PHAOSTRON INSTRUMENT & ELECTRONIC CO.
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FINAL DEVELOPMENT REPORT

FOR

1% ACCURACY, 40 and 100 MICROAMPERE RUGGEDIZED TAUT BAND PANEL METERS (5-1/2" x 4-1/2")

THIS REPORT COVERS THE PERIOD 2-1-69 to 4-31-69

Phaostron Instrument and Electronic Company
151 Pasadena Avenue
South Pasadena, California 91030

NAVAL ELECTRONIC SYSTEMS COMMAND, NAVELEX 05143B

CONTRACT NUMBER - N00024-67-C-1190

MODS-P001, P002, P003 and MODS-A001, A002

PROJECT SERIAL NO. XF02102 TASK 9633

MAY 1969

UNCLASSIFIED

Serial No. ________

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ABSTRACT

A total of thirty-six meters were assembled consisting of three lots of twelve each of the following types.

Type 1. 40 microamps. 2000 ohms. Temperature compensated.

Type 11a. 100 microamps 1000 ohms. Temperature compensated.

Type 11b. 100 microamps 1000 ohms. Temperature and R.F.I. compensated.

These were further broken into groups and subjected to performance and environmental tests as directed.

Whilst all the objectives were not attained, one hundred percent, substantial improvements for military type meters both initially and during regular field service can be realistically anticipated.

It is reasonable to expect a ruggedized long scale (4-3/4") precision (1%) taut band meter to be usable in any position, over a wide range of temperatures (0° - 50°C), that can be overloaded (X10) and dropped (1 ft.) and still maintain its original accuracy, during and after any combination of these conditions.

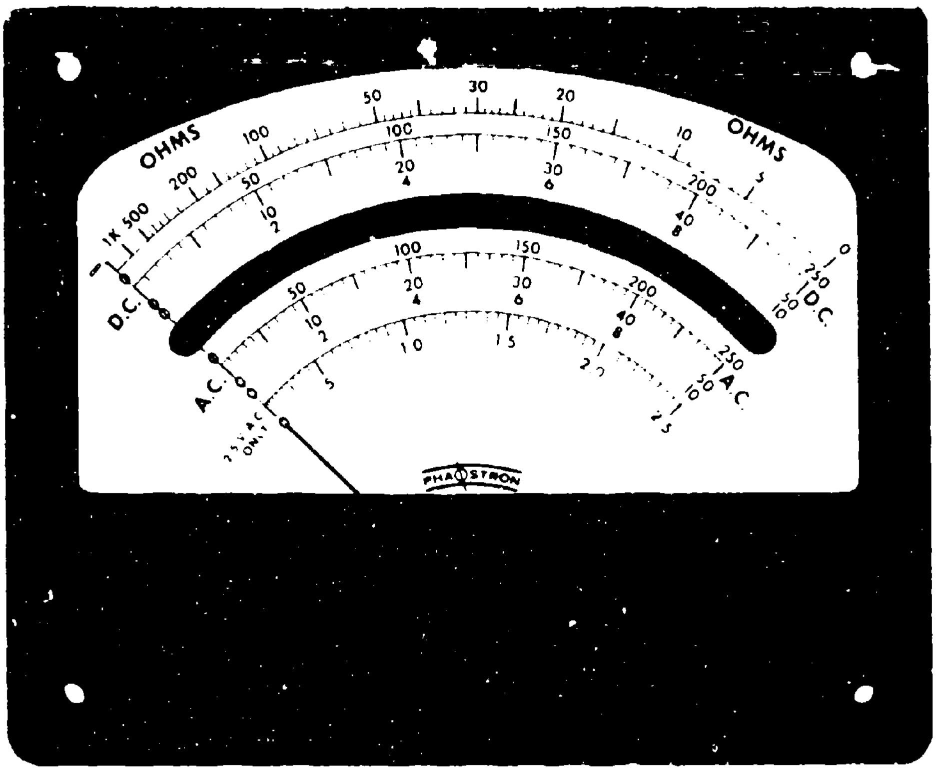


Figure 1. Front view of meter, full size

PART I

PURPOSE

To develop a group of precision taut band meters, ranges 40 microamps and 100 microamps, for incorporation into multimeter equipment. The units must pass all the environmental and other requirements of MIL-M-10304C except that the performance and accuracy of the units before and after the tests are generally required to be upgraded by a factor of two.

Additional objectives are improved terminal resistance compensation and radio frequency interference studies.

Specific requirements comparison table:

DESCRIPTION	MIL-M-10304C/17C	IMPROVED OBJECTIVE
Position influence	±2%	±1% of full scale
Linearity accuracy	Not Applicable	±1/2% " "
Initial accuracy	±2%	±1% " "
Exp. to extreme temps.	±10%	±2% " "
Momentary overload	±2%	±0% " "
Rotational influence	Not Applicable	±1% " "
Vibration	±5%	±2% " "
Random drop	±5%	±2% " "
Shock	±5%	±2% " "

GENERAL FACTUAL DATA

IDENTIFICATION OF PERSONNEL:

During the period February '69 to May '69 the personnel listed below charged time to the project.

Logan	68
Bobish	8
James	130
Bandas	130
Total hours	336

DETAIL FACTUAL DATA

INTRODUCTION:

This period was spent in assembling and performance testing thirty-six units.

This quantity was then divided as follows:

a) Type 1 (40 uA units) Quantity twelve (12) tested in accord with Table 1 with Six (6) being subjected to Group 1 tests, then divided into samples of three each for Group 11 and 111 tests. The final six were divided for the Group IV and V tests.

b) Type 11A (100 uA units) Same schedule as for Type 1.

c) Type 11b (100 uA units with temperature compensation and R.F.I. shielding) Same schedule as for Type 1.

The tests in Table 1 comprise some tests in accord with specific para's of Mil-M-10304, some tests performed per the MIL-M-10304 specification but modified per the requirements of the specific paras of Exhibit A of the contract. A few tests were original and were performed to specific paras of the Exhibit A.

