NBS TECHNICAL NOTE 930

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

# A Measurement Assurance Program for Electric Energy

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

[2] Located at Boulder, Colorado 80302.

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Issued September 1976

National Bureau of Standards Technical Note 930
Nat. Bur. Stand. (U.S.), Tech. Note 930, 23 pages (Sept. 1976)
CODEN: NBTNAE

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1976

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.46:930). Stock No. 003-003- Price 55 cents
(Add 25 percent additional for other than U.S. mailing).

# A MEASUREMENT ASSURANCE PROGRAM FOR ELECTRIC ENERGY

N. M. Oldham

A Measurement Assurance Program for Electric Energy is described which enables a meter laboratory to evaluate the accuracy of its calibration process relative to the legal unit of energy maintained by the National Bureau of Standards. A laboratory participating in this program periodically determines its process offset by testing an NBS transport standard as part of its regular workload (using the same procedures used to test its working standards). Subsequent monitoring and tests for local control can improve the reliability and assure the adequacy of the participant's calibration process.

Key Words: Electric energy; electricity; electric power; measurement assurance; transport standard; watthour meter.

## 1. Introduction

The National Bureau of Standards is charged with the responsibility of establishing and maintaining the national, legal unit of electric energy at power frequencies. The unit is disseminated by NBS through a watthour meter (Whm) calibration service and traditionally meter laboratories that use this service have sent their standard Whms to the Bureau for calibration. Most of these laboratories maintain the unit with one or more reference standard Whms which are used to calibrate their working standards. These fall into two groups:

A. Standards that are used at the meter laboratory to test industrial and residential type Whms before they are put into service for billing purposes.

B. Standards that are used in the field to test Whms that are already in service.

The accurate calibration of these meters is therefore the principal function of most meter laboratories. Those who tie directly to the legal units by shipping their reference standards to NBS run the risk of having undetected systematic errors in their calibration process due to changes in the standards during shipment or to peculiarities in the on-site test conditions. To avoid this each laboratory is thus faced with devising a program to prove that the standards did not change during shipment and that local test conditions introduce negligible uncertainties.

A new NBS calibration service greatly relieves the user of this responsibility by providing a transport standard whose value and uncertainty at the time of use by the laboratory have been carefully determined. By carrying out the transfer of the unit on-site with the procedures used for its regular workload, statements can be made about the uncertainty of its regular measurements. When this is accompanied by a program of continuing surveillance of the workload by remeasuring a set of working standards one has assurance of the validity of the uncertainty statements.

This effort to demonstrate that the measurement process is in a state of control has been given the name Measurement Assurance Program. The laboratories who set up such a program can not only demonstrate the adequacy of their measurement effort but also have the means for evaluating the effect of improvements to the process.

## 2. New Calibration Service

NBS now offers a new kind of calibration service which is designed to reduce uncertainties and provide customers with improved measurement reliability. It is based on similar services presently available in such areas as voltage and resistance which use NBS-owned transport standards to disseminate the units. The transport standard (in this case a standard watthour meter) is shipped to a participating laboratory where it is tested as an unknown using the same equipment and techniques normally used to test the participant's working standards. Upon completion it is returned to NBS for final calibration and data analysis. A test report is issued (see Appendix 4) giving the difference between the unit maintained by the participant and the legal unit maintained at NBS, including a complete error analysis of the measurement.

Transport standards are commercial standard Whms carefully selected to represent the best of each meter type. They are sent to the participant by commercial air freight with special ground transportation. Rugged, cushioned fiberglass containers are provided to reduce shipping hazards and acceleration monitors on each meter detect unusually rough handling. Barring mishaps in transit this new service can generally provide a more accurate means of tying to the national standards than the traditional calibration service.

