up with a single plan, or to report the results of the survey and let you decide which course is best for you. In regard to surveys, may I, on behalf of all the Committee Chairmen of NCSL, ask you to please answer all NCSL business inquiries promptly? We are all dependent upon the mails for our committee work to get the job done. Some of the worst offenders, in this regard, operate the largest and most successful laboratories in the country. We need this information; yours may be the one bit of information that will help all the rest of us. Please answer NCSL correspondence!

The second part of our presentation will be a panel session. Our panel is to be made up of people from all of the environments in which laboratories are to be found: R&D, Universities, Commercial, Corporate and large Production facilities. The gentlemen you will see at the table met for the first time Monday night to formalize this presentation. The one thing we did was to agree to disagree, and so we are going to bring the disagreements to this floor. With your help, we may arrive at some commonalities in the five environments represented. There does not seem to be a single pat set of operation plans which can be used across the board. We want your inputs too.

In addition to the men you have already met, we have asked Bob Roscoe of General Dynamics to represent the view of a large production facility; in this case, aerospace. Rollin Schneider of the Sandia Corporation will field for the Research and Development type of operation, and Wes McPhee of M.I.T. Instrumentation Lab will present the University side of the picture. We will try to keep the discussions within the program, within the boundaries of the Geneva Convention, and away from those subjects covered in detail by other committees. I will start by making a comment and ask each gentleman to give a statement as to his position. We will then ask for comments or questions from the floor before going on to another subject. We will not try to summarize at this time; conclusions, if any, will be put into the proceedings. Please feel free to address any one of the gentlemen and see if we can't give a good answer.

Mort Angelo: We will start out by saying that in setting up a laboratory the subject of cost will pop up. A decision will have to be made as to what will be calibrated. I think it should be mandatory that all measuring devices and instruments having a direct bearing on the quality of the product should be part of the mandatory recall system. This applies also to R&D reports when instruments are used to gather data.

Lew Wallace: I can't subscribe to it. If mandatory recall means bringing the equipment in on a periodic basis, then we can certify and calibrate this equipment only to a very limited extent. For instance, you are calibrating a piece of equipment for me and I say I am only going to use it under this condition and at this particular point. What you don't know is that someone else will come in later and use this equipment under a different set of conditions within the intent of the designed equipment. They do not get the benefit of the "not for data" program, and slip into complacency. I think if you are going to use mandatory recall, you have to do a complete calibration.

Rollin Schneider: I would like to propose a substitute for mandatory recall for R&D work. When you start sending out recall cards to scientists in the R&D area, the first thing they probably do is to throw the card in the wastebasket, and don't send their instruments in. You must have professional people in your Standards Laboratory that speak the language of the scientist and can go to him and discuss his measurement problems; determine with him which instruments should be sent into the Standards Laboratory and which do not need it. Some of the instruments the scientist is using are for indication only, or maybe for ballpark measurements; these do not need mandatory recall or rigorous calibration. Those instruments he is using for data-taking as he develops his project should be in a recall system, but you must convince him that they should be calibrated and jointly agree. He will then send them in; this has been our experience at Sandia.

Lew Wallace: We have a similar case of this "not-for-data" situation. Our customer, the Air Force, insists that we call it in once a year just so they know that you are aware. Just recently, we changed our policy with the idea that our business is calibration; therefore, we are going to calibrate it. However, if the man is using it for indication only, we will put on another label which tells him just how we calibrated it. In this particular case, it is probably plus or minus 10%, which means we can do the job quite cheaply. It will have to be pretty bad before we do any adjustment or repair on it and the man still has a useable piece of equipment. You mentioned that these people have a tendency to ignore a card when you call the item in. We don't send a card, we send a man to pick up the item, and we do pretty well.

Wes McPhee: You may have a fight on your hands with some of the PhD's who think they know more about equipment than we do.

Lew Wallace: We have had that same experience. I think that one point you made should be emphasized in all of our dealings. It is very important to sit down with these people, their measurements problems and measurements needs, and show them how you can help them. Many of us are involved in situations where we must use complex mathematical equations, or find that we have voluminous data on which the various computing machines available can greatly relieve our workload. We don't go out and take a short course in differential equations so that we can solve our own mathematical problems: we turn it over to someone who has already had the short course. We do not go out to learn to program a computer, because there are programmers who can do this for us. I believe you can look upon the personnel of the Standards Laboratory as experts who have already taken the short course. This is the thing we have to sell and, having sold this, I think we will find both the PhD and production line worker very pleased to have someone help them do their work. If we can emphasize this, we will minimize the struggle to physically remove the equipment from one location to another so that we can calibrate it.

Rollin Schneider: Can we muddy the water a little bit, Mort? We talked earlier this morning about responsibility. Of course, some of the Military contracts flatly require that things be periodically calibrated. One of our customers, an industrial customer, developed the idea—this is non-military—that the man running the test is responsible for the quality of his measurements. He had an in-house standards laboratory and he might take it an instrument once an hour or once a year, depending upon what his faith in the instrument was.

At the AOA meeting at Cocoa Beach, the electrical workshop portion was devoted to advancing metrology. We got into the use of computers in standards work and suddenly this industrial customer found that his standards laboratory, which was standing by for the engineer, was suddenly thrown in the middle of the whole complex. The man in the laboratory read the transducer, plugged the numbers into a cable in the wall and said, "I don't even know where the information is going, I'm getting a typed card back." Suddenly the standards laboratory man became responsible instead of the man running the test. He now had to deal not only with familiar instruments, but also had to become a programmer and a computer man.

Wes McPhee: We are familiar with R&D even though we are connected with M.I.T. as an educational institution. We have direct responsibility to Jerry Hayes and the boys at Pomona. We have NASA contracts and find that we have to put ourselves in the middle between the user and the contract officer. We have tried the cooperative approach over a good number of years. I agree with Schneider that if you go out and physically impound these instruments, you are going to arouse greater antagonism to your program, but you do have a contractual obligation. We find that sometimes we get these instruments in and find they are out of specification. We notify the user that this was the case, and advise him that he should re-examine his data. That has helped in some cases.

Dean Grisamore, George Washington University: We don't have trouble with mandatory recall periods because the technician merely goes through the laboratory at the end of the class period and picks up those instruments in bad shape. We have a sort of built-in inspection system because the instructor designs the experiments and has some idea of what the answer should be. If the student can't get the answer with the piece of equipment he is using, you jump on the student, and if that doesn't produce results, then you look at the equipment. The problem of mandatory recall just doesn't come up for a technician. We have more work than he can possibly do and I think we keep ahead of it. We obviously don't have the degree of responsibility as to calibration that other laboratories have, but I would like to make one comment or so. Is this mandatory recall system really mandatory? If you are going to make a lot of exceptions on recall, then obviously it is not mandatory.

The second comment is directed toward the people who have trouble with their R&D scientists and PhD's. If a mandatory recall system is devised on some logical basis, even as illogical as cost to a PhD, you explain to him why you have it. He certainly is going to have his opinion as to how important it is that his instruments be calibrated to an ant's eyebrow, but he is part of the system and realizes that some things have to be done even though he doesn't like them. Of course, when it becomes inconvenient, he is going to say something. I think the point is to explain to him, on a rational basis, why you have the recall system.

Wes McPhee: I would like to invite you up to M.I.T. sometime and perhaps you can see our problem. The very fact that Jerry Hayes has developed this cartoon on "Why Calibrate" points this up. It hits every operation we have in greater or lesser degree. I know of some of the industrial companies in our area where people are actually sent home if they are caught using an instrument out of date. It is very hard to come up with a fair and equitable solution to this problem, but I think that we have got to make a realistic approach.

Mort Angelo: We may be a little more fortunate than some of the other companies. Our Engineering Department has agreed that calibration is necessary. I am talking about our research people; it was proven to them that research dollars are hard to come by and that the results must be correct the first time.

From the floor—Ed Quane, Bendix Systems Division: We have been talking here in previous sessions about meaningful measurements. I think it applies to this R&D thing that we have just discussed. I run into the same problem of whether or not R&D people require calibrations, and in my installation they come up with the excuse that all they are doing is making comparative readings. The point I am making here is that before a measurement can be made meaningful, it must be reduced to number and magnitude and unit. I have found this to be most effective in jogging the people who say they don't need calibrated equipment. You have got to reduce their results to numbers and magnitudes before somebody else can put it to work.

Lew Wallace: Among the comments made last evening, Ed's remarks are particularly pertinent. Explain to your R&D friend that the results of his work, unless he is in pure research, are going into a product to be manufactured. He is most concerned, or he should be, with the profit and loss relation in the corporation that employs him. Make him aware that by using not just relative data, but "absolute data", it will be much easier to move his project out of R&D into production. Although it is quite frequently true that R&D people are interested only in comparative data, you might point out to them that calibration includes a thing known as precision. An instrument can have a change in precision which might affect his comparative data.

Harry Shore, U.S. Army Electronics Command, Fort Monmouth, N.J.: I strongly disagree with believers in a voluntary recall calibration program for R&D. It never works. Regulations require that we periodically recall for calibration, and it isn't a matter of choice for the scientist as to whether he will relinquish the instruments—he must. I agree with Wallace and Grisamore that it is most helpful to put on an educational program to make the scientist realize the importance of releasing his equipment, in order that it can be calibrated and returned to him to make meaningful measurements.

Paul Long, Western Electric: In regard to this recall, I think we are really looking at how it is working in particular organizations. Probably, all of us will agree that we must have some sort of recall. The research people realize what corrections might be necessary in their data in order to give it true meaning to anyone else who might use these data. I think we should concentrate on a way of educating the people we are going to recall this equipment from. After all, what good are any measurements if they have no foundation, no reference. We are shirking our job if we worry about complaints we might get from R&D people. I think we should put through an educational program to explain the importance of this recall program.

Wes McPhee: This is the approach we have taken. I personally have spoken at several project seminars and brought up the examples which you suggested and I think this has been helpful. If you can personally acquaint a group of competent engineers with the situation, I believe they do become a little more aware. We found that this approach does work. Memos are not the answer, as they are too easily put aside, and little consideration is given to them.

Lew Wallace: I would like to comment on that also. We have found that research scientists are very reluctant to read memos. We found that when our measurement engineer sits down with the research scientist and discusses instrument problems and the instruments he is using, we have much greater success than with memos.

Earl Gard, Army Primary Lab, Philadelphia: We are presently operating successfully the military type of recall in which a sticker affixed to the instrument shows the date of expiration of the calibration; this is a great help in getting it back on time. It gives the user an opportunity to anticipate when the next calibration is due. It has been my experience that it is almost impossible to control the use of a portable piece of equipment. If we insist on a 100% calibration, the interval can be adjusted according to the history of that particular type of equipment. In industrial applications, in order to save money, the sticker could be left off a piece of equipment used just to make indications. However, one might ask why the equipment was bought in the first place.

From the floor: One point that hasn't been mentioned I think is quite important. Most of these R&D programs have limited budgets, and in our case, each program pays for its calibration time. If we go in and tell them it is going to take eight hours to re-certify the oscilloscope they are using, they scream and you can hear them from one end of this country to the other. I think it is quite important to bring forward the fact that calibration can actually produce savings to their program. When I have been able to show them this, I have no more squawk when pulling the equipment of the laboratory and calibrating it for them. Also, we have a difference in classification. If equipment is used as an indicator, it is classified as an unvalued instrument, and the user can have it for six months without its being touched. If it is used for direct data, it gets another classification and is called in at certain recall intervals.