TABLE I

TEST PROCEDURE

	Group I Tests (6 samples) Numbered 1 thru 6	Method Para. of MIL-M-10304C	Requirement Para. Exhibit A
A	Visual and Mechanical	4.7.1.1	---
B	Position Influence	4.7.2	1-1d
C	Rotation Influence	---	1-1k & 2(b)
D	Zero Adjuster	4.7.3	1-1a
E	Initial Accuracy	4.7.5	1-1f
F	Linearity	---	1-1e & 2(a)
G	Stickiness	---	1-1l & 2(c)
H	Response Time	4.7.7	---
I	Exposure to Ext. Temp.	---	1-1g
	Overload Capacity		
J	Momentary	4.7.13.1	1-1i
K	Sustained	4.7.13.3	---
L	Dielectric Withstanding Volt.	4.7.14	1-1j
M	Insulation Resistance	4.7.15	1-1h
N	Seal	4.7.16.1.1	1-1r
	Group II Tests (3 samples) Numbered 1, 2, 3		
O	Temperature Cycling	4.7.17	---
P	Moisture Resistance	4.7.18	1-1m
Q	Friction Error	4.7.19	---
L	Dielectric Withstanding Volt.	4.7.14	1-1j
M	Insulation Resistance	4.7.15	1-1h
N	Seal	4.7.16.1.1	1-1r
R	Impact Test for Windows	4.7.20	---
A	Visual and Mechanical	4.7.1.1	---
	Group III Tests (3 samples) Numbered 4, 5, 6		
S	Thermal Shock by Immersion	4.7.21	---
N	Seal	4.7.16.1.1	1-1r
A	Visual and Mechanical	4.7.1.1	---
	Group IV Tests (3 samples) Numbered 7, 8, 9		
T	Vibration	4.7.22	1-1n
U	Random Drop	4.7.23	1-1o
V	Shock	4.7.24	1-1p
	Group V Tests (1 or 3 samples) Numbered 10, 11, 12		
W	Magnetic Field	---	1-1q
X	Steel Panel Effect	4.7.5	---
Y	Power Consumption (Resistor)	4.7.8	---
Z	Damping Factor	4.7.6	---

DESCRIPTION OF TESTS, PERFORMANCE & COMMENTS:

A. Visual and Mechanical

Consists of a visual external examination of the meters of specific requirements to ensure that such call outs as terminal identification, dial markings, polarity, color scheme, scale visibility, finishes, etc. are met.

One requirement is that the length of the longest scale be at least 5 inches. By definition (para 6.6.15 of MIL-M-10304) this is the length of the path described by the tip of the pointer in moving from one end of the scale to the other. Working with the three variables of movement pivot center, length of pointer and the arc of the scale a 5 inch scale could be obtained only by placing the top scale arc above the numerals. From both an aesthetic and human engineering viewpoint this approach was discarded and the final form of the two scale types is shown in Fig. 2, which are full size and have a maximum scale length of 4.75 inches.

The material for the mirror insert, to provide anti-parallax readings by lining up the pointer reflection with the pointer has traditionally been thin metalized glass. Lack of distortion and high refle ctivity are its important features. It is however brittle and mechanically weak. Highly polished metal foils have been used, usually nickel or chromium plated brass, these while unbreakable, invariably show grain marks either from the base material or from the polishing process which shows up by distorting the image. A new approach was used on these meters, pressure sensitive foil-cals were applied to the surface of the dial pans. The results were disappointing as the reflective properties of the metal deposit on plastic failed to show the sharpness desired. A thicker and stiffer base material would show some improvement.