The registration of a transport standard may be affected by variations in test conditions such as voltage and temperature, and if the test conditions at the participating laboratory differ from those at NBS, a false offset may be observed. The participant is therefore asked to record the average value of each parameter that may affect Whm registration during the test (see Instructions and Data Sheet - Appendix 3). These values are used with previously determined parameter coefficients for each transport standard to normalize the registrations to a single set of test conditions - typically 120V, 5A, 300 or 600W, 60 Hz, 25°C and sinusoidal waveform. For example, if the average temperature during a test is 23°C and the temperature coefficient of the transport standard is 0.010%/°C, the percentage registration will be normalized to 25°C by applying a 0.020% correction. The normalizing procedure compensates for offsets and fluctuations in test conditions at both laboratories and will generally further improve the accuracy of the calibration.

The accuracy of each parameter measurement is also important and can affect the uncertainty of the calibration procedure. For example, if the voltage measurement is in error by 2 volts and the transport standard voltage coefficient is 0.005%/V, when normalized the registration will be in error by 0.010%. This would not pose a problem if all other working standards calibrated by this precedure had the same voltage coefficient. Whm coefficients, however, may vary in both magnitude and sign and care must be taken to minimize errors in each parameter measurement.

## 3. Transport Standard Calibration

NBS transport standards are compared to the average of the bank of Whms (NBS primary standards) used to maintain the national unit of electric energy at 60 Hz. The formula used to compute the percentage registration of the transport standard $r_{NBS}$ is

$$r_{NBS} = \frac{k_t n_t r_s}{k_s n_s} + P_{NBS} \tag{3.1}$$

where

$k_t$ = constant of the transport standard in energy per unit output,

$n_t$ = number of unit outputs of the transport standard,

$r_s$ = percentage registration of the NBS primary standards,

$k_s$ = constant of the NBS primary standards in energy per unit output,

$n_s$ = number of unit outputs of the NBS primary standards, and

$P_{NBS}$ = the normalizing term (see Appendix 1).

The first term of this equation describes the basic relationship between the transport standard and the NBS primary standards. The second term describes the effects of the parameters that may influence Whm registration.

The transport standard is calibrated at the participating laboratory using the format outlined on the data sheet. It should be tested as an unknown working standard and a value of precentage resistration $r_{LAB}$ reported for each observation. When the results are processed at NBS, $r_{LAB}$ will be normalized to $R_{LAB}$ at 120 volts, 5 amperes, 300 or 600 watts, 60 Hz, 25°C and sinusoidal waveform by

$$R_{LAB} = r_{LAB} + P_{LAB} \tag{3.2}$$

where $P_{LAB}$ is the normalizing term (see appendix 1).

The difference between the percentage registrations assigned at the participating laboratory and at NBS is given by

$$\Delta R = R_{LAB} - R_{NBS} \tag{3.3}$$

where $R_{NBS}$ = mean of $r_{NBS}$ (computed before shipping to the customer's laboratory) and $r'_{NBS}$ (computed after return to NBS). The total uncertainty of $\Delta R$ using a 3 standard deviation limit is

$$U_{\Delta R} = SU_{NBS} + \frac{3}{\sqrt{n}} \sqrt{S^2_{LAB} + S^2_{NBS}} \tag{3.4}$$

where

$SU_{NBS}$ = systematic uncertainty of the NBS calibration process,

$S_{LAB}$ = the standard deviation of the participant's calibration process,

$S_{NBS}$ = the standard deviation of the NBS calibration process, and

$n$ = the number of independent observations made at each laboratory (an independent observation is loosely defined as a set of two or more readings separated by several hours from any other set of readings).

## 4. Measurement Assurance Program

The NBS transport standard can periodically provide the participating laboratory with a means of evaluating its systematic errors. The accuracy of local measurements, however, depends upon the performance of the measurement process in between transport standard calibrations. This note describes a Measurement Assurance Program which focuses on the properties of the measurements being made rather than the quality of the standards used. It is the measurements (calibrations) made by the laboratory that its customers are concerned about - they all need assurance that the uncertainty of these measurements is within the required limits. Just as NBS has a Measurement Assurance Program to provide evidence of the accuracy of its results so also does the participating laboratory need its own program in support of its results.