Tom Rollins: I suggest that perhaps we are looking at the wrong problem. I believe it is not mandatory recall, but what the management attitude is towards the accuracy of the data the scientist takes. If the management insists that correct data be taken, there will be no problem. There are very good ways of assuring that the data will be correct; there are proven design and review techniques that will do just this sort of thing. I would suggest also that when it comes to persuading scientists and engineers, the standards people are probably out-voted. Their time could be spent in learning more about the business, not in wasting public relations efforts. If management and scientific personnel establish the policy, everything else will work out very easily. There are means to accomplish this—one is the use of a library for calibrated gear. If you inventory your equipment, you may find a scientist has ten or more pieces of gear which he cannot possibly use at one time. By taking this surplus equipment, putting it into a library, and keeping it in good shape, it is possible to have adequate equipment without spending any more money for it.

Wes McPhee: I heartily agree with Rollins' concept, but I have been trying for six or eight years to sell an Air Force man on the same thing. Although I have made some in-roads, I feel that I am so far from the ultimate it is pathetic. We work strictly through some projects which have mandatory recall and some which do not. If you ask for equipment to go into an equipment pool, you can get one of the greatest collections of antiques you have ever seen. I think some may have seen it at an IEEE show of 50 years ago. Those are the ones given to the pool; not the usual equipment that we know is sitting on the shelves within some of these projects.

George Gastineau: As to the point of establishing instrument pools, you might acquaint management with the cost reduction program the government is trying to get established. I am pretty sure Mort and others are acquainted with this program. I would like to get top management to look at one consolidated instrument pool which would be a centralized effort, and force the agency to make sure the plan is set up right.

I hope that the committee as a whole has agreed that R&D equipment should be calibrated or at least controlled. Even though your policy statement states that scientists will have their equipment controlled, you still have to have some area where these pieces of equipment will be returned to the laboratory. Again, your top management is going to be the ones. It is a shame at this NCSL Conference, we get all our calibration people here but we don't see top management attending. Sometimes I think your top management are the people who should attend this conference with you to get across some of these ideas.

Frank Dyce, Martin Company, Orlando, Florida: We had quite a problem on our recall system until we changed our structure. All our equipment is handled and controlled by the Facilities Division and is used by the Engineering Division and calibrated by the Quality Division. From the records being kept, we know who has equipment with calibration past due and this can be used as a sort of black list. Engineering was given the responsibility for recalling the equipment by actually having a man go by and pick up the equipment from the person using it, and the responsibility was given to a manager who could put a little pressure on.

In Martin's R&D group, they are using, in some cases, much higher caliber equipment than we have in our laboratory and we actually could not calibrate it. However, there are quite a few instruments between this area down to the monitoring instruments, and I think somebody is trying to fool us, Can you assume that these people, just because they have a Ph.D. and know all about silicon carbide crystals, know all about how to calibrate Leeds & Northrup potentiometers, etc.?

Bob Roscoe, General Dynamics/Convair: We started out with this idea of a limited calibration where we had certain systems, composed of a lot of commercial items, and some Convair built items; these were used to check out a product for the government. We used a procedure written by an Engineering group and in these particular cases, we found that certain instruments were used only at certain points. For example, a voltmeter used to check 115 volts was calibrated only right around 115 volts. A vacuum tube voltmeter in the system was used because of its high impedance. Here again, we put a limited calibration on it; it paid off in the time we saved in adjustments and repairs, because we didn't bother to change capacitors and resistors (which could drift) because they were not using them at these high frequencies.

From the floor: What piece of test equipment is being used by more than one person at various points along the line?

Bob Roscoe: Single, individual items of portable test equipment, multimeters, should be calibrated because a man can make a measurement with them. However, we know that most of the time they use it as a continuity checker and it is cheaper to buy one than to have a technician assemble a battery and a bulb. They wonder if that power pack is turned on; they will slap a multimeter on and if the needle moves, O.K. Most of the time, if a technician or an engineer wants an accurate measurement, he's going to get a different meter. We will put a tag on the limited calibration item, and mark it as $\pm 10\%$.

From the floor: On the sticker you indicate the limited range in which it has been calibrated. In case anyone else should borrow that meter, are they necessarily expecting calibration assurance?

Bob Roscoe: That is right. When we put a decal on, we show the date due and a huge red stamp "Limited". In some cases, we tell them what we did or did not do.

Wes McPhee: We follow the same procedure in our case. Anyone picking up a unit can see if it was completely calibrated or to what extent it is limited.

From the floor: I would like to ask those operators of equipment pools or libraries what consideration they have given to standby calibration of shelf life.

Mort Angelo: One of the largest equipment pool operators keeps a small bank of currently calibrated pieces of equipment. Say they have one hundred scopes but their flow is five; they keep a backup of five fully calibrated scopes. When the card comes up through the IBM recall system, the equipment gets a sticker, "Must be Calibrated Prior to Use", and is placed on the shelf uncalibrated until needed.

Jim Mallison, Douglas Aircraft Co., Inc.: What about the other ten thousand items in the inventory of which you have only one or two? You can't stand the damage to schedule waiting to get them calibrated immediately for someone that needs them. Can you give it consideration for shelf life of perhaps double the regular calibration?

Mort Angelo: I don't see why not, we do it with dimensional tools. When you have equipment sitting on the shelf that is not being used, it is better that you put it on inactive status until someone asks for it. You should always use your recall system to plan your work load, but never let your work load be so planned that you cannot take care of emergencies.

C. R. Harris: The whole purpose of calibration and recall is meaningful measurements with units and numbers that are properly assignable. To me, this means consistency, and inevitably this brings us back to this word "traceability", as defined yesterday by Mr. Barnett.

From the floor: I am from General Electric Company-Spacecraft, Philadelphia. We found that most of these R&D people actually modify the equipment in many cases, and this is the main reason they don't want it calibrated. They send it in to you and your technician says, "Look at that, the whole section has been removed; you'd better send it back to the manufacturers." Two weeks later, an engineer comes up and says, "Where is my special counter?" We have really not done too much with this problem. We have had a mandatory recall system only within the last year. We have about 20,000 instruments on inventory, 18,000 electronic and 2,000 mechanical, and we will always average 30 to 40% of these out of calibration date. Our Quality Control Operating Procedure says that one week after the calibration period has expired, the first level of management will be notified.

After the second week it goes to the second level with copies to the third level. Believe it or not, we get action right away.

We had a three year experiment on shop life of instruments, and we find it excellent for mechanical gages, but it is not of much value on electronic instruments, especially on things such as recorders, whose ink dries up. Late Friday afternoon somebody comes down and needs something calibrated. We may have several pieces of calibrated equipment ready, and this is really very nice, although it hasn't really reduced our over-all costs.

Lew Wallace: I do not believe that we can afford to put fear into a person as a reason for wanting an instrument to come back. I believe we must put education foremost in the minds of these people, and the awareness of the need for meaningful measurement. Then we do not have to be too concerned about the specific methods for recall, mandatory or otherwise.

Dean Grisamore: A bit of information that I happen to remember from the meeting at Disneyland: there was considerable discussion about leaving power on electronic equipment while it was not being used. This reduced the maintenance considerably and kept the instrument in calibration.

NCSL 66

SESSION 13: WORKLOAD CONTROL

The following report was prepared and presented by the NCSL Workload Control Committee:

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1. Introductory Remarks

E. J. Arsenault

After listening to the reports from many of the other NCSL committees, you are probably wondering what is left for the Workload Control Committee to do? What is our mission? Simply stated, it is studying *the product* of the calibration program. What is the product? Calibration service? Technology? After processing all the equipment and having performed a complete service, the evidence of this effort is calibration data on some form of record. This is the product. Let us look at it through the eyes of management with the intent to review and analyze the operation and techniques of managing the calibration program as a business. This may shock some of you; however, anything that requires money to operate and produces a product, has to be considered a business. For every dollar spent, there must be some justification for value received. Keep this in mind. A business analysis of the Calibration Program begins with the acquisition of the raw material: such things as recall methods, inventory control, operation of instrument loan pools, workload planning, identification, etc. bring the raw material into the organization.

As data is recorded, we begin the manufacture of our product. What type of data is produced? It varies depending on each organization's requirements. The data is processed in some form, evaluated, filed, stored, or programmed on E.D.P. or A.D.P. Most important, but forgotten in many cases, is: What do you do with this product once you have manufactured it? The calibration program shows a profit if you can apply this data to improving the calibration system.

I want to pause at this point to emphasize the fact that our organizations produce an abundance of data. What is of great concern is the amount of data actually applied to improving the operation of a calibration program. Someday, laboratories are going to have to stand up to justify the cost of all this elaborate processing and storage of information, and be able to point out the cost of its service vs. the value received. We may be surprised to find out that it costs us ten dollars to save every dollar. Not very good business.

Our study has shown that calibration interval is the factor in the calibration program that stands out by itself as an influence on manpower, capability, facilities, cost of operation, even the extent of your organization's inventory. The whole calibration program revolves around this cycle; it controls the level of quality and the total cost. Open up the average calibration interval by 10 percent, and manpower, operating costs, facilities, etc. (assuming the inventory constant) will drop accordingly. Close the calibration cycle by the same degree, and costs will go up. This single important parameter in the calibration program is the least well managed, and is given the least attention by engineering-type personnel. This may shock you, but think how often top-notch technical people are assigned to resolve a particular technical problem, for example, in data processing and evaluation. How many are assigned full-time to follow a Calibration Cycle Program in an effort to develop an intelligent approach? We have already realized it's the heart of the program as far as cost is concerned.

The contributions of this Committee will be to provide some of the techniques which have proven themselves, through experience, to produce good management of the calibration program. The report issued may not contain material that can be applied directly in practice to your own particular organization. There is no such thing as one technique being applicable to everyone. The committee will present good operating techniques—not the only ones—not the best—but some of those which have been shown to achieve some degree of success. It will be up to each organization to use creative imagination to develop the calibration program required to carry out its responsibilities. There is no desire to standardize, because standardization in this area of management will tend to deflate a good calibration program. We must keep this program dynamic. With business changing so rapidly today, it is most important to identify the level of quality that your program will have to maintain. Ideally, we would like to see a calibration program in which the level of quality could be raised or lowered to meet the requirements of the product.

The Committee obtains data by conducting surveys, based on the experience of its members. Over the past few years, we have been fortunate to have members who not only were experienced, but most willing to work in this area. Workshops provide the best and fastest way to exchange information that any committee can use, as evidenced by the success obtained at the one held in Anaheim last year. To date, the Committee has gathered sufficient information to begin identifying operating techniques to be drafted into procedures for submission to the Recommended Practices Committee for evaluation, and hopefully, final publication in a handbook.

2. Background

The Committee's activities over the past two years have been directed towards gathering data and techniques presently employed throughout the country in their respective areas of responsibility. In 1965, the Committee identified three major areas of responsibility as follows:

Data Collection, Utilization, and Analysis.

Recall Methods and Concepts, and Workflow Planning.

Calibration Intervals.

Subcommittees were established for each of these responsibilities with the intent that through specialization, the Committee could make more significant contributions. To obtain as much information as possible within a short period of time, the Committee decided to conduct a series of workshops which were held in August of 1965 in Anaheim, California. Six individual workshops were conducted, and the results are part of this committee report.

In 1966, the Committee established two objectives for the coming year. First, they were to prepare a report for presentation at this Conference. The second objective was to review all the information that had been accumulated over the past year with the intention of identifying laboratory practices which have been employed and have achieved a reasonable amount of success. These practices, in turn, are to be submitted to NCSL to be considered for inclusion in the RECOMMENDED PRACTICES FOR STANDARDS LABORATORIES MANUAL.

3. Summary of Report Content

This report includes a de-briefing of the workshops that were held in 1965. Each subcommittee is including their findings as to the present "state of art" that exists in the areas that they have evaluated. These reports will also identify some of the laboratory practices which have been proven successful and could be employed by other organizations.

The Committee recognizes that its report is not complete in all respects, nor does it represent the only practices that should be employed in the areas that have been evaluated.