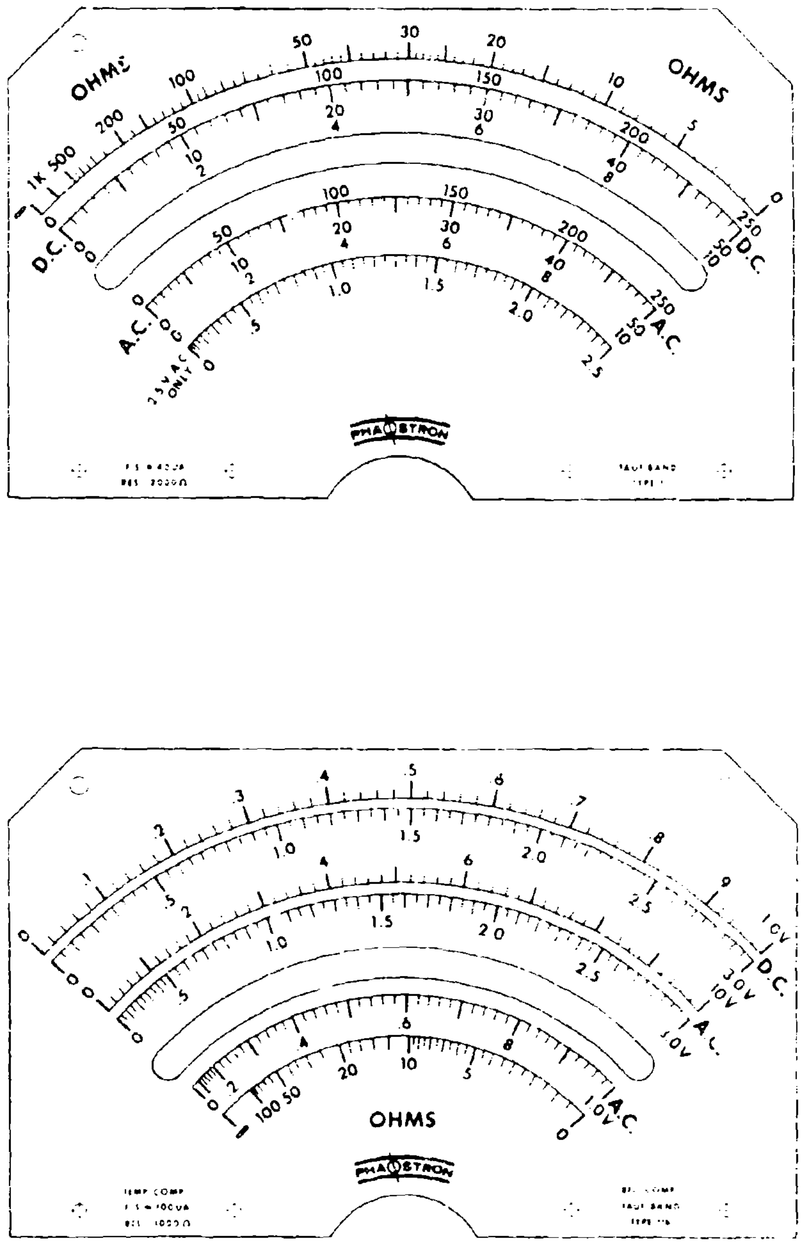


Figure 2. Dial layouts, full size

The windows were machined from polycarbonate plastic sheets that were surface protected during manufacture by peel-off paper on both sides. It is apparent that normal handling to assemble to the meter, attach the zero adjuster button and anti-static treatment all contribute to marring the surfaces. The environmental tests further degraded the optical clarity of the windows. This matter is referred to later under the recommendations section.

B. <u>Position Influence</u>

The meters are mounted in the vertical position with the pointer set to the center of the zero mark by adjusting the zero button. The meter is then rotated 60° from this position in both C.W. and C.C.W. directions. The deviation of the pointer at these positions is noted and measured by applying an electrical current of the required polarity and value to return the pointer to its original position. The value of the current is expressed as a percentage of the nominal full scale current. It is a requirement that the deviation not be in excess of 1%.

TABLE II. Position Influence

SAMPLE NO.		1	2	3	4	5	6
Type 11a 100 uA	CW CCW	+1.0% +0.4%	+0.9% 0	+1.0% -0.3%	+0.9% +0.4%	+0.5% -0.2%	0 +0.3%
Type 11b 100 uA	CW CCW	+0.3% -0.13%	+0.62% -0.19%	+0.26% +0.07%	+0.27% -0.24%	+0.20% +0.10%	+0.62% +0.40%
Type 1 40 uA	CW CCW	0 +0.30%	+0.50% +0.50%	+0.43% 0	+0.68% -0.23%	+0.43% +0.10%	+0.23% 0

\+ sign means pointer moved up scale.
\- sign means pointer moved down from the zero mark.

C. Rotational Influence

This is a requirement not presently called out in MIL-M-10304. It is a particularly useful check for portable meters which may be read from any position. The meters are mounted on a non-magnetic panel with the face in a vertical plane and the accuracy is established by taking ten untapped readings at the cardinal points of the scale. The meter panel is then placed in the horizontal plane with the face upward and the accuracy is determined in the same manner.

TABLE III. Rotational Influence

SAMPLES		1	2	3	4	5	6
Type IIa	Vert.	+.57%	+.87%	+.59%	+.80%	-.43%	+.35%
100 uA	Horiz.	-.57%	-.39%	-.58%	-.71%	-.81%	+.34%
Type IIb	Vert.	-.24%	-.61%	-.50%	+.31%	+.14%	-.40%
100 uA	Horiz.	+.19%	-.47%	-.24%	-.62%	+.20%	+.24%
Type I	Vert.	-.73%	-.70%	-.58%	-.48%	-.35%	-.95%
40 uA	Horiz.	-.78%	-.98%	-.73%	-.73%	-.40%	-.83%

The requirement was for the maximum error not to exceed 1% of full scale at any cardinal point on the scale. The most accurate meter of the type IIa and IIb, numbers 6 and 5 are also the two of the groups that had the least position influence error. This interesting relationship did not follow through on the 40 uA units. These being the heavier moving element, have more sag with the meter pace vertical

TABLE IV. Meter #6 Type IIa. 100uA

Horizontal & Vertical Accuracy

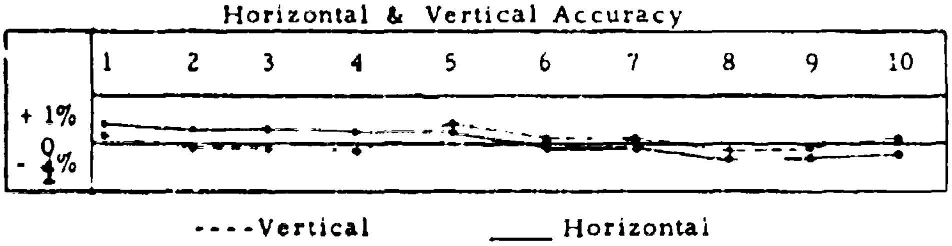
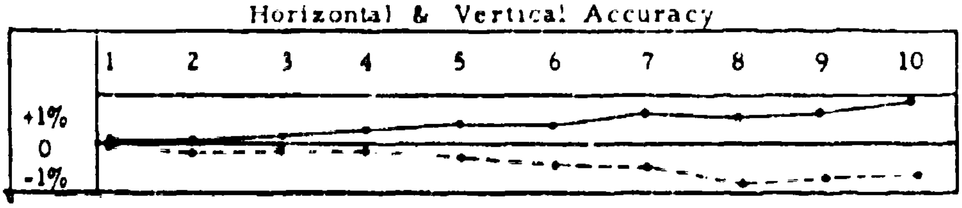


TABLE V. Meter #4 Type IIa 100uA

Horizontal & Vertical Accuracy



Generally it was found that when the maximum error is in the region of 0.35% or less, this maximum could be located anywhere on the scale, (Table IV at points 1, 5, 8). When the maximum error approaches the limit of 1% this was invariably located at the 6, 8 or 10 points (Table V).