If a stable meter were repeatedly measured over a long period of time a sequence of non-identical results would be found. Evidence of non-randomness might be present if the results were grouped by apparatus used, ambient conditions or other factors. The random variability may be of two or more levels; for example, duplicate measurements made in the same hour may agree better than results from measurements made a day or a week apart. One needs a procedure for determining these properties some extra effort has to be devoted to just this purpose.

The participant's process has uncertainties caused by:

A. Systematic errors

1. Due to non-variable system errors which either escaped detection or are known but left uncorrected (for example, relay timing errors).

2. Due to the uncertainty of non-variable system errors for which a correction is applied (for example, the uncertainty of a potential lead resistance measurement).

3. Due to the uncertainty of variable system errors for which a correction is applied (for example, thermometer error which can result in uncertain temperature correction).

B. Random errors:

1. Due to random drifts in the entire calibration process which cannot be accounted for.

2. Due to random process drifts which can be accounted for - type 3 systematic errors - but are left uncorrected (for example, the uncorrected effects of random temperature fluctuations).

Systematic errors can be determined by calibrating the NBS transport standard as a working standard. If the participant's corrections are then adjusted to make $\Delta R = 0$, the uncertainty due to the systematic errors of the participant's process can be reduced to the uncertainty, $U_{\Delta R}$, of the NBS transport standard calibration.

Random errors of the process can be determined through local statistical analysis by the participant. This can be done by regularly calibrating a group of typical working standards to determine the long-term process standard deviation. These repetitions should be done under the same conditions as the regular workload. One wishes this sequence of measurements to answer the question "What if the test meter had been recalibrated at a later date - within what limits would such calibrations fall?" It is therefore important that the sample group be representative of the entire group of working standards calibrated by the participant and that the measurements be taken far enough apart in time to be truly independent. Ideally the long term process standard deviation $S_{LAB}$ would be computed from measurements made on each of the working standards at one or two week intervals.

Using information obtained from both the NBS transport standard and local statistical analysis, the participant can calibrate a typical working standard to an uncertainty $U_{LAB}$

$$U_{LAB} = U_{\Delta R} + 3 \frac{S_{LAB}}{\sqrt{n}} \tag{4.1}$$

where

$U_{\Delta R}$ = the systematic uncertainty of the calibration process.

$S_{LAB}$ = the long term standard deviation of the participant's process

n = the number of independent observations made during the test.

The result is a program which can both transfer the legal unit to the participating laboratory and provide a periodic monitor of the calibration process using accepted statistical techniques. It is designed not only to provide measurement assurance but measurement efficiency as well. Once process control is achieved (tests for control are described in Appendix 2), the calibration intervals may gradually be increased.

A meter laboratory wishing to participate in this Program for Electric Energy should:

A. Calibrate a bank of typical working standards on a continuing basis to determine a long-term standard deviation of the calibration process.

B. Calibrate an NBS transport standard.

C. Adjust its unit to make $\Delta R = 0$.

D. Test for local process control at regular intervals.

E. Recalibrate an NBS transport standard (about one year after the initial test).

## 5. Conclusions

A Measurement Assurance Program has been described which represents a new philosphy in electricity metering. It focuses on the measurement output of the meter laboratory rather than just the accuracy of its primary standards. A new calibration service which uses NBS transport standards to determine the participant's measurement offset is now available. When this is combined with a regular program of surveillance of the measurement effort by periodic measurements on the same group of working standards, the laboratory can maintain continued assurance of the adequacy of its measurements and the validity of its uncertainty statements.

The procedures which enable one to characterize the measurement process also permit one to study its properties and the extent of improvement brought about by modifications in the process.