4. Summary of Workshop Sessions

4.1 Data Collection, Utilization and Analysis

The workshops were held on August 19, 1965. Six individual workshops on the subject of data collection were held, two such workshops being held simultaneously. Each workshop worked to an outline which was presented at the beginning and, in most cases, the entire outline was covered.

It appears that everyone records some of data in their laboratories. The type and amount of data depends on both the interest and the accuracy level at which the individual laboratories operate. For instance, most standards laboratories record all variable data, while calibration laboratories, especially those dealing with dimensional measurements, maintain only a check list and date as to when an instrument was calibrated. Most participants indicated that they stored and filed their data in the usual manner, but kept this data for different periods of time. Some maintain data for a year, others keep data only from the last two or three calibration records, while some maintain data on instruments for their entire active life.

No one expressed any concern over the cost of obtaining and filing calibration data. As to the various methods employed in recording data, this was primarily affected by the size of the operation concerned. Small operations, those usually having less than five thousand items, had a complete manual system of recording data such as the Visicard system or Kardex system. With the larger operations, the data is recorded manually and then is processed through an E.D.P. or A.D.P. system from which they extract the key information recorded on the original calibration record. This is keypunched and filed for future reference. These cards are usually sorted in various manners and then presented in a tabulated run-off to allow post-analysis of the calibration data. In some instances, the information keypunched on the cards is forwarded to a computer for storage on magnetic tape.

In general, we found no one in great opposition to recording some type of data, and most participants agreed that the requirements in MIL Specs made it mandatory in most cases. Although some people record variable data, none of the participants indicated that this variable data was processed to an E.D.P. system and stored permanently on magnetic tape. There was a strong feeling that only those data for which there was a predetermined need and application should be recorded.

In the area of application of data, everyone indicated that they employed calibration data to determine and adjust calibration intervals. Some members indicated that they supplied calibration curves with every instrument, while others only provided this information upon request. There appeared to be some interest in gathering reliability information to evaluate various types of instruments for both costs and dependability. One of the most common applications for calibration data is the updating of an automatic recall system. Every one of the participants indicated that they used this information in some form to establish when an instrument is to be recalled for the next calibration interval. As far as the costs that are encountered by the various laboratories in evaluating calibration data, there appeared to be no problem. Most members indicated that they absorbed this cost in the normal operating expenses, and very few were able to break out this cost separately in order to properly evaluate its contribution.

On measuring tools that are employed in aiding management, most members indicated that either the number of instruments processed by an individual on a weekly basis, or the number of hours per instrument are the standard criteria used to measure the efficiency, effectiveness and productivity of a laboratory. One member employs a complexity rating based on the number of data points as the means to measure efficiency and productivity of their operation. This more equitable basis aided the measurement of individuals who calibrate simple instruments as compared to those working on a complex system.

Some members expressed concern over the establishment by some laboratory operations of a quota per man over a specific time. They indicate that such a measurement causes a technician to cut corners in an effort to meet his quota, which in turn causes degradation of the quality of the calibration service.

Many laboratories review their data to determine the economical life of an instrument. The criterias and techniques employed vary with each operation, but there appears to be concentrated effort to eliminate high cost items from the active listing. Aside from the variable data, such things as calibration and maintenance hours, material costs, initial costs, age of the equipment and organization owning equipment are included in the calibration data form. Some of the participants indicated that when technicians were requested to sign calibration data sheets, the quality of the data was vastly improved. They felt that when an individual was given full responsibility for the recording of such information, that he was more conscientious in providing a more accurate calibration report.

Generally speaking, the workshop conferences were unable to uncover any operation which actually employed the computer facility to perform any analysis of the calibration data, except in highly specialized applications. The major application was for storing and filing of data on magnetic tape and then through various sorts and presentations, the data was tabulated for the purpose of performing manual analysis. There were very few instances in which sound criteria had been established to determine such things as calibration intervals, economical life, reliability, utilization, and quality level for a calibration system.

4.2 Workflow Planning and Recall Methods

4.2.1 Calibration Organization Public Relations

The general approach of selling management on the value, advantage, and necessity for a calibration program has been to stress goodness of measurement, potential cost savings resulting from reduced errors and reduced rework, and the requirements of military specifications. The existing problem appears to be how management is to be convinced of the need for the program. A major solution appeared to be the use of the Company's own motivation people. One participant contributed the information that his organization had used them to make a study on how to sell management a calibration program. This included listing the calibration *costs* to show management the situation in the past and developing an approach to the problem from a very positive direction. The general recommendation as the result of the discussion came to the point that management must be sold in terms of dollars and cents, because this is the prime area of interest.

4.2.2 Standardization Committee on Procurement

The problems of instrument procurement are handled in one company by a committee which standardizes instrument procurement for the entire company. This committee is made up of representatives from the procurement group, the Facilities Planning Group, the Quality Control organization, representative users, and a member of the Standards Laboratory. This committee reviews all instrumentation requirements and then determines the types (by manufacturer/model number) which are to be purchased, based upon requirements, reliability histories, general vendor service history, and any other qualities which may be important. The decision of the committee, as far as the corporation is concerned, constitutes the sole justification of a purchasing source, and removes such requirements from competitive bidding.

4.2.3 Instrument Cost Analysis

This discussion primarily centered in the problem of equating numbers and units in calibration costs so that comparison may be made between various companies. It was decided that the Workload Committee of NCSL should attempt to determine such units so that various inputs, anonymous or otherwise, may be compared by laboratory managers to develop accurate information on the relative costs of operating calibration facilities.

4.2.4 Calibration Justification Guide

This subject matter involves a universal checklist to be used by calibration people for the justification of equipment, engineer training, labor for the laboratories, travel budgets, etc. The consensus indicated that this would certainly be helpful to provide a reminder of all the elements that should be considered when developing additional requirements and accordingly additional costs.

4.2.5 Limited Calibration

Discussion of various techniques to provide calibration services for only those parameters which are used resulted in the general conclusion that this practice is advantageous under certain conditions. The major requirement for proper conditions is that there be considerable stability in the usage of the instruments in question. Such applications as Systems Calibration, involving the calibration of the instruments as they are actually used in a measurement system, result in a considerable saving and a reduction of calibration costs. It also has the advantage of giving additional surety to the measurements since the calibration includes the inter-connecting wiring and other potential sources of measurement error.

4.3 Calibration Intervals

Discussions concerned the criteria by which calibration intervals should be established to assure that instruments remain within proper performance tolerances. While it was agreed that interest related to all categories of equipment and standards, prime interest centered about proper intervals for test and measuring equipment supported by calibration laboratories rather than on standards themselves.

It was agreed that calibration intervals should be based upon criteria connected with the out-of-tolerance condition of instruments. This required defining what was meant by out-of-tolerance; how many parameters had to be out-of-tolerance before an instrument was to be considered out-of-tolerance, etc. The majority felt that any parameter that was out-of-tolerance meant the whole instrument was out-of-tolerance, if that parameter had, in fact, some subsequent importance in the instrument usage. They believed that once accepted for use, instruments should not be tested beyond their usage characteristics (if this can be determined).

Next came the problem of deciding just how high an out-of-tolerance level could exist. The out-of-tolerance allowed ranged from 30% to 1%; however, the broad majority had an actual practice figure of 20% to 10%, striving for an improvement to 10% to 5%. The 5% figure in Military Handbook 52 was frequently referred to as the guide in this matter.

Next ensued a spirited debate about how to apply changes to calibration intervals. Some advocated applying these changes to instruments by model number; others reported some success in their particular organization by applying interval changes to individual instruments. They felt that the latter method provided much more accurate means to compensate for usage environment, use parameters, and more definable and meaningful reliability figures. No one questioned the technical wisdom of this approach but did question its practicability in view of ensuing difficulties in scheduling and balancing workload.

A short time was spent concerning how to express calibration intervals. The majority concluded that the old method of calendar days or months was the best compromise between precision and scheduling practicality. The use of running time meters, elapsed time devices, on-off counters, etc. was discussed and it was generally concluded that while these had specific applications, they have yet to be proven as a significant means of prescribing calibration intervals.

Other matters were covered, such as proper data to collect. Many felt that over-all go-no-go information was adequate enough. Others felt that indications of individual parameter out-of-tolerance conditions were a necessity; others felt that variable data was essential to assure lab quality. It was noted by many that much could be learned about reliability, maintainability costs and proper support for test equipment through properly analyzed calibration interval data.

5. Recall Methods, Concept, and Workflow Planning: A Comprehensive Instrument Control System

J. R. Myers

5.1 Introduction

It is very easy to recall an instrument for calibration, we need only to know the calibration due date and, of course, how to locate the instrument; but, you may ask, how did this instrument get into the laboratory for its initial calibration? What happens if an instrument is transferred to another facility? How many instruments are uncalibrated because we have not yet learned of their existence? It is not enough just to recall instruments. The so-called recall system has to become a complete and comprehensive instrument control system before an effective calibration program can exist.

5.2 The System Requirement

To operate an adequate instrument control system, we must be able to obtain up-to-date information on the description and location of every instrument under our jurisdiction. This information is best obtained by teaming up with the company's inventory control department. To use any other method results in redundant effort, thus wasted time and money. We must also identify each instrument in a manner that will give easy and positive identification of the instrument. Once again, it is best to join forces with the inventory control department. This information as to identity, description and location can be made accessible to both entities. We can add our own inputs, giving the calibration status, calibration interval, date last calibrated and the date due for recalibration. Sorting of the information stored in our integrated record system facilities preparation of instrument service requests, workload forecasts, work completed reports, calibration due lists, etc.

The forms we use to input the record center become a very important part of the instrument control system. Much effort can be saved if the form that the inventory control people use to input the inventory control records has a portion that can be used by the calibration laboratory to input the instrument control records. The forms that are used by the shipping and receiving department personnel to move instruments in and out of the facility should also be designed to input the integrated record system. The form that is used to recall an instrument for calibration should have portions to assist the department responsible for the instrument in keeping their internal records.

5.3 The System In Operation

When a new instrument is received (or fabricated), the inventory control department assigns a control number to the instrument and initiates a receiving notice (or fabrication notice). One copy of this notice is sent directly to the records center to input the inventory records. A second copy is sent to the calibration laboratory so that calibration status may be determined and a calibration interval assigned. If the item requires calibration, it is considered due for calibration and is moved directly from the receiving department (or assembly area) to the calibration laboratory. The calibration date and recalibration due date are entered on the second copy of the notice at time of calibration. The completed second copy is then sent to the record center to input the instrument control portion of the system. A third copy of the notice is turned over to the department owning the instrument so that they may use it as property record card. Once an instrument has received its initial input to the system, the information stored in the integrated record system is sorted by department and recalibration due date to obtain recall information. A service request form is then printed for each instrument due. This service request is sent to a responsible person in the department possessing the instrument, so that the instrument can be located and moved to the calibration laboratory. One copy of service request is retained by the using department so that they have a record of instruments "in calibration". A second is sent to the record center when the instrument is received by the calibration laboratory to notify the record center that the instrument has arrived for calibration. (If this second copy is not received by the record center, the instrument is listed on a delinquent list that can be distributed to management.) A third copy of the service request is completed at time of calibration, then sent to the record center to update the recall information. The fourth and final copy of the service request is a traveler: this copy is returned to the department responsible for the instrument to be matched with the first copy so the "in calibration" file may be cleared. Should an instrument be transferred or otherwise disposed of, a copy of the shipping document or disposition form is sent to the record center to change the location information, remove the item from the recall schedule, or update the inventory records as required.