TABLE VI. Distribution of Maximum Errors

Scale	0	1	2	3	4	5	6	7	8	9	10
Vertical			1		1	1	8		1		6
Horizontal		1			1	1	4		8	1	2

To eliminate a possible source of confusion as to the direction of error in relation to the cardinal points on the scale when taking readings, the method used throughout this report is thus;

a) The meter is energized to center the pointer at a cardinal line, this can be done with considerable precision.

b) The value of electrical current is noted from the standard supply and recorded on the test sheet.

c) When the current value is greater than the nominal for the check point the error is noted as negative (-) as this represents the location of the pointer to the cardinal point when the exact nominal electrical current of that point is applied. For example, with a pointer set on mid-scale the value of current is read as 50.1 microamps, if the current is then reduced to the nominal value of 50 microamps the pointer will indicate below the line by 0.1 microamps, which is termed a negative or low indication.

Similarly, when the current value is less than the nominal for a check point the error is noted as positive (+) or high actual indication.

a) For clarity and ease of comparison all current values have been reduced to percentages.

D. Zero Adjustment

It is a requirement that the insulated zero adjuster shall be rotatable 360° without damage to the meter and provide a minimum of plus and minus 3° deflection of the pointer relative to the center of the zero mark.

This design feature occasioned no problem, as the total adjustment range is in the region of 10°.

E. Initial Accuracy

This test is identical to the ten untapped readings with the meter in the vertical position as performed under C. Rotational influence. Table III.

F. Linearity Accuracy

This is a new requirement not previously called out in MIL-M-10304. It is defined as meaning all cardinal points shall be proportional to full scale deflection within 1/2% of full scale when checked in the following manner.

Adjust the pointer of the sample meter to zero on the upper volt scale using the zero corrector. Connect the meter with a variable resistor in series to a precise D.C. voltage source. Adjust the voltage source to a convenient D.C. voltage output. Adjust the variable resistor so that the pointer of the sample meter with the selected D.C. voltage applied is precisely at full scale. No further readjustment of the variable resistor is allowed. Adjust the voltage source so that the pointer of the sample meter falls precisely on each cardinal point on the upper volt scale. The voltage required to have the pointer of the sample meter fall on each cardinal point shall be determined. The accuracy of linearity shall be determined as follows:

$$\text{Linearity Error} \quad \% = \frac{1a - 1b}{1c} \times 100$$

1a = Actual value of excitation voltage output from precise voltage power required to produce the selected deflection to (each cardinal point).

1b = The theoretical value of excitation voltage output of precise voltage source for the selected deflection (each cardinal point) obtained by proportional values of actual full scale excitation.

1c = Actual value of excitation (voltage output from precise voltage source) for full scale deflection.

All the 100 microamps meters met the requirements and Table VII shows the actual errors for Type 11a which is typical of Type 11b.

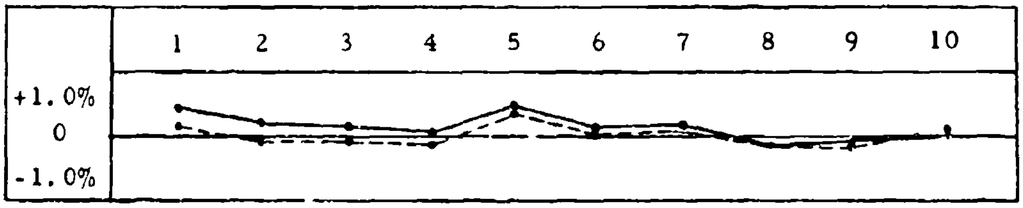
TABLE VII - Type 11a, 100 uA

Linearity Accuracy (Taken in Vertical Position)

SCALE	1	2	3	4	5	6	7	8	9	10
SAMPLE 1	+.38%	+.27%	+.37%	+.41%	+.43%	+.24%	+.36%	+.14%	+.18%	0
2	+.13%	-.05%	-.09%	+.01%	+.12%	-.04%	+.14%	-.06%	+.02%	0
3	+.17%	-.05%	-.10%	-.02%	-.01%	+.02%	+.04%	-.21%	-.20%	0
4	+.10%	+.01%	+.04%	+.11%	+.13%	-.01%	+.16%	-.03%	+.03%	0
5	+.02%	-.11%	-.12%	-.14%	-.18%	-.38%	-.20%	-.37%	-.17%	0
6	+.43%	+.23%	+.18%	+.08%	+.50%	+.14%	+.18%	-.16%	-.05%	0

TABLE VIII. Meter #6, Type 11a, 100 uA

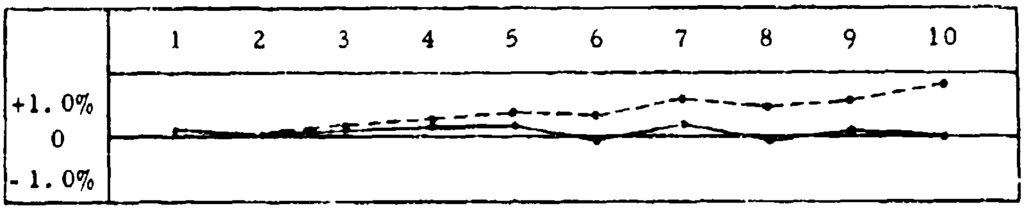
Vertical Linearity and Vertical Accuracy



______Linearity ----Accuracy

TABLE IX. Meter #4, Type 11a, 100 uA

Vertical Linearity and Vertical Accuracy



It should be noted the accuracy curves are taken from Tables IV and V and that when the basic accuracy check points are all unilateral from the nominal the linearity is better than the accuracy as shown in Table IX.

When the basic accuracy check points are bilateral from the nominal values as shown in Table VIII then the linearity is not as good as the electrical accuracy.

Four of the six Type 1, 40 uA meters had an error figure in excess of 0.5% - namely 0.68%, 0.55%, 0.93%, 0.58%. These errors occured about the mid-part of the scale. The reason for this has not been resolved.