## Appendix 1

Normalizing terms

These terms are used in eqs (3.1) and (3.2) to normalize NBS and participating laboratory results to the nominal set of test conditions - 120 volts, 5 amperes, 300 or 600 watts, 60 hertz 25°C, and sinusoidal waveform.

$$P_{NBS} = \Big[(V_{NBS} - V_n)(C_{VNBS} - C_{Vt}) + (I_{NBS} - I_n)(C_{INBS} - C_{It})$$
$$+ (W_{NBS} - W_n)(C_{WNBS} - C_{Wt}) + (F_{NBS} - F_n)(C_{FNBS} - C_{Ft})$$
$$- (T_{NBS} - T_n)C_{Tt} + (H_{NBS} - H_n)(C_{HNBS} - C_{Ht})\Big]$$

where

A. V, I, W, F, T, H represent the parameters voltage, current, power, frequency, temperature and harmonic distortion, respectively.

B. the subscripts NBS and n represent the average measured parameter value at NBS and the nominal value, respectively. (For example, if the average measured voltage during a test at NBS is 121 volts, $V_{NBS}$ = 121 volts and the nominal voltage is 120 volts, $V_n$ = 120 volts.)

C. Coefficients are represented by C and the subscripts NBS and t refer to the NBS primary standards and the MAP transport standard, respectively. (For example, the voltage coefficient of the MAP transport standards is represented as $C_{Vt}$). The temperature coefficient of the NBS primary standards $C_{TNBS}$ is omitted because the standards are housed in a chamber whose temperature fluctuations introduce a negligible error.

$$P_{LAB} = \Big[C_{Vt}(V_n - V_{LAB}) + C_{It}(I_n - I_{LAB}) + C_{Wt}(W_n - W_{LAB})$$
$$+ C_{Ft}(F_n - F_{LAB}) + C_{Tt}(T_n - T_{LAB}) + C_{Ht}(H_n - H_{LAB})\Big]$$

where the subscript LAB represents the average measured parameter value at the participating laboratory.

## Appendix 2

### Maintaining Process Control

The validity of the uncertainty statement (4.1) depends on the process staying in a state of statistical control. Also it is assumed that no dependence of the results on ambient conditions or other factors has developed. Therefore the results on the bank of working standards should be used to check these assumptions.

Standard deviation

After each set of about 4 to 8 results a standard deviation, $s_{LAB}$, should be computed and the ratio

$$\frac{s_{LAB}}{S_{LAB}} < \sqrt{F(m_1-1,\ m-1,\ 0.99)}$$

compared with the critical value for $\sqrt{F}$ given in the table where

$m_1$ = number of values (independent observations) in $s_{LAB}$

$m$ = number of values (independent observations) in $S_{LAB}$

If the critical value in the table is exceeded, then the process must be regarded as out of control and the uncertainty statements are no longer valid. The process standard deviation should be redetermined.

Percentiles of the F Distribution

$F_{.99}(m_1-1,\ m-1)$

$m_1-1$ = degrees of freedom for numerator

$m-1$ = degrees of freedom of denominator

| $m-1$ \ $m_1-1$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 30 | 7.6 | 5.4 | 4.5 | 4.0 | 3.7 | 3.5 | 3.3 |
| 40 | 7.3 | 5.2 | 4.3 | 3.8 | 3.5 | 3.3 | 3.1 |
| 60 | 7.1 | 5.0 | 4.1 | 3.7 | 3.3 | 3.1 | 3.0 |
| 120 | 6.9 | 4.8 | 4.0 | 3.5 | 3.2 | 3.0 | 2.8 |
| ∞ | 6.6 | 4.6 | 3.8 | 3.3 | 3.0 | 2.8 | 2.6 |

Use of table:

For example, if $S_{LAB}$ is computed from 41 independent observations ($m-1 = 40$) it can be tested for consistency by computing $s_{LAB}$ based upon four independent observations ($m_1-1 = 3$). If $s_{LAB}/S_{LAB} \leq \sqrt{4.3}$, the test indicates that the process is in control.

