



**EDDY CURRENT TESTING FOR NON-FERROUS METALS AND ALLOYS**

**VERIMET<sup>®</sup>**  
**PORTABLE**  
**CONDUCTIVITY TESTER**  
**MODEL M4900C**  
**OPERATION MANUAL**

## **PROPRIETARY INFORMATION**

This document and the subject matter disclosed herein include proprietary rights of Verimation Technology, Inc. This manual has been prepared for the express and sole purpose of assisting operating and testing personnel in the efficient and accurate use of the M4900C Conductivity Meter. This portable Verimet<sup>®</sup> uses patented state-of-the-art techniques. Neither this document nor the information disclosed herein shall be reproduced or transferred to other documents or disclosed to others for any other purpose, except as specifically authorized in writing.

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**TABLE OF CONTENTS**

INTRODUCTION .....	1
M4900 VERIMET CHARACTERISTICS .....	3
Eddy Current characteristics .....	3
Instrument Specifications .....	3
Norm/Off/Comp Switch .....	3
Comp Adjustment Knob .....	3
Probe Cable Assembly Plug-in.....	3
Probe/Cable Assembly .....	4
AC Adapter/Charger.....	4
Instrument Specifications .....	4
Figure 1: The M4900C Verimet.....	5
OPERATION .....	6
Measurement Fundamentals .....	6
Norm Mode .....	6
Comp Mode.....	7
Comp Adjustment Knob .....	7
Battery Operation.....	7
Basic Accuracy .....	7
Operational Accuracy.....	8
Standards.....	8
Temperature Compensation.....	8
Edge Effect.....	9
Lift-off Effect.....	10
Thickness Effect.....	10
Technical Notes .....	11
FIGURE II .....	11
CONCLUSION .....	12

## INTRODUCTION

We believe that the portable M4900C is the simplest and most accurate conductivity tester available. It is a direct reading DIGITAL instrument in the true sense of the word, calibrated to read I.A.C.S. conductivity (the International Annealed Copper Standard) from 12% TO 110% I.A.C.S. This conductivity tester was designed to move 0.5% accuracy from the lab to the plant and on the line where it's needed. It retains the simplicity and stability that have made the Verimet popular. We hope it sets a new standard and moves the state-of-the-art forward.

To operate the tester, simply plug the unit's charger in, turn the unit to COMP and start testing. Test a metal part's conductivity by holding the probe by its body and position the face of the probe flat against the metal surface. The conductivity will be displayed as a simple number, like 61.2 (the indication for nearly pure, annealed aluminum).

It must be understood that conductivity is a function of temperature. Try holding a standard in your hand while reading the conductivity to show the effect. An increase in temperature of the test sample will result in a decreased conductivity reading, whereas a drop in the test sample's temperature would produce an increase in conductivity reading (for most metals). The change of conductivity may be as much as 2% every 5° C (9° F).

The M4900C features temperature compensation, using a single COMP control to adjust readings to calibration standards. An accurate progressive compensation technique using the single COMP control achieves ½% field accuracy for aluminum, without the "curve-bending" used with analog instruments. This unique combination of linearity-of-response and automatic tracking of temperature coefficient make this instrument both very accurate and very easy to use. Like a modern voltmeter, it virtually carries its own internal standard.

The displayed conductivity may also be affected by sample thickness and sometimes by geometric factors. The probe can "see" small areas around it as well as directly to the front. These are considered to be interfering factors which you should be aware of. For more information, see the ACCURACY section.

The M4900C series Verimet instruments measure electrical conductivity using a variable frequency technique. As a result, they not only share the advantages of traditional designs but improve on them considerably:

- a. Direct nondestructive testing.
- b. No contact required between test probe and material.
- c. Rugged portable construction.
- d. Sensitivity.
- e. Accuracy.
- f. High speed operation.

## **INTRODUCTION (continued)**

In addition, the M4900C provides several new enhancements compared to conventional conductivity testers:

- g. Linearity - a linear response over the entire range with no gain setting or lift-off adjustment necessary.
- h. Simplicity - a single COMP control to compensate for temperature changes, material thickness, etc.
- i. High sensitivity to changes in conductivity due to temperature, hardness, stress, or deformation.
- j. Stability - digital design does not need periodic balance, null, or sensitivity adjustment.
- k. Interchangeability of probes.
- l. Constant penetration depth, regardless of material or conductivity.
- m. Repeatability: does not use a bridge-type measurement; hence is not sensitive to noise, instrument temperature, or external changes in hand capacitance, etc..
- n. Exceptional lift-off range due to advanced detection techniques and probe design.
- o. Predictable readings on thinner materials.
- p. Minimal edge effect - small fixed size of eddy current field allows measurement of small areas.
- q. Digital output (via LawTalker option) to printer, computer, plotter, etc.