G. Stickiness

As defined by the exhibit for this new requirement a d.c. current with less than 0.05% ripple and noise shall be applied to the meter under test. This current shall be increased slowly from 0 to 100% with stops at each of the cardinal points on the upper scale without over shooting and consequent backing down to the required value. The procedure shall then be repeated in the descending direction (If over shot occurs, the test shall be repeated starting at the beginning). The rate of change of current between each cardinal shall be gradual requiring 5 ± 1 seconds between each cardinal point. The current readings of the reference shall be read and recorded for each cardinal point on the meter under test in both the ascending and descending directions. The meter under test shall not be tapped, and shall move smoothly and shall not jump between cardinal points and the ascending and descending readings of the reference standard shall be within 1% of the cardinal point of the meter under test.

TABLE X. Stickiness, Maximum Error

SAMPLES		1	2	3	4	5	6
Type IIa	Ascending	.59%	.64%	.52%	.74%	.37%	.29%
100 uA	Descending	.80%	.71%	.79%	.68%	.31%	.77%
	Difference	.38%	.83%	.81%	.58%	.45%	.86%
Type IIb	Ascending	.54%	.55%	.50%	.48%	.26%	.34%
100 uA	Descending	.49%	.47%	.26%	.24%	.33%	.29%
	Difference	.74%	.72%	.35%	.27%	.31%	.35%
Type I	Ascending	.70%	.70%	.53%	.55%	.28%	.98%
40 uA	Descending	.50%	.35%	.60%	.40%	.28%	.83%
	Difference	.90%	.48%	.90%	.35%	.45%	.65%

As well as showing the current reading error in Table X we have added a line marked "Difference" which gives the maximum difference between the worst case ascending and descending readings. It does not necessarily have a relation to the ascending and descending numbers as these are the accuracy figures as called for.

H. Response Time

Steady electrical power sufficient to produce momentary end scale deflection shall be applied to the meter. The length of time in seconds for the pointer to come within 1% of full scale of the actual point of rest shall be recorded: The circuit resistance shall be 100,000 ohms to eliminate circuit damping effects. The average of five readings shall be taken.

TABLE XI. Response Time

SAMPLES	1	2	3	4	5	6
Type IIa Seconds 100 uA	1.77	2.1	1.74	1.81	2.2	1.86
Type IIb Seconds 100 uA	1.83	1.90	1.69	2.28	1.87	1.90
Type I Seconds 40 uA	1.97	1.89	1.72	1.80	1.96	1.87

The requirement per the exhibit was that response time was not to exceed 3 seconds.

I. Exposure to Extreme Temperatures

The accuracy error shall not exceed 2% over the entire temperature range from $-28^{\circ}C$ to $65^{\circ}C$ when determined as follows and measured as a voltmeter. The meters shall be maintained at a temperature of ;

$-28^{\circ}\,{}^{+0}_{-3}{}^{\circ}C$, $0^{\circ}\,{}^{+0^{\circ}}_{-3^{\circ}}$, $15^{\circ}+0^{\circ}C$, $35^{\circ}\pm 2^{\circ}C$, $50^{\circ}\pm 2^{\circ}C$ and $65^{\circ}\pm 2^{\circ}C$

for not less than 2 hours at each temperature, until thermal stability is attained. An accuracy measurement shall be taken at each extreme temperature in accordance with 4.7.5 of MIL-M-10304 except untapped readings shall be taken at each cardinal point. The meters shall then be subjected to a temperature of $85^{\circ} \pm 3^{\circ}C$ for 6 hours. The meters shall be returned and maintained at $25^{\circ}C \pm 2^{\circ}C$ for a sufficient time to attain thermal stability. The accuracy reading shall then be made at $25^{\circ}C \pm 2^{\circ}C$ except untapped readings shall be taken at each cardinal point. Whether or not the meters indicate freely at the extreme temperatures and at $25^{\circ}C \pm 2^{\circ}C$ without tapping shall be observed and recorded.

This advanced requirement by calling for check points between the extreme temperature limits occasioned considerable testing and investigation. During the formal testing a total of seventy readings were taken on each individual unit.

TABLE XII. Exposure to Extreme Temperature
Maximum Error as Voltmeter

Temperatures		-28°C	0°C	15°C	35°C	50°C	65°C	25°C
Type IIa	1	-.15%	-.96%	+.21%	+1.2%	+1.84%	+1.88%	+.58%
100 uA	2	+.68%	-.55%	+.54%	+1.39%	+1.94%	+1.96%	+.95%
	3	+.86%	-.22%	+.86%	+1.48%	+1.89%	+1.94%	+1.39%
	4	+.42%	-.56%	+.84%	+.79%	+1.61%	+1.77%	+.45%
	5	+.95%	-.75%	+1.38%	+1.45%	+1.99%	+1.97%	+.70%
	6	-.48%	-.97%	-.81%	+.63%	+1.08%	+1.47%	-.46%
Type IIb	1	+.30%	-.97%	-.94%	+.50%	+1.00%	+1.27%	+.26%
100 uA	2	+.33%	-1.32%	-.74%	-.47%	+.47%	+.85%	+1.07%
	3	-.54%	-1.47%	-1.43%	-.40%	+.72%	+1.05%	+.92%
	4	X	-.59%	-.45%	+.92%	+1.39%	+1.97%	+3.29%
	5	+.35%	-1.01%	-1.00%	+.25%	+.56%	+.70%	+.23%
	6	+.37%	-.85%	-.69%	+.27%	+1.04%	+1.34%	+7.58%
Type I	1	+2.46%	-1.03%	-1.23%	-.73%	+.56%	-.94%	+.59%
40 uA	2	+3.28%	-.91%	-1.11%	-.59%	+.78%	+.64%	+.96%
	3	+3.46%	-.40%	-.45%	+.75%	+1.08%	+.40%	+1.05%
	4	+2.94%	-1.71%	+.50%	+1.19%	+1.33%	+.73%	+.79%
	5	+2.58%	-.46%	-.69%	+.28%	+.84%	+.74%	+.93%
	6	+3.48%	-1.04%	-1.20%	-.85%	-.76%	-.98%	-.93%

A failure occured on Sample #4 of the Type 11b at -28 °C where no indication was obtainable. At 0°C the unit functioned and the rest of the test was then conducted. Unit #6 of the type 11b showed considerable increase in sensitivity after the soak at 85°C. It was left as is so the subsequent tests could be performed as they were not concerned with accuracy. It is likely that a resistor in the compensation network had shorted out.