Process average

The average registration for the bank of working standards can also be used to monitor process performance if it is sufficiently stable (or if its change with time is predictable). For the same grouping as with the standard deviation check, compute the average, $\overline{x}_{m_1}$ and the ratio

$$\left| \frac{\overline{x}_{m_1} - \overline{x}_m}{s_{LAB} \sqrt{\frac{1}{m_1} + \frac{1}{m}}} \right| < 3$$

where

$\overline{x}_m$ = the long term average registration,

$\overline{x}_{m_1}$ = the short term average registration

If the ratio exceeds 3, checks should be made to determine whether the working group has changed or whether it is the laboratory's reference standards which have changed.

Transport standard

The process offset ($\Delta R$) will probably change from one transport standard calibration to the next and while the participant's corrections should initially be adjusted to make $\Delta R = 0$, future adjustments to zero should be made only if

$$\Delta R > \frac{3}{\sqrt{n}} \sqrt{s_{LAB}^2 + s_{NBS}^2}$$

Further information on data analysis and statistical techniques is available at NBS.

Appendix 3

# TEST INSTRUCTIONS

1. Before testing:

   a. On transport standards equipped with accelerometers note if any have been tripped (ball bearings rolling free in the plastic housing) and record the g value and direction on the lid of the meter. Reset the accelerometers using the attached tool, being sure to match the spring to the set screw color code.

   b. Level the meter using its level indicator.

   c. Mount the enclosed thermometer on the meter in the designated location and use it to record the average measured temperature for each test run.

   d. Isolate the test area from external magnetic influences. Example: place the meter at least 20 cm (8 in ) from other magnetic circuits and current carrying conductors.

   e. Energize the current circuit with a continuous control - current should be increased and decreased gradually, because current switching transients can magnetize an induction watthour meter.

   f. Energize at rated power at least 1 hour before the test. Internal light sources where they exist must also be energized.

2. a. Unless other arrangements have been made, the transport standard should be tested as an unknown working standard at 120 volts, 5 amperes - 1.0 power factor and 0.5 power factor current lagging.

   b. To assure statistical independence, do not perform the test on a single day but rather over several days with 4 sets of readings made for each power factor. Example: 1st day - take 2 consecutive readings at each power factor in the morning and 2 at each in the afternoon. 2nd day - repeat the procedure for a total of 8 observations per power factor. Use a separate data sheet for each power factor.

3. With each run, record *Date, Time, Power Factor, Transport Standard Reading* and *Corrected Percentage Registration* (defined in the Code for Electricity Metering as: "...The ratio of the actual registration of the meter to the true value of the quantity measured in a given time, expressed as a percentage". Example: if the meter registers 0.015% fast, record as 100.015%). Report results to the nearest 0.001%.

4. Test Conditions

a. *Average Measured Values:* These figures, to be recorded with each run, are the average readings of the instruments used to measure the different parameters and will partially compensate for random variables such as voltage drift. Average readings are often difficult to make without integrating instruments and unless such equipment is available these figures will have to be operator estimates. Example: if the voltmeter reading drifts uniformly from 120 to 121 volts during a run, record 120.5 as the average measured voltage. Comment on any measurement that was unusually difficult to average - include numbers. The "remarks" column can be used to record any unusual influences that vary from run to run. Examples: electrical or mechanical shocks, distortion, etc.

b. *Measurement Uncertainties:* These figures indicate the degree of accuracy to which each parameter is measured and in general will simply reflect the instrument accuracy. Example: in a voltage measurement, if influences such as lead resistance are negligible, the voltage measurement uncertainty figure will simply be the voltmeter uncertainty.

c. *Relative Humidity:* Record the average relative humidity during the entire test period. Comment if there were large fluctuations in this figure.

d. *Potential Lead Resistance:* Lead resistance in the potential circuit (between your standard and the meter under test) exceeding 0.05Ω can cause significant power factor errors. Comment on compensation or corrections made for lead resistance.

e. *Harmonic Distortion:* 3rd harmonic introduced into the current circuit of an induction watthour meter will interact with 3rd harmonic generated in the potential circuit of the meter to produce an errorneous torque porportional to the harmonic magnitude and phase. The picture may be further complicated when higher order harmonics are introducted into both the current and potential circuits. Any information on harmonic content in both waveforms will be helpful in establishing limits of uncertainty.

f. *System Standard Deviation:* Most meter laboratories routinely compare their working standards to their primary standards and these measurements can be used to determine a process standard deviation. If this figure is not provided the standard deviation of the actual MAP comparison (a less reliable figure) will be used in the test report.

g. REMARKS: Use this space and the back of the data sheet to comment on any pertinent measurement or estimate.