Many additions can be made to our system. We can add calibration history information, standards used, performing lab, hours required, etc., thus enabling the system's use for many analysis requirements. If the program is carefully set up, it becomes very easy to operate. Give consideration to having the inventory control department assign a *separate* series of control numbers to furniture, fixtures, etc. This will eliminate the need for reviewing calibration status on desks, chairs, etc. Nomenclature and manufacturer information should be coded to eliminate sorting errors caused by abbreviations, transposed letters, etc. Model numbers should be carefully entered to eliminate possible segregation of instruments because their model numbers have a prefix or suffix that indicated rack mounted, special paint or the like.

It is well to remember that an integrated inventory control/instrument control system saves money for the company by eliminating duplication of effort; in addition, this type of program can increase management support of a mandatory periodic recall system.

6. Data Collection, Utilization, and Analysis Subcommittee Report

J. Vondracek

6.1 Data collection and utilization requirements are to be found in most of our contracts for hardware and study reports. The military specifications state: "Records shall be maintained on the recalibration status, condition, and corrections or repairs for each inspection, measuring and test equipment." Also stated is the requirement for "variables data" to be used to determine the adequacy of maintenance. Our non-military customers are usually interested in whether their instrument was good or bad, and what the data showed.

6.2 The establishing of any data system requires the identification of data elements common to all instruments and satisfying our own and our customers needs.

6.2.1 General instrument control data should consider:

Name of Manufacturer
Model Number
Serial Number
Property Identification or Control Number
Location
Date Calibrated
Date Due For Calibration

Other desirable control data could include:

Original Cost
Annual Maintenance Cost
Standards Required
Date of Acquisition
Procedure Number
Technician's Name

6.2.2 Variables Data should consider:

Actual Data Points
Out-of-Tolerance Data
Initial and Final Calibration Data
Adjustments
Repair Parts Used
Maintenance Actions Accomplished
Repair Parts Costs
Calibration Costs
Usage Environment
Utilization

The control data and the variables data that are collected determine to a large extent the management techniques utilized in the performance of the calibration program.

6.3 Data Systems must be well defined and the needs for each individual data element and data report evaluated.

6.3.1 Selection of the types of information desired and the frequency of reports have a major effect on system costs.

a. Daily work load control reports may appear to be expensive but may save the work of several clerks.

b. Instrument failure rates and reliability factor ratings of individual instruments or groups of instruments assist the planning of any instrument replacement program.

c. Calibration interval evaluation or calculation can be done automatically by a computer.

d. Reports showing location at the last calibration simplify the process of annual property inventories.

6.3.2 There are three basic types of data systems currently in use:

a. Manual Systems—All control and variables data must be accumulated, filed and retrieved by hand. Reports easily modified to meet individual needs. Manual systems are normally limited to 3000 to 5000 instruments.

b. Electronic Data Processing Systems are maintained on IBM cards. These systems are in use primarily in the range of 2000 to as high as 90,000 instruments. Data reports are limited as to those that can be obtained from sorting, tabulating, and counting operations. Data accumulation is simplified but computations other than addition or subtraction must be performed manually.

c. Magnetic Tape systems represent the most sophisticated systems available for control, management reports, and data manipulation. Tape records may be used on any size data system but programming set-up and machine time usually restrict the use of magnetic tape systems to 10,000 or more individual instruments.

6.3.3 A brief review of the data system costs at General Electric Co., Redstone Arsenal, General Dynamics Corp., and McDonnell Aircraft Corp. shows that the data collection, utilization and analysis operations vary in cost from $1.20 to $1.92 per instrument processed. Over 50% of this cost is in the data collection portion of the task. Putting the data into useable formats and reports is the smallest part of the cost.

6.4 The true product of the Standards and Calibration Laboratory is data. From it we get:

1. Product quality assurance.
2. Control of our calibration system.
3. A measure of the efficiency and effectiveness of the calibration process.

7. Calibration Subcommittee Report

Methods of Establishing Calibration Intervals

J. L. Hayes

The establishment of calibration intervals has long been the weak technical link in the calibration chain. At the present time, there appears to be no definite single solution to this problem. One of the reasons for this is that calibration is concerned with so many different types of equipment—electrical, electronic, microwave, physical, optical, etc. Secondly, every organization requiring calibration has different minimum reliability levels, failure definitions, cost limitations, and testing procedures, each having a direct bearing on the setting of optimum calibration intervals. The broad guide lines used by many are found in the Calibration Intervals section of Military Specification MIL–C–45662B, entitled, "Calibration System Requirements."

"Calibration Intervals. Measurement and Test Equipment and Standards shall be calibrated at intervals established on the basis of stability, purpose, degree of usage, precision, accuracy, and skills of personnel utilizing the equipment. Intervals shall be shortened as required, to assure continued accuracy, as evidenced by the results of preceding calibrations, and may be lengthened only when the results of previous calibrations provide definite indications that such action will not adversely affect the accuracy of the system. To support decisions relative to lengthening of calibration intervals, the contractor shall perform a statistical analysis of quantitative data generated from past calibrations. Frequent checks shall be made to prevent continued use of devices which may be out of calibration."

There are five general methods in use today for the establishment of calibration intervals; these are broadly outlined in following sections. It is emphasized that these techniques are given in the simplest form and that with certain modification many of the disadvantages listed might be overcome. It should also be noted that there is considerable crossover in these techniques and portions of each may be used in constructing a satisfactory program.

7.1 Fixed Interval Through Engineering Intuition

This is by far the most prevalent method in use today. It requires that individuals with experience in the general subject equipment area generate an educated guess as to how long an item might be expected to remain in tolerance. This method of determination usually treats the model and manufacturer as a group. It is less often treated as a generic classification (e.g. signal generators, attenuators, pressure gages, etc.). This also serves as the starting point for all other existing methods.

7.1.1 Advantages

(1) Lowest initial expense.
(2) Offers short-term flexibility.
(3) Serves small number of items well.

7.1.2 Disadvantages

(1) Ultimate expense may be extremely high through unsupported decisions.
(2) Requires the same individuals who made the initial decision (or others equally qualified) to monitor and adjust periods.
(3) Does not yield useful substantiative data.
(4) Does not establish reliability level.
(5) Does not finally conform to MIL–C–45662B.

7.2 Fixed Interval Through Data

Using attributes data from calibration reports, decisions may be made on the magnitude of lengthening or shortening periodic intervals. There are various forms of evaluation using statistical techniques and decision criteria. An example of an 85% reliability decision table is shown below.

Percent of Instruments Out of Tolerance Incoming to Lab	Present Period Mo.	Change To Mo.		Present Period Mo.	Change To Mo.		Present Period Mo.	Change To Mo.
25% or more	3	1		6	3		12	6
15 to 25%	3	2		6	4		12	9
10 to 15%	3	3		6	6		12	12
5 to 10%	3	4		6	9		12	18
5% or less	3	6		6	12		12	24

In order to utilize a table such as the one shown, the following areas must be investigated:

Use of data which represents only drift through normal use; elimination of data on repaired and damaged items.

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The calibration procedure and test equipment are correct and compatible.

The out of tolerance or failure definition is sound.

The data sample is sufficiently large to warrant meaningful decisions.

The use of collected variables data might be of great assistance in the above investigations. This method of determination usually treats the model and manufacturer as a group. It may also be used by serial number or generic group.

7.2.1 Advantages

(1) Establishes definite reliability level.
(2) Yields useful substantiative data.
(3) May be programmed for ADP.
(4) Conforms to MIL–C–45662B.
(5) Ultimate expense will be low through supported decisions.
(6) Serves large calibration workloads well.

7.2.2 Disadvantages

(1) Initial expense is high.
(2) Inefficient for small samples.
(3) Chronic failing instruments are overlooked.
(4) Requires sophisticated data acquisition and handling.
(5) Requires detailed management.

7.3 Variable or Floating Intervals

This method treats each individual item or instrument separately, by serial number, in one of several ways, for example:

Using ADP or manual history records based on estabilshed reliability criteria, an evaluation is made on the individual item each time it is processed and the date of next calibration is assigned.

—or—

Without regard to history records and specific reliability criteria, each time an individual item is processed and found to be within tolerance, the technician expands the next interval by a certain amount (e.g., increase by one month). If an out of tolerance condition is found, the subsequent period is shortened (e.g., decrease by three months).

7.3.1 Advantages

(1) Highly responsive to needed interval adjustments.
(2) Using history records, it conforms to MIL–C–45662B.
(3) By not using history records, it costs little to operate.

7.3.2 Disadvantages

(1) Overlooks need for immediate technical investigation.
(2) A smoothly controlled calibration workload is difficult to achieve.
(3) By not using the history/reliability method, a definite reliability level would not be known.
(4) Susceptible to subjectivity of individual technician unless carefully monitored.

7.4 Interval By Use Time

This method requires that an elapsed-time indicator or usage tag be installed on the item to be calibrated. After a predetermined "on" time has been reached, the instrument is submitted for calibration. This method of determination usually treats the model and manufacturer as a group. It may also be used either by serial number or by generic group.

7.4.1 Advantages

(1) Frequently used equipment received proportionately more attention than rarely used instumentation.
(2) Permits a constant evaluation of equipment utilization.
(3) Conforms to MIL–C–45662B.
(4) Ultimate expense will be low if average equipment usage is low.

7.4.2 Disadvantages

(1) Usable only when the following conditions are met:

A. Application limited because of need to properly activate elapsed-time indicator.
B. Proof of data on usage rather than on deterioration.
C. Free from "off" time drift.
D. Deterioration to be free from number of "on-off" sequences, loading, handling, etc.

(2) High initial cost.
(3) Easy for user to disconnect timer or run it backwards.
(4) A smoothly controlled calibration workload is difficult to achieve.
(5) High cost of monitoring timers and policing program.

7.5 Interval By In-Use Testing

Critical parameters within instruments are checked frequently (daily, weekly, or monthly) in their use environment using portable calibration equipment. From this, data is collected and statistical analysis made to determine need for a complete calibration of instrument parameters. This method integrates calibration into a quality control function. The in-use testing technique may treat items individually, either by serial number, or by model-manufacturer.

7.5.1 Advantages

(1) Provides any attainable.
(2) Provides useful peripheral data, both attribute.
(3) Conforms to MIL–C–45662B.
(4) Provides maximum availability for user.

7.5.2 Disadvantages

(1) Not practical for calibration workloads geographically separated.

(2) Requires sophisticated data acquisition and handling.

(3) Requires detailed management.

(4) Requires close inventory control to find instrument to be monitored.

(5) Present calibration equipment not completely suitable for portable use.

NCSL 66

SESSION 14: DEVELOPMENT OF RECOMMENDED PRACTICES FOR NCSL

W. R. Holmes, Chairman

General Dynamics, Electric Boat Division, Groton, Connecticut 06340

The session on Recommended Practices was set up in the following manner to illustrate several points. First, to illustrate how another society handled Recommended Practices, we have a presentation by Ralph Clarridge entitled, "The Development of Recommended Practices in the ISA." Second, to illustrate various technical points to be considered when writing a Recommended Practice, Jim Murdock of the Philadelphia Naval Shipyard will accomplish this with his talk, "Effect of Installation on Measurement System Accuracy." Third, I would like to tell you what NCSL is planning* in the area of Recommended Practices.

**Editor's Note:* The 6-page "Proposed Procedure for Generation and Publication of NCSL Recommended Practices" may be obtained from Mr. Holmes.

THE DEVELOPMENT OF RECOMMENDED PRACTICES IN THE ISA

Ralph Clarridge

Vice President Elect, ISA Standards and Practices Dept., IMB Fed. Syst. Div. Huntsville, Ala.

Recommended Practices and Standards have been a major activity within the ISA for twenty years. ISA work in this area has been difficult, time-consuming and sometimes boring to the many participants, but the results are now being recognized as a major ISA contribution to the instrument industry, to manufacturers as well as users. The method of originating and producing these standards will be reviewed along with some of the problems which have been encountered.