As can be observed all the 100 uA meters met the requirement but the 40uA failed at the -28°C temperature.

J. Momentary Overload Capacity

It was required there be no permanent change in indication when subjected to 10 applications of a current equal to 10 times full scale value of the meters, to be applied nine times for 1/2 second each time with 1-minute intervals, followed by an interval of 1 minute, after which the current shall be applied for 5 seconds. After 1 hour the permanent change in indication shall be noted.

TABLE XIII. Change After Momentary Overload

SAMPLES	1	2	3	4	5	6
Type 11a, 100 uA	.22%	.23%	.29%	.38%	.57%	.25%
Type 11b, 100 uA	.23%	.19%	.55%	.20%	.15%	.33%
Type 1, 40 uA	.68%	.35%	.78%	.08%	.13%	.45%

Having no allowance for change is absolute and final. We will note our observations under recommendations.

K. Sustained Overload Capacity

It was required meters be energized with a current 20% greater than the end scale value for eight hours. After this time the load is removed and the temporary zero shift noted. After a further eight hours the permanent zero shift shall be noted and the permanent change in indication determined.

Allowances were 1% of full scale temporary zero shift
1% of full scale permanent zero shift
2% of full scale permanent change in indication

TABLE XIV. Sustained Overload Results

SAMPLES	1	2	3	4	5	6
Type lla, 100 uA						
Temporary Zero Shift	.60%	0	.60%	.40%	.80%	.40%
Permanent Zero Shift	0	0	.50%	0	. 2%	. 2%
Permanent Change	.25%	.09%	.17%	. 19%	. 27%	.27%
Type llb, 100 uA						
Temporary Zero Shift	0	0	0	0	0	.25%
Permanent Zero Shift	0	0	0	0	0	0
Permanent Change	.13%	.13%	.22%	.16%	.09%	.31%
Type 1, 40 uA						
Temporary Zero Shift	0	.25%	. 5%	. 5%	. 1%	0
Permanent Zero Shift	0	.18%	.13%	.14%	.23%	0
Permanent Change	. 6%	.08%	.43%	.35%	.65%	.45%

L. Dielectric Withstanding Voltage

The requirement is for 3000 volts A.C. 60 cycles to be applied between the terminals of the meter and the metal case and the terminals and the zero adjuster.

Here we are a little embarassed for it was known that extra air-gap clearance or insulation was needed between the pointer tip and the inside of the bezel. This was overlooked on the final samples and the meters flashed over at voltages between 2400 and 3000 V.

M. Insulation Resistance

The requirement is to measure the resistance offered by the insulating members of the meter to a d.c. voltage of 500 ± 10%. It shall not be less than 20 megohms.

Units 1, 2 and 3 of Type 11a, 11b and 1 all passed this requirement.

N. Seal

To meet this test the meters are submerged in water in an enclosure. The pressure within the enclosure shall be reduced to an absolute pressure equal to 2.5 inches of mercury and maintained for 4 hours and then returned to normal. After 4 hours at normal pressure the meters are removed, dried and examined.

All the meters met this requirement except for one that leaked around the zero adjuster. This was due to a loose lockwasher which was replaced and the test rerun.

O. Temperature Cycling

The meters are subjected to five cycles of 30 minutes at -55° +0° -3°, 15 minutes at 25°C +10° -5°, 30 minutes at 85°C +5° -0° and 15 minutes at 25°C +10° -5°. They are then examined for warping, cracking, discoloration or anything to affect the utilization

Samples 1, 2, 3 of each group met this requirement.

F. Moisture Resistance

After a 24 hour conditioning period the meters are exposed to ten cycles, each of 24 hours of temperatures from 25°C to 65°C and humidity from 80 to 98 RH.

The accuracy error shall not exceed 2% of full scale at every cardinal point and the frictional error shall not exceed 1% of full scale upon completion of the exposure.

TABLE XV. Moisture Resistance Effects

SAMPLES	1	2	3
Type 11a, 100 uA			
Accuracy	1.14%	1.69%	0.65%
Friction	0.57%	0.43%	0.47%
Type 11b, 100 uA			
Accuracy	.66%	2.29%	.38%
Friction	.53%	.48%	.32%
Type 1 40 uA			
Accuracy	.90%	.98%	2.23%
Friction	.98%	.45%	.70%

Two units, #2 of Type 11b and #3 of Type 1 failed to meet the 2% accuracy.

H. Friction Error

Is similar to G. Stickiness and is conducted in a like manner.

R. Impact Test For Windows

For this test the meters are solidly mounted, face up, on a heavy base. A 4-ounce steel cylinder, with a spherical nose of 1 inch radius is then dropped from a height of 8 inches onto the center of the visible window opening.

This test was performed on samples 1, 2 and 3 of Type 11a, 11b and 1 without trouble.

S. Thermal Shock by Immersion

In this test the meters are subjected alternately to 10 cycles of immersion in tap water at 85° to 88°C then 0° to 2°C. The length of time for each immersion shall be 20 minutes. Not more than 5 seconds shall elapse between immersions.

Sample 4,5 and 6 of Type 11a, 11b and 1 were subjected to this test without any deletereous results.

T. Vibration

Consists of going from 10 Hz to 55 Hz to 10 Hz in one minute at .06 double amplitude for two hours in three planes for a total of 6 hours. The units are vibrated from side to side, front to back and up and down. They are energized for five minutes and de-energized for five minutes throughout the testing period.