## **OTHER USES:**

Electrical conductivity is a very sensitive barometer for the detection of defects and for sorting conditions such as heat treat or temper, hardness, case depth, aging effects, etc. It is widely used in the aircraft industry for alloy sorting and defect testing.

## VERIMET M4900C CHARACTERISTICS

The Verimet M4900C Conductivity Tester (see Figure I) is a portable battery powered direct-digital-readout instrument, which measures the electrical conductivity of non-ferrous metals and displays the result in percent IACS. It has true linear response and 0.1% resolution over the range of 12% to 110% IACS.

### INSTRUMENT

The Verimet M4900C Conductivity Meter is a rugged cast aluminum construction portable instrument with a simple carrying handle. To simplify operation, a single knob controls temperature calibration. A transducer (probe) is placed on the sample (unknown value), and readout occurs automatically.

### NORM/OFF/COMP SWITCH

In NORM mode (the upward switch position), the instrument reads actual conductivity and the COMP control will not affect this “calibrated for lab” reading. In the center position the instrument and power are disconnected. In COMP mode (the downward switch position) the instrument reads compensated conductivity from a standard or unknown sample at the test temperature. Readings are then adjusted by turning the COMP control.

### COMP ADJUSTMENT

This control compensates for temperature or other effects under variable conditions by adjusting the reading to a preset lab condition. 20° C is the IACS specified standard temperature.

### PROBE/CABLE PLUG-IN

The plug-end of the 4900M216-Probe/Cable assembly has a female latching connector keyed for correct installation into the top of the instrument. It is precision made from a rugged metal and Delrin housing.

### IMPORTANT

The 4900M216C Probe/Cable Assembly is similar in appearance to older probes (such as the 4900M202). ***It is only compatible with the M4900C Verimet instrument.*** All 4900M216C probes are interchangeable among C type instruments. ***For maximum accuracy, use only the probe(s) that came with the instrument.***

## **PROBE/CABLE ASSEMBLY**

This probe/cable assembly has optimum operating lift-off over a much wider range than previous probes. Spacings from 0 to 0.025 inch will change the reading by less than 0.5% IACS (often, little change occurs to as much as 0.05 inch lift-off, from 12% IACS up through the entire aluminum conductivity range to about 65%).

## **AC ADAPTER/CHARGER**

When plugged into the unit's side receptacle, the AC adapter provides external power for operation and for charging the internal batteries. When the instrument is ON the charge rate is reduced to a moderate level. A full charge (which lasts from 12 to 18 hours of continuous operation) will take about two days. To charge the unit fully when OFF takes 8 hours. While not under charge (in portable operation), the decimal lights begin to glow when you have 15 minutes of accurate use remaining. All units are cycled from full to zero charge before shipment.

## **INSTRUMENT SPECIFICATIONS**

### **SIZE**

Height: 6-3/4" (17.2 cm)

Width: 3-3/4" (9.5 cm)

Depth: 2-3/4" (7.0 cm)

Front Face Mount Carry Handle: 1-1/4 inch (3.2 cm)

### **WEIGHT**

2-1/2 lb. (1.13 kg.)

### **POWER**

AC Adapter Power Supply Model 2700

115 VAC

50 /60 Hz

Battery (rechargeable NiCad)