I. Introduction

Speaking for the Instrument Society of America, we are happy to participate officially in the Third National Conference of Standards Laboratories. In turn, I am delighted with your interest in the activities of the ISA Standards and Practices Department. Our modest success in this area should encourage NCSL in similar activities, for certainly there are many common procedures which could be documented in the form of Recommended Practices for the benefit of all laboratories.

In this particular connection, I wish to call your attention to two rather active divisions in the Technical Department which might be most useful to the NCSL. These are the Measurement Standards Instrumentation Division under Douglas Strain and the Physical and Mechanical Measurement Instrumentation Division under T. M. Mathison. If either of these groups can serve the NCSL in the field of instrumentation, do not hesitate to call on them.

II. History of the Standards and Practices Activities in the ISA

Let us look back on the instrument industry in the early 1940's. It was composed of many small suppliers, each of whom had certain unique designs which were applicable to limited segments of the instrument market. In addition, even in supplying the same market segment, each manufacturer searched for features which would increase his share of the market. This is a good and sound practice in a competitive market. However, as any market matures, the search for novelty often results in pseudo-advantages which may be grist for the mills of sales promotion but which, in turn, restricts the flexibility and interchangeability of the product. Specifically, in 1940, the instrumentation of any one manufacturer could be interconnected to create a system, but instruments of another manufacturer could not be inserted into that system without modification. At this same time, the large industrial instrument users, particularly those in the oil refining and chemical processing industries moved further toward the large integrated plant. No *one* manufacturer could supply all of the sensors, transmitters, recorders, controllers and valves that were required for any one plant. Instruments of different manufacturers had to be interconnected. A reasonable degree of interchangeability was highly desired.

Concurrently, throughout the country, local groups were forming to discuss these new problems of instrumentation. This local exchange of information helped solve some installation, maintenance, and technician education problems, but it also served to emphasize the need to work with the various manufacturers toward reasonable standards—and with each other—in documenting certain procedures of mutual interest.

It was in this climate that these local groups gathered together to form the Instrument Society of America. It brought together not only a plethora of instrument problems, but also a group of competent technical people with a burning desire to solve the.. This is the reason the ISA has been so active in the standards and practices area and also the reason a good share of our present recommended practices is most useful in the petroleum and chemical processing fields.

In 1946, the ISA Standards and Practices Committee was established with the purpose of preparing and publishing carefully written standards and practices to be available to instrument manufacturers and users in all industries. ISA Recommended Practices were to be prepared only after a thorough industry survey indicated that there was a wide agreement among both users and manufacturers on the need for unified procedures for the use of measurement and control devices, standard terminology, uniform dimensions, conversion constants or safety procedures. If no widespread common agreement or practice could be found in industry, no document would be generated. The ISA has not and does not intend to issue standards and practices which reflect the opinions of only a small portion of the industry, or to attempt to dictate procedures by means of mandatory standards. The formal statement of the goals of the ISA Standards and Practices Department follows:

Purpose

Enhance the instrumentation technology through the preparation of standards and practices which are developed on the consensus principle, are unbiased, widely applicable, and authoritative.

Function

Compile and publish consensuses of technical practices. Provide organizational structure for other related activities: bibliographies, abstracting, referrals, and short courses.

Let us look at some of the Recommended Practices which have been developed through the years. The work on 8D–RP1 – "Thermocouple and Extension Wire Practices," was started in 1948 but it was not until 1959 that its tentative status was removed. Almost immediately work was started on converting this to an American Standard but it was not until 1964, 16 years from the origin of the work, that this became a reality. It is now known as American Standard C96–1–1964, "Temperature Measurement Thermocouples."

Work on 8D–RP2 – "Manometer Tables," started in 1947; the first version was published in 1949 and tentative status was removed in 1952. New information became available from the National Bureau of Standards which was incorporated in a revision issued in 1962. It is interesting to note that Dr. Brombacher of NBS led this committee throughout its life.

In the early forties control valves of the same size from different manufacturers had different face-to-face dimensions. Of course, each manufacturer claimed certain advantages for his particular design. Under the priority and limited supply situation that existed during World War II, valves from one manufacturer were frequently assigned to a site prepared for those of another manufacturer. The situation was most unsatisfactory. In 1947, Committee 8D–RP4 – "Control Valve and ByPass Manifold Installations," was formed and subsequently issued RP4.1, "Uniform Face-to-Face Dimensions for Flanged Control Valve Bodies," in 1950, with the help and cooperation of the Fluid Controls Institute, consisting of the major manufacturers of control valves in the U.S.A. The second RP issued by this committee RP4.2 "Standard Control Valve Manifold Designs for Carbon Steel Valves," was published in 1956 and still retains its tentative status. Now, with improved reliability in control valves and with higher piping and installation costs, this subject is being reviewed again with the probability that a new RP will be issued covering a less costly bypass manifold system.

Another committee 8D–RP12 – "Instruments for Hazardous Locations" has been active since 1950 under the leadership of F. L. Maltby. This committee has six subcommittees which have progressed as follows:

RP12.1, "Electrical Instruments in Hazardous Atmospheres," with a tentative practice published in 1960;

RP12.2, "Instrinsic Safety for Electrical Instruments," with a tentative practice published in 1965;

RP12.3, "Explosion-Proof Electrical Instruments" which has not yet progressed to the point of publication;

RP12.4, "Instrument Purging for Reduction of Hazardous Area Classification," with a tentative practice published in 1960;

RP12.5, "Sealing and Immersion Standards for Electrical Instruments" which has not yet been published;

RP12.6, "Wiring Practices for Hazardous Area Instrumentation," which is not yet ready for publication;

RP12.7, "Electrical Safety in Dusty Atmospheres" (new);

RP12.8, "Area Classifications" (new);

RP12.9, "Flame Arrestors" (new).

In 1958, this committee prepared a source book entitled, "Electrical Safety Abstracts;" the volume was revised and expanded in 1960. Over the years, RP12 has been one of the most active and best documented committees in the history of the standards and practices program.

Committee 8D–RP16 – "Variable Area Meters" formed in 1954 had the same problem experienced by 8DRP4. There were (and are) three major manufacturers of rotameters in the USA, and each had his own terminology and dimensions. Eventually, by a rather unusual technique, a method was found for resolving their differences and the following were published between 1958 and 1961.

RP16.1, 16.2, 16.3, "Terminology, Dimension, and Safety Practices for Indicating Variable Area Meters (Glass Tube, Metal Tube, and Extension Glass Tube Types),"

RP16.4, "Nomenclature and Terminology for Extension Type Variable Area Meters (Rotameters),"

RP16.5, "Installation, Operation, and Maintenance Instructions for Glass Tube Variable Area Meters (Rotameters),"

RP16.6, "Methods and Equipment for Calibration of Variable Area Meters (Rotameters)."

All of these RP's are still in tentative status.

Other areas in which the I.S.A Standards and Practices Department has made major contributions to both the instrument user as well as the manufacturer is in Dynamic Response Testing, Turbine-Type Flow Transducers and Transducers for Aerospace Testing.

There are several reasons for detailing the older recommended practices which have been developed by the I.S.A. Note first, that they are quite diverse, varying from rather precise physical constants (e.g., thermocouple and manometer tables) to dimensions of selected hardware (control valves and rotameters) and on to guidelines used in dynamic response testing. Note also that with few exceptions there has been no attempt to duplicate or incorporate standards developed by other recognized authorities even though these are rather closely related to instrumentation. For example, A.S.M.E.'s Power Test Code has several sections devoted to measuring instruments, and the A.S.T.M. specifications cover many laboratory instruments.

Another point that should be observed is that the development of recommended practices (and standards) is long and tedious. Sixteen years were required to get an American Standard on thermocouples, and even then, the committee did not start from ground zero. It took fifteen years for 8DRP12 to produce an I.S.A. recommended practice on intrinsic safety and there is more work to be done on this particular item. It is also true that some committees were able to complete their work in two or three years but it appears that these are exceptions.

At this time it might be emphasized that all committees of the ISA Standards and Practices Department have not been successful in their work. Referring to Figure 1, ISA Recommended Practices Projects, only 50% of the committees formed through the years have produced or are working actively on recommended practices. Note the cancellations and consolidations. Here are the reasons for the situation as I see it: 1) some subjects selected were of passing interest to the instrument industry or were trivial from the long range viewpoint; 2) some subjects were so involved that the committee was overwhelmed by the job to be done and abandoned all hope; 3) in several cases work in other societies led to the abandonment of a project; and 4) on occasion, the death or reassignment of a dynamic committee chairman has terminated a project.

Here are some of the *milestones in the Department's history:*

First ISA RP Committee Formed..............	1946
First ISA RP Published..........................	1948
Organized ISA Standards and Practices Department....................................	1956
First ISA Standards Bibliography Published (Electrical Safety)............................	1959
First Compilation of ISA RP's Published...	1963
First ISA Short Course Related to Standards Held (Electrical Safety)......................	1964

III. Source Material for ISA Recommended Practices

Ideas come from individuals and ideas are usually generated "where the shoe pinches." Each of us follow certain practices in our daily lives both at home and at work. However, it is only when life becomes a bit uncomfortable and is beyond one's personal control to change, that one thinks of "standards." In any event, "when the shoe pinches" we usually speak out, and if the pinch is in instrumentation and control, the proper place to speak out is within the ISA. Sometimes this is in the form of a paper in which an individual lists the problems which would have been avoided or time which would have been saved if a standard or practice had been available to guide him. In other cases, he has pointed out the merit of accumulating and presenting data in a standard format to make comparisons by subsequent investigators easy and meaningful.

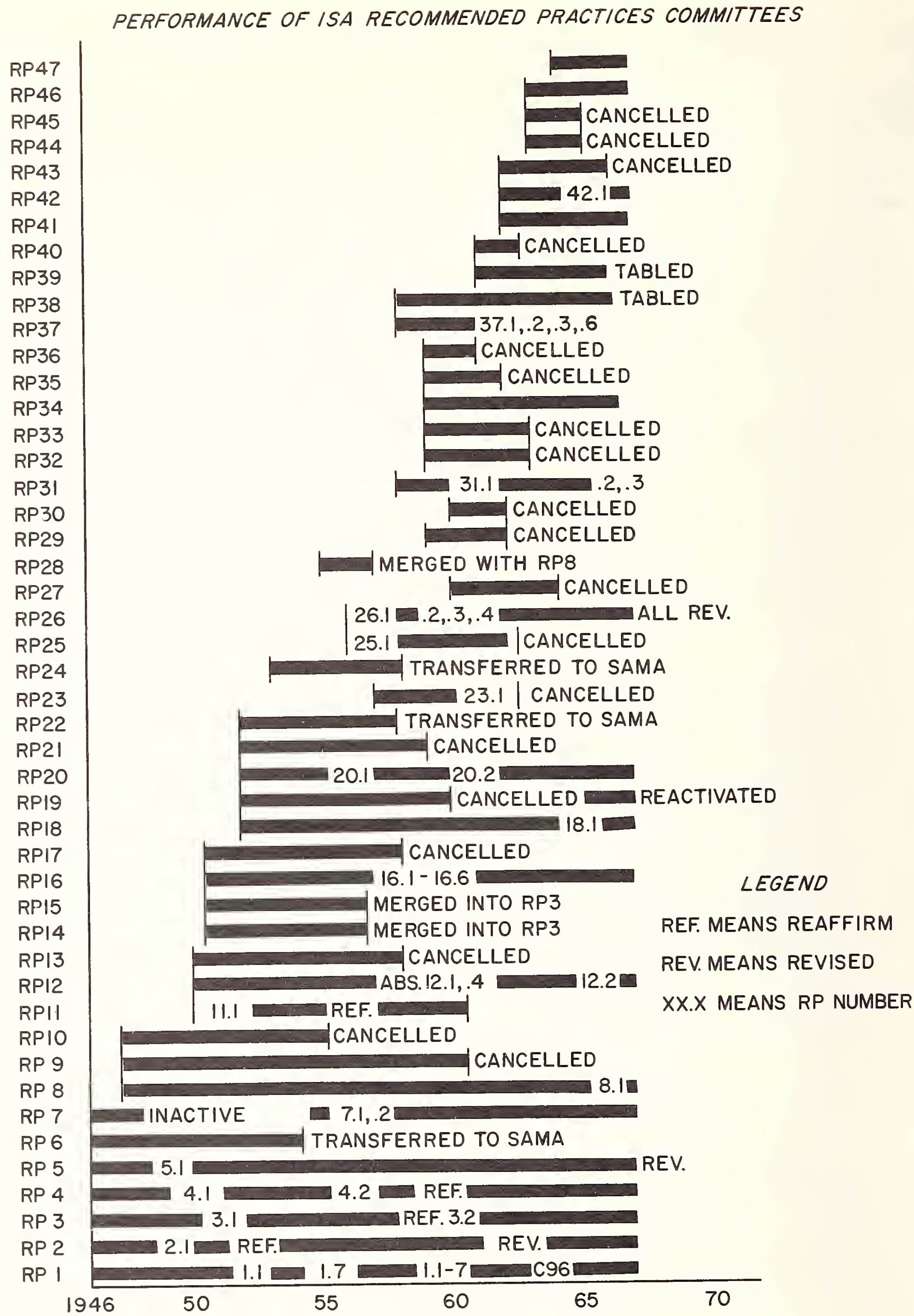
Other sources are the working committees of the ISA Technical and Industry Departments who find that in order to communicate reasonably and to move ahead responsively in their respective fields, an accepted framework of terms and standardized dimensions are necessary. I suspect that I would not be here talking to you today if MESTIND and the NCSL did not recognize the desirability of certain standards or accepted practices which will make progress a little easier.