When information on a particular parameter is unavailable and a reasonable estimate cannot be made leave the space blank and comment in REMARKS.

5. When the test is completed place the data sheets in the shipping container with the MAP transport standard and return them to NBS.

Shipping instructions:

a. Ship air freight prepaid to Washington National, Dulles International or Baltimore-Washington International Airport on the route with the least number of transfers and stops.

b. Arrange to have the meter "hand carried" to the air freight office if possible.

c. Where air freight is inconvenient choose the surface carrier route with the least number of transfers and stops.

d. Mark the container:

HOLD AT AIRPORT (train station, etc.)<br>
AND CALL - High Voltage Measurements Section<br>
National Bureau of Standards<br>
Gaithersburg, Maryland<br>
(301) 921-3121

e. When the instrument is en route, telephone NBS (at the above number) with pertinent transportation information including: waybill number, carrier and flight number, destination and estimated time of arrival.

# NBS MAP DATA SHEET

ORGANIZATION:
MAIL ADDRESS:
TELEPHONE:
OBSERVERS:

TRANSPORT STANDARD NO. ________
POWER FACTOR ________

NBS
211 ENERGY MAP
TEST NO. ________

| TEST NUMBER | DATE | TIME | TRANSPORT STANDARD READING | AVERAGE MEASURED VALUES OF PARAMETERS: VOLTAGE to 0.1V | CURRENT to 0.01A | POWER to 1W | FREQUENCY to 0.001 Hz | TEMPERATURE to 0.1°C | CORRECTED PERCENTAGE REGISTRATION |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| 2 | | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| 3 | | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| 4 | | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| 5 | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| 6 | | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| 7 | | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| 8 | | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |
| | | | | | | | | MEAN | ____ |

ESTIMATED MEASUREMENT UNCERTAINTIES:

VOLTAGE ________ %
CURRENT ________ %
POWER ________ %
FREQUENCY ________ %

OTHER PARAMETERS:

REALTIVE HUMIDITY ________ %
POTENTIAL LEAD RESISTANCE ________ Ω
HARMONIC DISTORTION: ________
a. 3rd IN CURRENT WAVEFORM ________ %
b. OTHER - ________________
PROCESS STANDARD DEVIATION ________

REMARKS:

FORM NBS-259
(3/66)

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

# REPORT OF TEST

OF

ELECTRIC ENERGY AT 60 Hz

USING

NBS TRANSPORT STANDARD NO. ______

Participating Laboratory

Measurements made by the participating laboratory on NBS Transport Standard No. _______ using its regular procedure for calibrating standard watthour meters were as follows: (All results reported in percent)

A. Offset Between Participating Laboratory and NBS

The percentage difference, $\Delta R$, between $R_{LAB}$, obtained by the participating laboratory and $R_{NBS}$, assigned by NBS was

| | Power Factor | |
|---|---|---|
| | 1.0 pf | 0.5 pf (lag) |
| $\Delta R = R_{LAB} - R_{NBS}$ | ______ | ______ |
| $U_{\Delta R}$ (Uncertainty in $\Delta R$) | ______ | ______ |