TABLE XVI. Vibration Effects

SAMPLES	7	8	9
Type 11a, 100 uA			
Accuracy	.48%	.78%	.70%
Friction	.90%	.50%	.27%
Type 11b, 100 uA			
Accuracy	.92%	1.39%	.73%
Friction	.19%	.40%	.49%
Type 1 40uA			
Accuracy	1.50%	.85%	1.05%
Friction	1.00%	.43%	.15%

U. Random Drop

The meters are screwed to a flange inside a cylindrical steel sleeve. The sleeve is loose inside a rotating steel square compartment fitted with baffles. It is rotated for 45 minutes at 6 revolutions per minute. It is a punishing and noisy test, equivalent to dropping the meter continuously about one foot to a hard surface from all possible angles.

TABLE XVII. Random Drop Results

	Sample No.	7	8	9
Type 11a 100 uA	Accuracy Friction	.57% .90%	.84% .46%	.57% .50%
Type 11b 100 uA	Accuracy Friction	1.17% .24%	1.03% .36%	.51% .38%
Type 1 40 uA	Accuracy Friction	1.73% 1.35%	1.23% .65%	1.65% .30%

V. High Shock

The meters are mounted to a steel panel in a normal manner and the panel is bolted to a high shock machine that drops a 400 lb. hammer 1 ft., 3 ft. and 5 ft. onto an anvil plate welded to the plate holding the instrument panel. The three blows in turn are to the top, side and rear of the instruments.

TABLE XVIII. High Shock Effects

	Sample No.	7	8	9
Type 11a 100 uA	Accuracy Friction	1.24% .80%	1.01% 1.66%	1.06% .27%
Type 11b 100 uA	Accuracy Friction	1.27% .34%	2.05% .26%	.45% .84%
Type 1 40 uA	Accuracy Friction	1.30% .70%	2.43% .45%	.78% .33%

W. Magnetic Field Effect

Placing the meter in a coil producing a steady magnetic field of 20 oersteds made a change in indication of about 0.3% at full scale, lowering to zero at the lower cardinal points. 1% was allowed.

Type 11a	.30% max. change
Type 11b	.32% max. change
Type 1	.28% max. change

X. Steel Panel Effect

Placing the meters on .09 inch steel panel made slight changes in indication as shown.

TABLE XIX. Steel Panel Effect

	1	2	3	4	5	6	7	8	9	10
Type 11a	0%	.26%	.18%	.16%	.09%	.02%	.10%	.18%	.02%	.03%
Type 11b	.09%	.16%	.12%	.13%	.11%	.10%	.09%	.07%	.03%	.05%
Type 1	.15%	.03%	.05%	.05%	.45%	.35%	.15%	.07%	.08%	.05%

It is believed the .45 and .35 are in error.

Y. Power Consumption

The terminal resistance in ohms of the units are 25°C was:

TABLE XX. Resistance

	#10	#11	#12
Type 11a, 100 uA	998	995	996
Type 11b, 100 uA	998	1003	1004
Type 1, 40 uA	1985	1989	1993

Tolerance of 100 uA 1000 ± 10 ohms.

Tolerance of 40 uA 2000 ± 20 ohms.

2. Damping Factor

The damping factor is measured by applying sufficient momentary power to deflect the pointer to full scale. After the pointer has come to rest the steady deflection is recorded. This test is made with 100,000 ohms in the circuit to reduce circuit damping. The damping factor is the ratio of the steady deflection in angular degrees to the difference between the momentary deflection and the steady deflection also in angular degrees.

The requirement is for a factor of 2 minimum. The meters tested were infinity: coming to rest without overshooting the rest position.

It would be possible to engineer the movement to be critically damped when overshoot is present but does not exceed an amount equal to one-half of the rated accuracy of the instrument (ASA. C39.1.1964 Para. 3.17)

PART II

RECOMMENDATIONS:

As a result of this program and an analysis of the test results the following comments are presented. In an effort to be as objective as possible some of these remarks will take issue with some earlier statements and decisions. If a reconsideration of an approach or an objective indicates we should change our thinking we feel this is pertinent to this report

a. Scale Length

The contract calls for a 5 inch minimum scale length for the longest scale which we were unable to attain due to the space required by the bezel at the sides and top in order to obtain an effective watertight seal to the case. The top scale length of the dials shown in Figure 2 is 4-3/4 inches.

Recently the Army Signal Corps have been circulating a specification for rectangular taut band multimeter indicators in which they call for a 4-3/8 inch minimum scale length. Possibly a compromise of 4-1/2 inches could be adapted so there would be one industry standard with a competitive market position for the Services.

b. Case Size

The barrel of the meter case is of such a size that it appears it is a hold-over of a design that was able to accomodate multi-ranges with three or four terminals and had internal space for heavy shunts or many resistors. However we are only concerned with a single range and the few small components for temperature compensation.

If the barrel is shortened from 1-15/16" to 1-3/16" long and reduced in diameter from 3-3/8" to 2-3/4" it would still be adequate to accept any manufacturers mechanism. The terminal location presently shown would have to be changed.

c. Rotational Influence

This is actually a combination or lumped accuracy test which combines position influence and accuracy by requiring readings to be taken in both the commonly used positions, horizontal & vertical. We believe it is a good practical test but that it makes the separate position influence and accuracy tests redundant, whicl. is our case for suggesting they could be dropped.

d. Stickiness

The changes in current readings at the cardinal points whilst taking untapped ascending readings and comparing with untapped descending readings are occasioned by hysteresis of the bands, magnetic impurities in the moving element, deviation from perfect balance.

If it is the function of this test to obtain comparative data of meters we think that the amount of change is a more important factor compared with the 1% accuracy tolerance the specification requires. It is possible for a meter to be at the limit of 1% accuracy and with an extra friction error, technically fail to meet the requirement.

e. Temperature Effect Tests

Because of the mass of these units it was found that 2 hours was insufficient time to allow the meter to attain temperature stability. The time was therefore increased to 4 hours to attain stabilization.