A final source is the panel discussion in which selected individuals, usually eminent in their respective fields, present their ideas hoping to stimulate a creative response from the audience. Frankly, with few exceptions, I believe this is a barren activity first because it is hard to get more than a handful of individuals to attend a standards and practices meeting (if there is anything else to do) and second, few of those who attend really have a "shoe that pinches."

IV. The Development of an ISA Recommended Practice

When an idea for a standard or a recommended practice is proposed to the Standards and Practices Board, it is tested. The testing is quite flexible and depends, of course, on the competence and experience of the source. For example, a working technical committee could be expected to know of existing or related standards or standards activities in other societies, while this probably would not be true of an individual. In any event, here are the questions which must be properly answered before work is authorized by the Standards and Practices Board.

1. Is there an existing or closely related standard?
2. Is another society or group actively working in this technical area?


PERFORMANCE OF ISA RECOMMENDED PRACTICES COMMITTEES
RP47
RP46
RP45 CANCELLED
RP44 CANCELLED
RP43 CANCELLED
RP42 42.1
RP41
RP40 CANCELLED
RP39 TABLED
RP38 TABLED
RP37 37.1,.2,.3,.6
RP36 CANCELLED
RP35 CANCELLED
RP34
RP33 CANCELLED
RP32 CANCELLED
RP31 31.1 .2,.3
RP30 CANCELLED
RP29 CANCELLED
RP28 MERGED WITH RP8
RP27 CANCELLED
RP26 26.1 .2,.3,.4 ALL REV.
RP25 25.1 CANCELLED
RP24 TRANSFERRED TO SAMA
RP23 23.1 CANCELLED
RP22 TRANSFERRED TO SAMA
RP21 CANCELLED
RP20 20.1 20.2
RP19 CANCELLED REACTIVATED
RP18 18.1
RP17 CANCELLED
RP16 16.1 - 16.6
RP15 MERGED INTO RP3
RP14 MERGED INTO RP3
RP13 CANCELLED
RP12 ABS. 12.1, .4 12.2
RP11 11.1 REF.
RP10 CANCELLED
RP 9 CANCELLED
RP 8 8.1
RP 7 INACTIVE 7.1,.2
RP 6 TRANSFERRED TO SAMA
RP 5 5.1 REV.
RP 4 4.1 4.2 REF.
RP 3 3.1 REF. 3.2
RP 2 2.1 REF. REV.
RP 1 1.1 1.7 1.1-7 C96
1946 50 55 60 65 70
LEGEND
REF. MEANS REAFFIRM
REV. MEANS REVISED
XX.X MEANS RP NUMBER

3. Does the ISA have competence in this particular area or is another society or group better equipped to do this work?

4. Is the idea suitable for an I.S.A. Recommended Practice? (e.g., Is it well enough defined? Is the timing right? Will it be of permanent value? Is it in the field of measurement and control?)

5. Is a competent committee chairman available?

6. Can the committee be staffed with competent people?

When the answers to these questions are affirmative, a survey committee is formed and individuals in various industries throughout the country are queried on the possible value of such a recommended practice and the scope it should cover. Every effort is made to get opinions from an adequate sample of knowledgeable people. The survey chairman is assisted not only by the I.S.A. headquarters staff, but also by the Section Standards Representatives who are located throughout the country. Not infrequently the scope of the activity is broadened or altered by the response. When the consensus of the response is favorable, a Standards and Practices Committee is formed. Usually the chairman of the survey committee becomes the RP Chairman and the working committee members are selected on the bases of enthusiasm, competence and geographic location. Committees are expected to meet each month during the organizing and working period and at least once each quarter as the Recommended Practice is being assembled. Corresponding memberships are available for those who can contribute to the effort yet cannot attend every meeting. A Review Board, consisting of those who cannot work on the Recommended Practice and yet are knowledgeable in the field, is used to pick up errors and oversights when the first acceptable copy of the work is available. With this procedure, the final approval of a Recommended Practice by the Standards and Practices Board is little more than a formality. When this has been given, the RP is published in a "tentative" status, and periodically thereafter is reaffirmed or revised. Past experience shows that three man-years are needed for RP development. This period is equivalent to 12 men working 1-1/2 days per month for 5 years. The structure of the Standards and Practices Department in the national organization is indicated below:

ISA STANDARDS AND PRACTICES

National Organization

Standards and Practices Board:

- Department Vice President
- Department Vice-President-elect
- Standards and Practices Directors
- Board Secretary

Recommended Practices Committees and Liaison Representatives with
- ISA Districts and Sections,
- ISA Divisions,
- Other Technical Societies,
- Trade Associations,
- American Standards Association.

RP Committee Structure:

- Committee Chairmen
- Subcommittee Chairmen
- Local Members
- Corresponding Members

Boards of Review

V. Problems Encountered

Possibly you will be interested in some of the problems which have been encountered through the years. Some will be with us always; others have been solved by written guidelines stimulated by some unexpected experience.

Of course, the major problem is the RP Committee Chairman! The usual response to one of these situations where the "shoe pinches" is the burning desire to get a document or guideline *now*, not six months or a year from now. The novice cannot conceive of it taking one, two or even five years to create a good acceptable recommended practice. So this problem has been one of keeping his interest and enthusiasm through the seemingly interminable delays which are associated with a voluntary project.

The second problem was one of providing proper instructions for the chairman and the committee as a whole on procedures. The I.S.A. is, after all, a young society and there were no rules or guidelines in 1945. While procedures are never static in a growing organization, it is our opinion that this problem has been substantially solved.

I.S.A. meetings are open to the public and all interested individuals are urged to attend. For a long while this also applied to meetings of the various Recommended Practices Committees and the S & P Board. We were not concerned if members of the technical press were present and we did not request that the material not be released. This proved to be a bad practice, however, for the headquarters staff and the I.S.A. Executive Board did not like to see committee work summarized weeks and even months before the edited and corrected documents could be made available from Pittsburgh.

Occasionally, when a Recommended Practice is badly needed, a committeeman has accepted an invitation from a section or a division to talk on the subject material related to the Practice being developed. Of course, the I.S.A. does not wish to restrict such activity as long as the individual covers only his own work and contributions. But since it is almost impossible for an individual who has actively worked on a committee to restrict his remarks to his own work, in the discussion period if not in the paper, this practice is discouraged. The Standards and Practices Board strongly urges all committee members to defer such presentations until the Recommended Practice is published so that each contributor can be properly recognized.

Another problem which we have faced is the desire of enthusiastic I.S.A. members to "take over" or lead *every* project involving instrumentation. This is a natural urge in view of the name of the society and its relative youth. We, of course, have found that it is best to restrict our efforts to those projects which, through our membership, we are equipped to do well. In areas in which we believe the I.S.A. has an interest and can make a contribution, we provide liaison members to other technical groups and societies. In addition, I am pleased to say that in areas which were well developed before the I.S.A. existed or in areas in which a competent contributor cannot be found in the I.S.A. membership, we have declined participation even though some phase of measurement or instrumentation was involved.

VI. Conclusion

It is my hope that this review of the I.S.A. Standards and Practices activity will be encouraging to the N.C.S.L., and lead to a similar documentation of accepted practices which will be useful to all standards laboratories. Furthermore, if the I.S.A., or any of its committees can assist with this work, we will do our best to help.

EFFECT OF INSTALLATION ON MEASUREMENT SYSTEM ACCURACY

J. W. Murdock*

The two basic sources of measurement system error are (a) those inherent in the system itself and (b) those resulting from the use of the system. This paper discusses the latter, and concerns itself with the output of a measuring system that is error-free with respect to what its primary element actually senses. The necessity for an individual installation analysis to minimize errors is discussed. The following sources of errors stemming from use are illustrated—(a) installation of primary element, (b) location of primary element, (c) sampling, (d) effects of other variables, and (e) fluctuations of the variable being measured.

Introduction

What is an instrument?

In 1963, the Instrument Society of America published its Transducer Compendium listing 1,227 model series covering 37,700 individual transducers. This was based on the response of 230 manufacturers out of the 5,500 known manufacturers of instruments. Many of these transducers cannot, without additional components, make a measurement. To avoid, as much as possible, the confused state of today's instrument terminology, let's consider what is necessary to make a measurement. First, the variable must be "sensed," second, the effect produced by this sensing must be transmitted in some kind of device that communicates the results, i.e., indicates, transmits, records, controls, signals, or automates. Thus, in order to make a measurement, a system such as that shown in figure 1 must be used.

The primary element is that part of the system that first senses the variable to be measured. The energy change produced by this sensing must be transmitted to the communicating unit where it may be used directly or may be changed (transduced) to some other form in order to indicate, record, or signal. The energy signal may also be sent on to other components of a control or automation system. In some systems, the communicating unit may be very complex and consist of many parts, but all measuring systems must contain at least the 3 shown in figure 1.

A simple and well known measuring system is the liquid-in-glass thermometer as shown in Figure 2.

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The opinions and assertions of this paper are the private ones of the author and are not to be construed as official or reflecting the views of the Navy Department or the Naval Establishment at large.

Measurement Errors

Measurement of a variable never gives a result which is correct in the absolute sense. The numerical value determined also differs by some amount from the true value of the variable being measured. The amount of the deviation depends on the type of measuring system employed and upon the application on which it is used. This fact imposes upon instrument application engineers the duty of studying measuring systems and their applications to the extent that they can demonstrate, for a given case, that they have provided instrumentation to meet the degree of accuracy required for the purpose of the application.

The accuracy containable for a given measurement is dependent upon the following:

a. The method of applying the measurement system

b. The accuracy of the system itself

c. The accuracy of the observer and/or the readability of the scale or record

d. The characteristics of the variable being measured.