**READOUT**

Digital - 4 digit LED display, 0.4 inches (1.0 cm) high

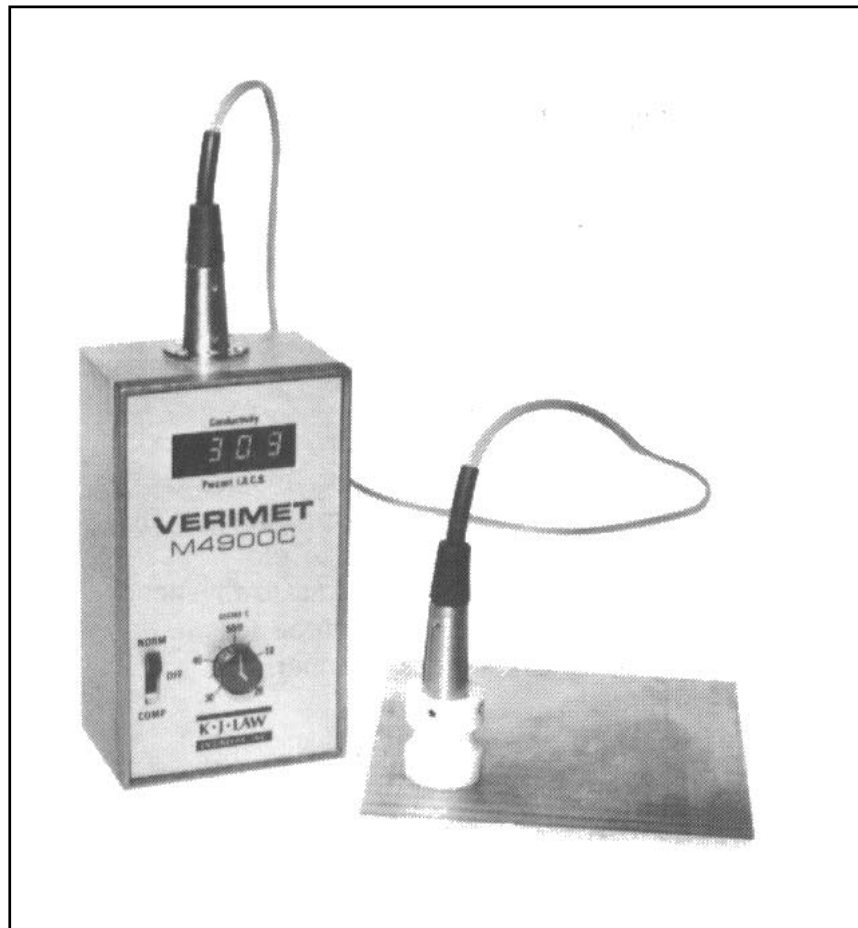
**AC ADAPTER/BATTERY CHARGER**

The model 2700 115 VAC-Adapter/Battery Charger can be plugged into the unit's side receptacle. It provides external power to the unit and charges the batteries.

**NOTE**

Optional calibration in MegaSiemens is available.

(100% IACS copper reads 58.0 MS).



**Figure 1. Verimet M4900C Accurate Conductivity Tester**



## OPERATION

### MEASUREMENT FUNDAMENTALS

With the switch left in the COMP position, place the probe on a conductivity standard of which the value is known. Turn the compensation dial until this known value appears on the instrument display. Leave the unit in this mode and the COMP dial at the setting obtained. Other samples of similar conductivity will automatically be compensated. The instrument is now ready for operation in the field or lab.

It is desirable to use a standard near in value to, or slightly higher than, the part being tested (see Operational Accuracy). Both parts must be at the same temperature. Whenever a significant part temperature change occurs the compensation dial must be re-adjusted. A periodic check using the known standard should be performed for this reason.

The other operational mode is NORM, and is not intended for field use because the COMP knob has no effect. The unit is factory calibrated in this way so NORM mode serves as a reference to measure the samples absolute conductivity. The sample's temperature coefficient is the ratio of conductivity change to temperature change (using 20° C as the reference is standard IACS practice). If you already know a sample's IACS conductivity value and temperature coefficient you could calculate its absolute conductivity at room temperature (see temperature compensation, page 7). With the Verimet it is simple to derive temperature coefficient by subtracting NORM from COMP readings and dividing by the temperature difference.

### NORM MODE

In NORM position, the unit will read the sample conductivity directly, but is NOT to be used this way in the field. NORM mode should only be used to "normalize" or to bring the unit to factory calibration and is not valid except at 20° C (68° F) coupon/standard temperature. This mode is not (as the name might first imply) intended for field use where temperatures vary widely, but only means that COMP mode has been disabled. However, it is sometimes useful (about every half hour) to record the NORM readings for comparison against COMP readings. The difference in readings for a sample (between NORM and COMP) permits calculation of the material's temperature coefficient.

A reading obtained in this mode of operation is the true conductivity of the sample being tested, not the rated IACS value. Usually, however, the IACS value is obtained by comparison against a known standard as with other less precise instruments.

## **COMP MODE**

This is the suggested operational mode in most cases because it corrects for temperature changes of the sample. Setting the switch to COMP enables use of the compensation dial. Operate the instrument in this mode whenever the temperature is not 68° F (20° C).

## **COMP ADJUSTMENT**

This control compensates for temperature or other effects by adjusting the reading to a preset lab condition under variable conditions (20o C is the IACS specification). By definition, IACS conductivity is obtained only at this standard temperature. When this adjustment is made, a sample should read at room temperature exactly what it would read in the NBS laboratory. Notice, therefore, that when the knob is set right at 20, no change in reading occurs from the NORM mode.