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B. Process Parameters Used to Calculate $\Delta R$ and $U_{\Delta R}$

| | Power Factor 1.0 | Power Factor 0.5 |
|---|---|---|
| 1. Percentage registrations normalized to 120 volts, 5 amperes, 300 or 600 watts, 60 Hz, and 25°C. | | |
| a. Measurements performed at NBS $R_{NBS}$ | ______ | ______ |
| b. Measurements performed at the participating laboratory $R_{LAB}$ | ______ | ______ |
| 2. Systematic uncertainties in assigning the units to the NBS primary standards $SU_{NBS}$ | ______ | ______ |
| 3. The measurement process used by the participant to determine $R_{LAB}$ has: | | |
| a. long term (accepted) standard deviations $S_{LAB}$ | ______ | ______ |
| b. standard deviations for this test $s_{LAB}$ | ______ | ______ |
| 4. The measurement process used by NBS to determine $R_{NBS}$ has: | | |
| a. long term (accepted) standard deviations $S_{NBS}$ | ______ | ______ |
| b. standard deviations for this test $s_{NBS}$ | ______ | ______ |

C. Uncertainty

The uncertainty associated with the value of $\Delta R$ depends on the systematic error in the value assigned by NBS and the extent to which random error affects the measurements at both NBS and the participating laboratory. The total uncertainty in $\Delta R$ with a 3 standard deviation limit for the effect of random error is

$$U_{\Delta R} = SU_{NBS} + \frac{3}{\sqrt{n}} \sqrt{\left(S_{NBS}\right)^2 + \left(S_{LAB}\right)^2}$$

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| D. Remarks | 1.0 pf | 0.5 pf (lag) |
|---|---|---|
| 1. Results of F tests indicate: | | |
| a. Process in control $S_{LAB}$ used in uncertainty statement | ☐ | ☐ |
| b. Process is either out of control or $S_{LAB}$ is not given, $s_{LAB}$ used in uncertainty statement | ☐ | ☐ |
| 2. Results of test for offset indicate: | | |
| a. No adjustment for R should be made | ☐ | ☐ |
| b. $\Delta R$ is significant and corrections should be adjusted to make $\Delta R = 0$ | ☐ | ☐ |
| 3. Other: | | |

For the Director
Institute for Basic Standards

OSKARS PETERSONS, Chief
High Voltage Measurements Section
Electricity Division

☆U.S. GOVERNMENT PRINTING OFFICE: 1976 210-801/411 1-3

NBS-114A (REV. 7-73)

| U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET** | 1. PUBLICATION OR REPORT NO. *NBS TN-930* | 2. Gov't Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|
| 4. TITLE AND SUBTITLE<br>A MEASUREMENT ASSURANCE PROGRAM FOR ELECTRIC ENERGY | | | 5. Publication Date<br>September 1976<br>6. Performing Organization Code |
| 7. AUTHOR(S)<br>N. Michael Oldham | | | 8. Performing Organ. Report No. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>NATIONAL BUREAU OF STANDARDS<br>DEPARTMENT OF COMMERCE<br>WASHINGTON, D.C. 20234 | | | 10. Project/Task/Work Unit No.<br>11. Contract/Grant No. |
| 12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*<br>same as item 9 | | | 13. Type of Report & Period Covered<br>Final<br>14. Sponsoring Agency Code |
| 15. SUPPLEMENTARY NOTES | | | |