The above breaks down into two radically different considerations, both of which are of equal importance. These may be designated as:

a. *Intrinsic accuracy* of the measuring system

b. The *accuracy* resulting from *conditions of use.*

The former is generally well treated by most engineers and data should be available for prediction. The latter is the most neglected, least understood and may be responsible for measurement errors of several orders of magnitude of that of the intrinsic accuracy of the measurement system. The reason for the neglection of the latter is that an individual analysis must be made for each application and installation.

Accuracy in Use

This paper is concerned with the output of a measuring system that is error free with respect to what its primary element actually senses. In other words, neither the primary element, the transmitting apparatus, or the communicating unit contribute to any errors. This idealized condition can be approached in practice by the calibration of the measurement system. While errors can result from the method of installation of the transmitting apparatus in some cases, these will not be considered in this paper.

With the error-free assumptions discussed above, the following sources of errors stemming from use must be considered:

a. Installation of the primary element
b. Location of the primary element
c. Sampling
d. Effects of other variables
e. Fluctuations of the variable being measured.

Examples

The following examples were chosen to illustrate some of the basic problems involved in the application and use of measurement systems. They are far from all inclusive and each installation must be analyzed as a separate problem.

a. *Installation of the Primary Element*

When the temperature of a fluid flowing in a pipe under pressure is to be measured, it is often necessary to encase the primary element in a protection tube or socket as shown in Figure 3. The following temperatures must then be considered:

1. The temperature of the gas
2. The temperature of the wall of the pipe
3. The socket temperatures
4. Ambient temperature

The indicated temperature of the measuring system is none of these temperatures. A heat transfer study is necessary to estimate the true temperature; the factors involved are:

1. The physical properties of the fluid and materials
2. The net heat transfer by radiation, conduction and convection from the well to the fluid, and to the pipe wall and to the primary element.
3. The velocity of the fluid. When the fluid is a gas, the difference between static and stagnation temperature may be appreciable at velocities above 300 feet per second.

b. *Location of Primary Element*

Figure 4 illustrates the effect of placing a flow primary element too close to an elbow. The primary element now receives a different velocity profile than the one it received when calibrated and consequently an error is produced.

c. *Sampling*

Figure 5 illustrates a very poor method of sampling a steam water mixture flowing in a pipe. This does, however, show very clearly the basic problem.

d. *Effects of other Variables*

Consider a conductivity apparatus used as a carbon-dioxide indicator for boiler flue gas. This device is not selective and can indicate CO_2 correctly only if the right amounts of nitrogen, oxygen, etc. are present. If such a device were used to indicate CO_2 content of air CO_2 mixture, very large errors would result because the primary element senses only thermal conductivity, not composition.

e. *Fluctuations of the Variable Being Measured*

Measuring systems are calibrated under steady conditions. When the variable measured is not under a steady condition, as illustrated in Figure 6, dynamic error will result.

Summary

It is important to note that all errors discussed are *uni-directional*, they do not affect the precision (Figure 7) of the system.

Most of the errors cited above cannot be avoided but their effects can be minimized by intelligent selection and analysis.

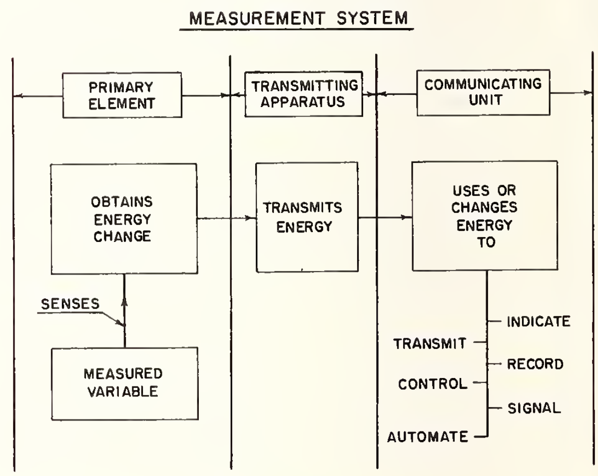

FIGURE 1. *Measurement system.*

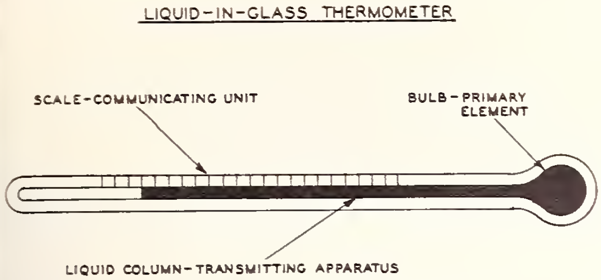

FIGURE 2. *Mercury-in-glass thermometer.*

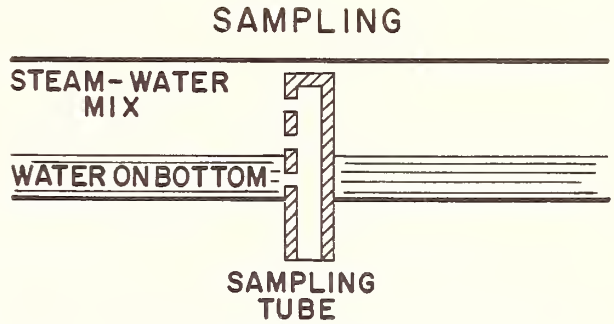

FIGURE 5. *Sampling.*

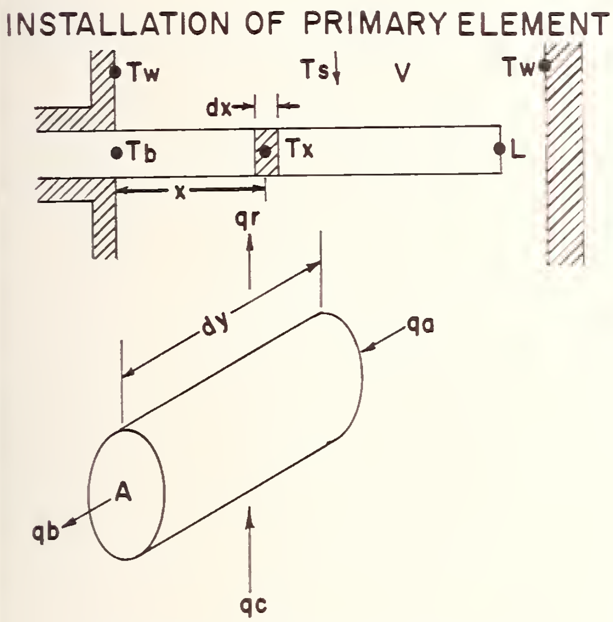

FIGURE 3. *Installation of primary element.*

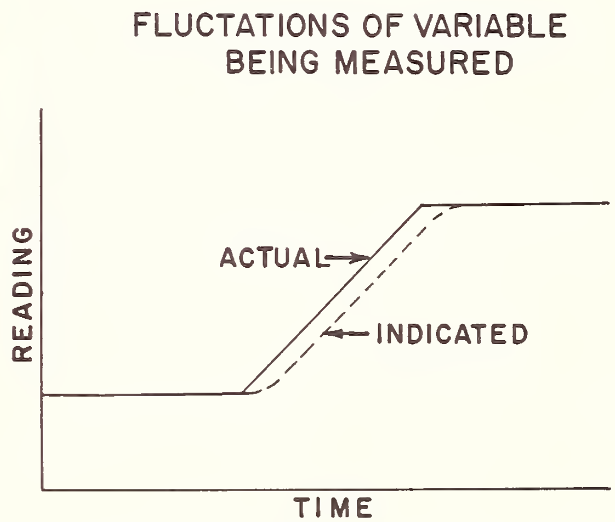

FIGURE 6. *Fluctuations of variable being measured.*

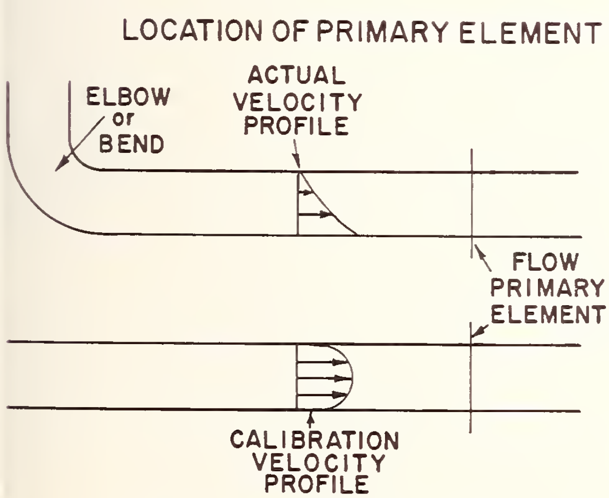

FIGURE 4. *Location of primary element.*

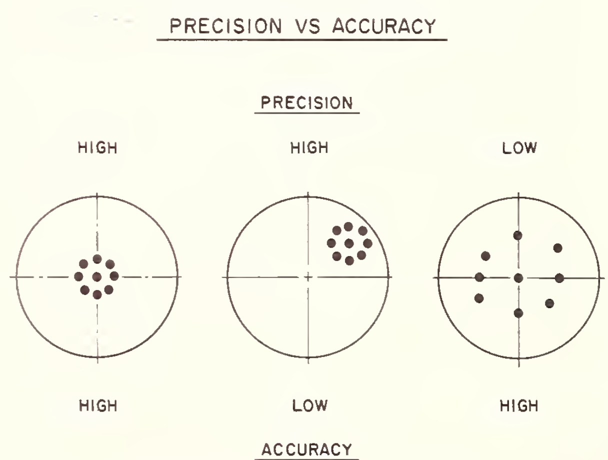

FIGURE 7. *Precision versus accuracy.*

RECOMMENDED STANDARDS AND PRACTICES

W. R. Holmes

The aim of the NCSL Committee on Recommended Standards and Practices for NCSL is to compile a manual which will be a guide book on operational management for those interested in Standard Laboratories—whether they be novices, operational laboratory personnel, or only interested in understanding or dealing with Standard Laboratories. The object of a Manual of Recommended Standards and Practices is to:

"Enhance the instrumentation technology by preparing and promoting recommended standards and practices which are competent, unbiased, widely applicable, and authoritative."

The program, when reduced to its least common denominator, is one of attaining general agreement. Its objectives, the development of Recommended Standards and Practices, are those which reflect common areas of agreement among Standard Laboratories and throughout the instrumentation industries. The establishment of recommended standards and practices for operation is the "mark of maturity" in a professional society. Once established it is necessary to assess and re-establish goals and examine procedures periodically.

Paradoxically, we in the standards business have not yet formulated a generally agreed upon set of standard practices for our own work. Practices are necessary for a Standards Laboratory: to provide a guide for those who want to start a Standards Laboratory, or for those who want to improve the operation of an existing Standards Laboratory. Moreover, individual Standards Laboratories, no matter how good they are, cannot be isolated from the general technical community of which they are a part. A Standards Laboratory must strive to achieve a uniformly accurate and compatible system of measurements not only in its own organization but with the organization's customers, vendors, and subcontractors. Accomplishing this involves having a nationally compatible system of measurements and standards.

Recommended Practices serve the very definite role of informing NCSL members, instrument users and manufacturers and Standards Laboratories about the present consensus in the areas of terminology, calibration, test and approved procedures, dimension, fabrication, installation and maintenance methods. During the development of Recommended Practices, communication is a vital necessity in order that all requirements for their validity will be met. After the need for a given Practice is established, it is necessary to define the scope of the Practice, obtain qualified technical people to develop it, and find still others capable of reviewing the work before publication. Publicity and circulation of the published practice are necessary in order to obtain the continuing review and comments which are the basis for further improvement. Exchange of information and opinions is vital to all group activities. If these activities are to accomplish the goals set before them, their communication must be effective. The task of creating new channels of communication, maintaining clarity within them, and assuring that all parties are kept as informed as they should is ever present.