1. While the switch is in NORM mode, the compensation knob has absolutely no effect on the instrument reading.
2. The International Electrotechnical Commission chose to specify conductivity by volume resistivity because thermal expansion and resistivity coefficients must both be considered.

## **BATTERY OPERATION**

We recommend you first read this short charging procedure before routine operation.

1. Insert AC adapter/charger connector into the instrument.
2. Plug AC adapter/charger into 115 VAC outlet.
3. Set the switch to “OFF” position and let the unit charge for approximately 16 hours.

### **CAUTION**

***DO NOT charge the unit for prolonged periods (days or weeks) or battery life may be reduced. Operating the batteries to a complete discharge on occasion will not harm them and could insure full capacity accuracy***

## **BASIC ACCURACY**

This instrument combines 0.1% resolution and exceptional stability with precision calibration. The M4900C reads conductivity within 0.5% over the range from 12 to 110% IACS. Before we certify the instrument, it must read a set of 9 conductivity standards with 0.2% of ascertained value under rigidly controlled conditions. The coupons used are NBS traceable.

Conductivity is an intrinsic characteristic which this instrument measures but there are interfering variables which are discussed below.

## OPERATIONAL ACCURACY

### Standards

Conductivity is usually determined by comparison of test objects against known standards. These are coupon blocks about 1-1/4 inch square (or larger) and 1/4 inch thick. We use the standards supplied by Boeing Industries as well as our own. Both are available options for use with the Verimet.

Any standard used has an uncertainty of its own. According to people who calibrate conductivity standards, the uncertainty levels are due partly to the instrumentation presently available and partly to the manufacturing methods of the standards themselves. For this reason, we cannot flatly state that your standards will agree with those used in our calibration. In fact, our level of precision may reveal some differences previously unknown. We see this as a challenge for coupon standards of more uniformity and accuracy.

We recommend calibration with two or more standards, starting with a higher value than the unknown. Otherwise, the uncertainty error of a low standard can be multiplied in the higher ranges (because higher temperature coefficient increases with conductivity). Note that maximum accuracy is obtained when the difference between the standards does not exceed 20% IACS. For more information about standards and calibration procedures see the technical reference section.

The M4900C has both progressive compensation and linear response. Therefore, calibration on two standards (which have different temperature coefficients) is done as accurately as possible.

### Temperature Compensation

The compensation dial does not really alter the basic calibration (which is internally set at the factory) but rather changes the reference temperature (68o F) of this calibration to that at which the COMP dial is set. Unlike traditional comparison methods, the instrument balance itself does not change at all. Yet the digital reading is offset just the amount required by the material temperature coefficient.

Examine the following formula to see how actual conductivity is affected by temperature:

$$C(T) = C(20) [1+TCF(20-T)]$$

The M4900C directly measures C(T) and calculates C(20), the IACS value as if actually measured at 20° C (68° F). The TCF (Temperature Correction Factor) is often listed with the IACS value on the certification sheets of conductivity standards. Typical values usually range from 0.002-0.004, resulting in 0.25% - 1.0% IACS changes even for a minor temperature change of 10° F.

The interesting thing about this change is that the required offset changes quickly with conductivity. In the case of pure aluminum, the real conductivity will change about 1% IACS for a temperature change of four degrees Celsius. For other conductivities the change is dramatically less. During development of this instrument we changed the temperature of some conductivity standards by 10 degree increments and made it track the resulting conductivity changes. Progressive Compensation is the result, so that by adjusting COMP for the correct reading on one standard you will also get the correct setting for a similar standard of different value.

What happens if a simpler non-progressive method of compensation is used instead? This is best illustrated by an example based on the rather extreme temperature of 42.5° C (109° F). The measurement of three standards of known IACS values results in the following:

- 60.0% @ 20.0° C (68.0° F)
- 44.9% @ 20.0° C (68.0° F)
- 29.2% @ 20.0° C (68.0° F)

<b>NORM @ 42.5°</b>	<b>COMP @ 60.0</b>	<b>COMP @ 29.2%</b>
54.7% (-5.3)	60.0% (+0.0)	57.8% (-2.2)
41.9% (-3.0)	45.9% (+1.0)	44.2% (-0.7)
27.9% (-0.0)	30.3% (+1.1)	29.2% (-0.0)

In contrast, the M4900C instrument read within 0.2% of the IACS values above.