It is proposed that an extra requirement be added. Before the tests start the accuracy of the meters, measured as a millivoltmeter at 25°C should be recorded. Then after all the tests the values can be compared with the final 25°C values.

The tolerance of the current (100 uA) value is 1% and the tolerance of the terminal resistance (1000 ohms) is 10 ohms or 1%. It is therefore possible for the reading of a meter as a voltmeter to show a 2% change when it meets the 1% current and resistance values.

Nominal 100 uA, 1000 ohms = 100 millivolts
Allowable 99 uA, 990 ohms = 98 millivolts
or 101 uA, 1010 ohms = 102 millvolts

It would therefore seem expedient to extend the tolerance band when subjecting meters to the temperature compensation tests.

f. Momentary Overload Capacity:

The specification allowed no change in indication due to this test of 10 times overload. (MIL-M-10704) gives 2% for 2% type meters). We believe it would be practical and consistant to allow 1% tolerance change after this test.

g. Linearity Accuracy

It seems that this test is almost identical to Para. 3.39 Tracking (Electrical) of ASAC39.1.1964. Some concern was felt at meeting a true linearity requirement of equal current increments versus equal angular deflection but as the linearity accuracy test procedure did not call for this the results turned out somewhat encouraging. However, should it be termed a Tracking accuracy or a Linearity accuracy?

h. Vibration

i. Random Drop

j. High Shock

These three tests are performed as a group; MIL-M-10304 allows 5% accuracy and 5% friction as a maximum after each and all tests. The exhibit requirement was for 2% accuracy and 0.5% friction.

The results showed increasing degradation with each test and two units (out of 9) failed the accuracy test, being 2.05% and 2.43%. Four units failed the friction (stickiness) test being 0.8%, 1.60%, .84% and .70%.

It is suggested that if 2% accuracy is deemed critical that one failure in four be allowed which would be in line with MIL-M-10304 and that for friction the tolerance be increased to 1%.

k. Case Terminals

1/4 x 28 threaded terminals are fine for 50 amps but we are only interested in 100 microamps, so we would propose they be replaced with glass to metal terminals soldered to the case. This would provide increased life reliability as opposed to two rubber gasket seals on each terminal stud and would take up less space.

l. Window Material

MIL-M-10304 Para. 3.5.4.2 allows the window to be of any material free from detrimental defects that would prevent the meter from being easily read.

A 1% meter is looked upon as a precision device but this accuracy is wasted if it is not optically easy and quick to read.

The polycarbonate plastic used for the windows meets all the environmental requirements and impact tests, but - there is no doubt the surfaces are inclined to have slight waves that introduce some distortion. Cleaning the front with a soft cloth that picks up small dirt particles will slightly abrade the surface Even the application of the necessary anti-static compound and the consequent wiping off produces a slight fogging effect. For a quality item that has to be closely read we now feel that a tempered glass window should be mandatory.

This would mean that for the RFI units the deposited conductive film would have to be used which is not so good an attenuator as the metal mesh above 18 MHz.

m. Mirror Scale

For the same reasons advocated for the window it is suggested that glass be used for the mirror.

n. Moisture Resistence

As two units did not meet the requirement of being within 2% accuracy after this test we feel that consideration could be given to rewording the requirement to agree with Para. 3.23 of MIL-M-10304. "..... The maximum allowable deviation following this test shall be 2 percent greater than the stated accuracy of the meter....."

CONCLUSION

One hazy area left is called by many names by different people, which is perhaps indicative of the vagueness of this area. Whether called friction, sticktion, stickiness, hysteresis or repeatability and whether caused by contamination, slippage, hysteresis, damping or magnetic impurities, the problem is real and shows up as a lack of determination of the true reading. It is undoubtedly more apparant with this size meter as the longer scale allows a greater resolution of readibility and a change of 0.1% is noticable.

Apart from this it is believed there is no need for further investigation as the acceptable possibilities of these units are now known to a much greater degree than previously; the proposals for changes in material can be considered minor and not critical and can be resolved by any competent manufacturer.

Any doubts that may have existed about the ability of the taut band to sustain the tests may be forgotten. No bands broke during the tests.

In regards to feasibility of production there are no reasons why these units cannot be produced in quantities, subject to usual dimensional control on parts, adequate in-line inspection and overall quality assurance.

PART III

SUPPLEMENTARY DATA

Statistics For A 5" Taut Band Mechanism

100 Microamps

Coil dimensions	.54 x .48 x .12 inches
Coil Winding	500 Turns
Coil resistance	435 Ohms
Weight of moving element	540 Milligrams
Size of ligament	.0048 x .00048 inches
Effective length each ligament	0.20 inches
Ligament material	Platinum, silver (90/10)
Breaking point of ligament	17.6 ounces - 500 grams
Restoring torque of ligaments	32 milligram centimeter for 90°
End spring tension	108 gram for both springs
End spring rate	3.85 grams per .001 inch
Magnetic flux in gap	4000 gauss

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13. ABSTRACT

A total of thirty-six meters were assembled consisting of three lots of twelve each of the following types.

Type I. 40 microamps 2000 ohms. Temperature compensated.
Type IIa. 100 microamps. 1000 ohms. Temperature compensated.
Type IIb. 100 microamps. 1000 ohms. Temperature & R.F.I. compensated.

These were further broken into groups and subjected to performance and environmental tests as directed.

Whilst all the objectives were not attained one hundred percent, substantial improvements for military type meters both initially and during regular field service can be realistically anticipated.

It is reasonable to expect a ruggedized long scale (4-3/4") precision (1%) taut band meter to be usable in any position, over a wide range of temperatures, (0 - 50 C) that can be overloaded (x10) and dropped (1 ft.) and still maintain its original accuracy during and after any combination of these conditions.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Meters						
Torsion Meters						
Measuring Devices (Electrical)						
Suspension Devices						
Suspension Bands						

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