Recommended Practices represents a particularly important contribution of the long-term growth of NCSL and is one of the project areas which will provide lasting contributions. It should be remembered, as I will stress again, a high level technical background, painstaking attention to detail, and patient reconciliation of many conflicting viewpoints are needed in this work. The contents of Recommended Practices will reflect the work of many people and will constitute a substantial cross-section of persons active in Standards Laboratories work. We hope that this handbook will be one of a series of steps which will eventually transform a variety of material from a variety of sources into a manual of approved recommended practices for standards laboratories.

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NATIONAL CONFERENCE OF STANDARDS LABORATORIES

ANNUAL REPORT OF THE CHAIRMAN OCTOBER 1965 TO OCTOBER 1966

J. R. Van de Houten

Membership

The membership continued to increase during 1966. As of September 30, 1966 there were 146 paid members (153 as of January 10, 1967). Only two organizations declared they would not continue their membership. A current list of members and member delegates is included as Appendix B.*

Finances

At the end of the year the treasury had a surplus of $21,057.59, an increase of $5,652.38 over the previous year end total. As a carry over from the previous year's operation, the books were closed on the August, 1965 Disneyland Workshop with a surplus of $707.18 and the May 1965 Columbus Workshop with a deficit of $37.21. The Gaithersburg Conference added $2,724.82: income from membership and interest on savings exceeded operating expenses by $2,257.59.

Financial statements summarizing the income and expenses during the year and a detailed summary of the Gaithersburg Conference expenses are included in Appendices C and D.

During the year the Board of Directors officially established NCSL's fiscal year as July 1 through June 30 to coincide with the membership year.

Liaison Delegates

Liaison has been established with a number of organizations whose interests are closely allied with those of NCSL. It is NCSL's intent to cooperate as closely as possible with all such organizations and to avoid duplication of effort. The liaison delegate is NCSL's primary means of communication with these groups.

Official liaison was established with two additional technical societies during the year and liaison delegates were appointed. These were the Institute of Environmental Sciences and the Precision Measurement Association.

A significant extension of the liaison concept resulted in the invitation and subsequent designation of two liaison delegates representing other countries: the British Calibration Service and Canada's Department of National Defence. It was recognized that a close relationship exists among standards laboratories throughout the world and that improved communication is essential. The common interests were apparent to those who attended the Gaithersburg meeting. All were captivated by the interest and friendliness of the representatives from other countries and the session on the "Unification of Industrial Measurements in Other Countries" was a highlight. Preliminary discussions were held by the Board of Directors and the Organization Committee on establishing an even more appropriate and active relationship by establishing a category of membership for foreign affiliates.

A complete list of liaison affiilations is included as Appendix E.

Committee Functions

Based on recommendations made by the Organization Committee the Board of Directors approved the establishment of 24 committees at the beginning of the elective year. Subsequently, a committee on "Procurement Regulations" was established in March 1966. A complete list of these committees and their functions is included as Appendix F.

Committee Membership

The committee chairmen and those committee members officially appointed by the NCSL Chairman are listed in Appendix G. In some cases persons not listed acted as unofficial members of the committee upon request of the committee chairman and materially contributed to the effectiveness of the committees.

It is noted that the By-Laws limit the chairmanship of committees under normal conditions to Members, Sponsors, or Liaison Delegates. However, any person, regardless or organizational membership, who can materially contribute to committee activities can be appointed to serve as a committee member.

*Editor's Note: The appendices cited were included in the original distribution of the annual report to NCSL Member Delegates, 10 Jan. 1967. Members may obtain additional copies from The National Conference of Standards Laboratories, c/o National Bureau of Standards (200.00), Washington, D.C. 20234.

Changes to By-Laws

During the year, the most significant change to the NCSL By-Laws was an increase in the number and length of term of the Vice Chairmen. Beginning with the newly elected officers for 1967 there will be four Vice Chairmen who will be elected for two-year terms. Initially, two will be elected for a one-year term to permit staggered terms of office. The Board of Directors will elect one of the Vice Chairmen to serve as First Vice Chairman. Besides providing active experience to more member delegates, this will assist the Chairman in long-range planning and in coordinating the work of the various NCSL committees.

The By-Laws had been amended earlier in the year to allow the Chairman to delegate certain coordination responsibilities to the various NCSL Directors.

National Measurement Standards Week

The greatest personal disappointment during the year was the failure to have Congress designate a National Measurement Standards Week to coincide with the dedication of NBS's new Gaithersburg facilities. Congressman George P. Miller introduced a joint resolution into Congress, however the House Committee on the Judiciary failed to act on H.J. Res 1247. Nevertheless, considerable interest and publicity were achieved. Most important, the groundwork has been laid for a future effort. The idea is an excellent one which would greatly benefit all persons involved with measurement standards. I sincerely hope another effort will be made by NCSL in the near future and that a campaign to take advantage of such a week can be planned by all standards laboratories and manufacturers of measurement equipment.

NCSL Secretariat

Based on a request from the NCSL Chairman, NBS has agreed to provide administrative assistance to NCSL. Specific items covered in the Memorandum of Agreement signed by Dr. A. V. Astin for NBS and J. R. Van de Houten for NCSL were:

1. Permit NCSL to use as a mailing address the following: "National Conference of Standards Laboratories, c/o National Bureau of Standards (200.00), Washington, D.C. 20234."

2. Accept and forward, or handle as requested, correspondence and communications received for NCSL.

3. Accept and deposit checks payable to NCSL and provide the Treasurer with periodic reports on checks received and deposited.

4. Maintain a list of NCSL member organizations, member's delegates, officers and committees, on the basis of information provided by NCSL officers.

5. Assist in preparation and mailing of NCSL literature or correspondence at the request of NCSL officers or committee chairmen, within such limits as may be agreed upon from time to time with the NCSL Chairman or Board of Directors.

6. Maintain the archival records of NCSL and store stocks of active documents for NCSL distribution.

Printing and mailing costs will be borne by NCSL for these items.

It is indeed fortunate that the services of an organization such as NBS are available. Thus, a gradual transition is possible towards the day when the establishment of an official full-time NCSL office and staff is required. In the meantime it will simplify means for all interested persons to obtain information.

NCSL and the National Measurement System

The concept of a National Measurement System being developed by Dr. R. D. Huntoon and the National Bureau of Standards is not only a fascinating but an extremely important one. Anyone in the measurement field should not only read Dr. Huntoon's presentations (see the Conference Proceedings) but should also study them several times, so that he may be able to intuitively apply portions of this concept to day-to-day activities.

The scope of the National Measurement System and the difficulties in any one group evaluating its many elements was recognized. In a memo to the NCSL Chairman, dated May 6, 1966, Dr. Huntoon and Mr. W. A. Wildhack of NBS suggested that NCSL examine the "Role of an NCSL Laboratory in the National Measurement System." The first response to this request was coordinated by Lloyd Wilson of Sperry Gyroscope and NCSL Corresponding Secretary. Copies of Dr. Huntoon's memo were submitted to a number of the committee chairmen who in turn responded for their committees. These were collected in a preliminary report to the Board of Directors by Mr. Wilson.

A full report on this activity is scheduled for presentation during the American Ordnance Association, Standards and Metrology Division, Annual Meeting scheduled for April 12 and 13, 1967 at the NBS Gaithersburg Laboratories.

Recommended Practices

It is my firm belief that the field of Measurement Standards needs improved methods for establishing and agreeing on the best administrative and technical methods to be used. By the preparation of Recommended Practices, together with Tentative Recommended Practices and preliminary reports, NCSL can be of great assistance to all members. Recommended Practices, methods, etc. already prepared by other organizations must be utilized to the greatest extent possible. This coincidentally provides a long-range program and measure of goal attainment for the NCSL committees.

The Conference Proceedings contain a report by Bill Holmes, General Dynamics/Electric Boat Division, Chairman of the Recommended Practices Committee. Most notable of his accomplishments has been the establishment of a definitive step-by-step program, including format requirements, for the preparation and publication of NCSL Recommended Practices. The program outline is included as Appendix H.

Significantly, the first two drafts of Recommended Practices were submitted to the Recommended Practices Committee during October by the Workload Control Committee. These cover the establishment and adjustment of calibration interval and operation of an instrument control system.

Long-Range Planning

In May, the Vice-Chairman, Orval Linebrink of Battelle Memorial Institute, was requested to evaluate the assets of NCSL and develop a long-range planning program. In the few months available, several interesting suggestions were submitted. The interim report submitted to the Chairman recommended that NCSL should consider future action to:

1. Better acquaint the general public with the general role and importance of measurements on our present and future technology.
2. Promote, through all levels of the schools, interest and understanding of the challenges and rewards in the field of metrology and standards.
3. Analyze the potential need and the steps necessary for establishing a permanent NCSL office staffed by an Executive Secretary.

This long-range planning is continuing and for years should be a major contributing factor in establishing those long-range goals and programs needed for NCSL's greatest effectiveness.

Future Meetings

The Board of Directors endorsed the general recommendations submitted by A. J. Woodington, Chairman of the NCSL Program Committee:

1. To continue sponsoring a Standards Laboratory Conference every two years. The next one is to be held in 1968.
2. During the alternate years, at least two smaller meetings, such as past workshops, would be held. The locations of these would be selected on a geographic basis so that extensive travel would be minimized.
3. NCSL will continue to cooperate with other organizations in programming meetings, such as has been done with ISA. In particular, the various committees will be encouraged to participate in such meetings.
4. Other organizations will be requested to participate and assist NCSL in the alternate-year meetings.

Calibration Procedures Library

The Calibration Procedures Library, with Don DeLauer of Vandenberg AFB as chairman, continues to be one of the most beneficial services offered by NCSL. A detailed report on this operation is included in the Conference Proceedings, but since the CPL is our principal expenditure, it warrants more than casual mention.

Most of the present 72 members have been actively taking advantage of the 22,648 line entries in the library. Although there are redundant and inadequate procedures, collectively they represent an abundance of pooled knowledge. Newly developed calibration techniques (and even some old ones), instead of being proprietary to a few individuals, are made available for the benefit of all members —they should prove invaluable to any organization preparing calibration procedures for its own use. At Aerojet, for example, we have found many uses for these documents, and their use has resulted in an approved and validated cost reduction of $20,686 for 1966. And we now have more and better procedures than would have been possible otherwise. Other organizations have realized comparable savings, which more than offsets the cost of NCSL of $5,205.68 and to the Air Force for their generous assistance and use of their facilities. Improvements are still necessary, of course, and are continually being made in several areas.

To help offset the expense of the library to the NCSL, and in recognition of the cost savings to them resulting therefrom, the Navy is providing financial assistance through NBS. At the same time, NCSL has agreed to evaluate ways of improving the services provided and to take steps to make the library self-sustaining. The final report of this evaluation is due in June 1967.

ISA MESTIND

The close ties between NCSL and the Measurement Standards Instrumentation Division (MESTIND) of the Instrument Society of America were again apparent during the 21st Annual ISA Conference and Exhibit in New York last October. NCSL accepted MESTIND's invitation to assist in the programming of two sessions. One session, "Audit Package Results," was jointly programmed with MESTIND and the other, "NCSL Activities Report," was programmed by NCSL. Shel Richardson, General Electric, Schenectady, and an NCSL Director, acted as program chairman for NCSL. And as Chairman of NCSL's Measurement Comparison Committee he was also active in the presentation.

As has been our custom, a Board of Director's Meeting was scheduled for that week and was, in fact, selected as the time to officially turn over the reins to the new Board of Directors.

The new NCSL officers and Board of Directors for 1967 officially assumed office on Oct. 25, 1966. Their names, mailing addresses, and telephone numbers are listed below:

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