Without “Progressive Compensation” the error of measurement depends strongly on whether a higher or lower standard is used in calibrating the instrument for the sample temperature. With the M4900C set to 42.5° C, the three standards listed above measure within 0.2% IACS. The chart illustrates what happens without this patented method.

Only at the 20° C setting do the COMP/NORM mode readings correspond. At other temperatures, the unit will effectively compensate for any temperature difference above or below the 20 degree (factory-norm) setting. This really works well for the Boeing standards we calibrate to. The COMP setting tracks actual temperature within 3° C on their coupons. We recommend, however, that anyone not using Boeing standards first recalibrate accordingly.

On this basis, we can make an offer you probably never heard before. Because of the temperature calibrated COMP control, it is possible to fine-tune the Verimet response to your own standards:

Set COMP to room temperature (actually the standard’s temperature) and then re-adjust a vernier control (R32) inside the instrument to give exact agreement to your standards.

Now this probably won’t help you unless very fine accuracy is required for the temperature calibration of the COMP knob. If temperature accuracy of the COMP knob is of no concern to you then this is unnecessary and not recommended. If you do proceed to adjust R32, be cautious of the instrument’s battery connections while opening or closing the case.

### **Edge Effect**

Edge effect is caused by electromagnetic fringe flux and the finite size of the probe in relation to the sample being measured. Ideally, the sample size should be 1.25 inches square or larger. The probe has a larger area of influence than it’s face size. To demonstrate edge effect, move the probe away from the center of the standard and the reading will begin to change. With a standard size coupon it is not noticeable until the edge of the probe approaches within ¼ inch of the edge of the standard.

### **Lift-off Effect**

This probe/cable assembly (4900M216) has optimum lift-off over a wider range than previous probes. Spacings from 0 to 0.025 inch will change the reading by less than 0.5% IACS, from 12% up through the entire aluminum conductivity range. Other instruments must provide another adjustment to minimize the change in lift-off effect with conductivity range. We think you will find the operational lift-off range of this instrument and probe to be quite exceptional.

### **Thickness Effect**

This effect can cause errors with any eddy current tester and you should understand why it happens. Both conductivity and frequency affect eddy current “penetration depth.” The eddy currents are stopped more quickly in a high conductivity metal but can penetrate deeper if the frequency is sufficiently low (see technical notes, item 2). In some cases the test material allows some fraction of these currents to penetrate entirely through a thin sample.

Unlike the Verimet, other conductivity testers have a different penetration depth for each conductivity as they operate at one frequency. They must use a different curve for each conductivity. With our method, the one-sigma depth constant remains fixed and the depth of penetration doesn’t change. The normalized curve of Figure II applies to any nonferrous material within the measurement range, regardless of conductivity. The effective penetration depth of the Verimet is a constant 0.050 inches!

Usually, this penetration depth is difficult to calculate. Both conductivity and frequency must be known beforehand. However, the M4900 series Verimet holds this depth constant by adapting the frequency to the conductivity. Any sample 0.05 inch or thicker can be measured without any error from penetration through the part. For thinner test pieces there are methods for offsetting the resulting error. For example, the curve shown in Figure II plots the response error of our Verimet. Just “normalize” your data according to the sample thickness you have. The COMP knob may be used to correct for smaller errors.

The shape of this curve is the same so that a sample 0.015 inch thick will read 80% of its true conductivity. In fact, the curve is so linear up through this point that a slope of 5%/mil approximates the thickness response. In effect the Verimet can be used to measure thickness! Or just measure your sample’s thickness and derive the conductivity per Figure II. Of course, we suggest that you generate a data curve with your particular instrument for maximum accuracy.

### **NOTE**

The total (effective penetration depth) of eddy current penetration in nonferrous metals is approximately defined as:

$$\text{depth (inch)} = 26 / \text{square-root} (\text{COND} \times \text{FREQ})$$

where: (COND in IACS %)