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

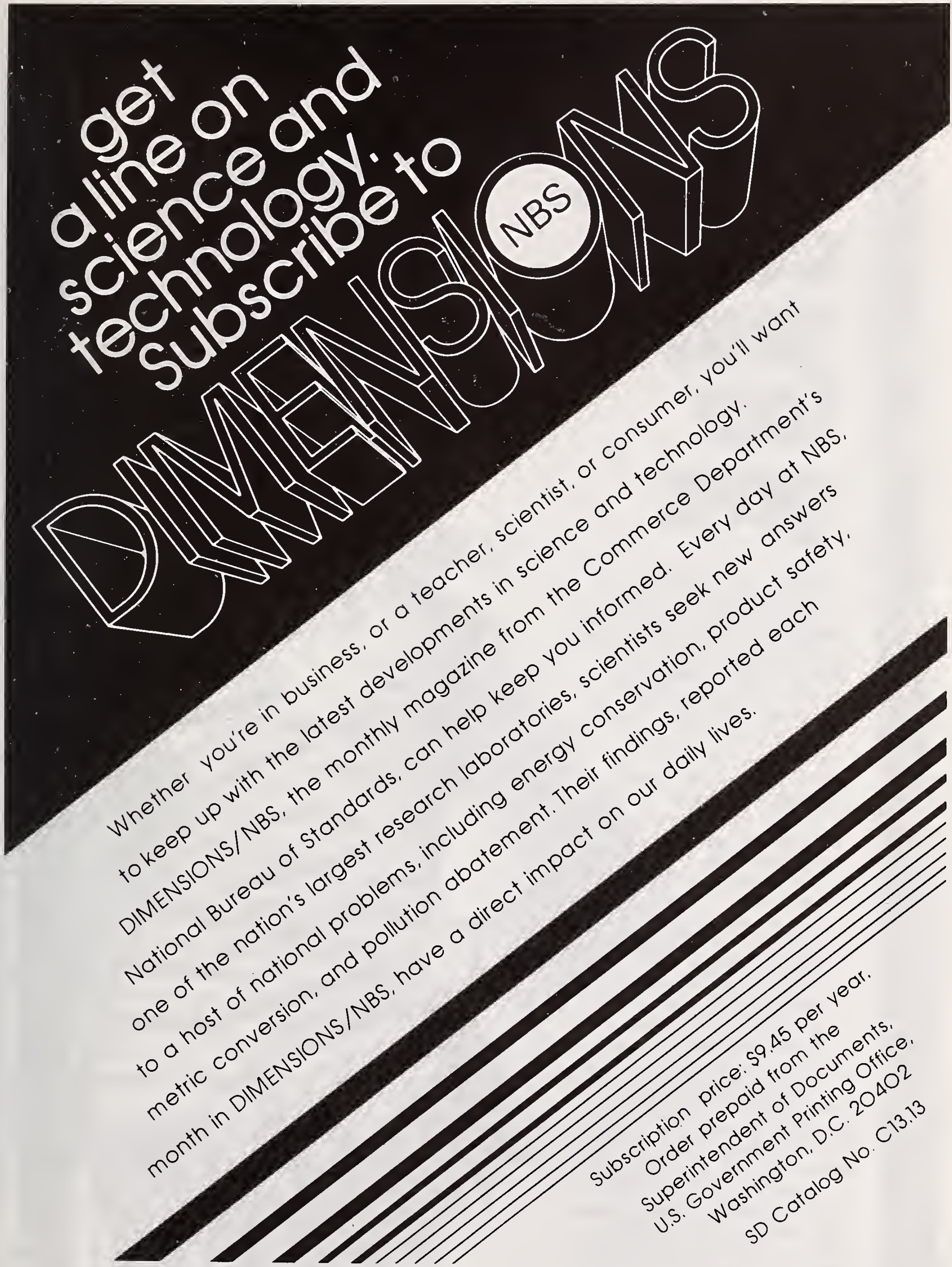
A Measurement Assurance Program for Electric Energy is described which enables a meter laboratory to evaluate the accuracy of its calibration process relative to the legal units of energy maintained by the National Bureau of Standards. A laboratory participating in this program periodically determines its process offset by testing an NBS transport standard as part of its regular workload (using the same procedures used to test its working standards). Subsequent monitoring and tests for local control can improve the reliability and assure the adequacy of the participant's calibration process.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Electric energy; electricity; electric power; measurement assurance; transport standard; watthour meter.

| 18. AVAILABILITY [X] Unlimited | 19. SECURITY CLASS (THIS REPORT) | 21. NO. OF PAGES |
|---|---|---|
| [ ] For Official Distribution. Do Not Release to NTIS | UNCLASSIFIED | 23 |
| [X] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13. 46:930 | 20. SECURITY CLASS (THIS PAGE) | 22. Price |
| [ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151 | UNCLASSIFIED | $0.55 |

USCOMM-DC 29042-P74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