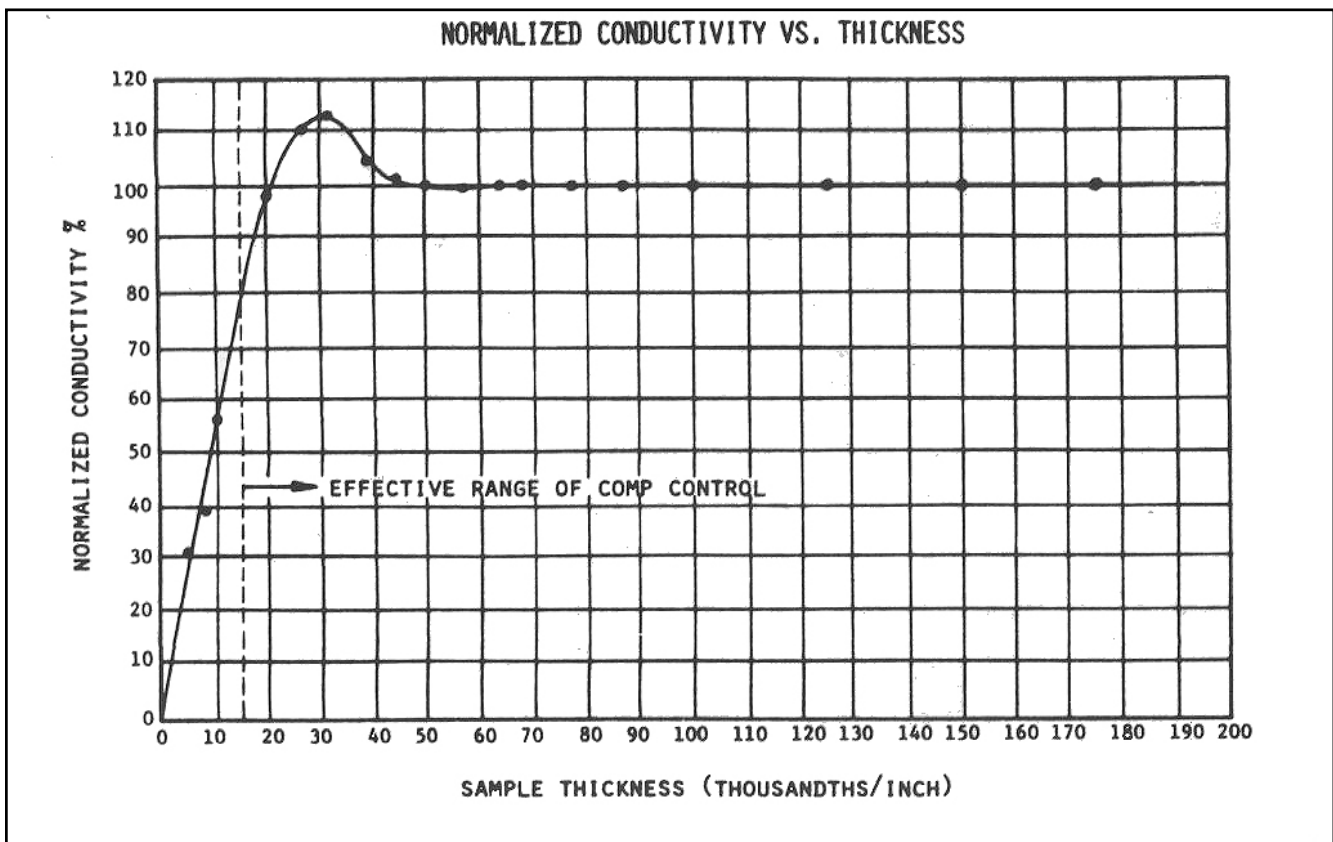
(FREQ in Hertz)

**Technical Notes**

For more information about eddy current testing of conductivity (especially for aluminum) see:

1. American Society for Testing of Materials: ASTM document B193 - Resistivity of Electrical Conductor Materials.
2. ASTM document E1004-91: Recommended Practice for Electromagnetic (Eddy Current) Measurement of Electrical Conductivity.
3. Boeing Aircraft Company, BSS7351 (B): Temper Inspection of Aluminum Alloys
4. Douglas Aircraft Company DAC 25-2171: Eddy Current Conductivity Testing - Equipment and Procedures.

Eddy current testing utilizes electromagnetic fields which cause pulsating currents within the metal being tested. These currents flow in patterns which change according to the material properties of the metal, especially it's conductivity. Without doing more detailed analysis you might guess that higher conductivity would mean that such currents would flow more easily. That's true but they also penetrate less deeply into the material at a given frequency because the stronger currents tend to counteract deeper penetration.



**Figure 2. Normalized Conductivity VS Thickness Plot Illustration**

## **CONCLUSION**

Under ordinary conditions the M4900C is unaffected by electrical interference, hand capacitance, moisture, or instrument temperature. Normal precautions will assure consistent and accurate readings under most conditions. The instrument's precision will enable the operator to notice many small conductivity changes often masked by drift or reference errors in other instruments.

Applications vary widely for an instrument of this type. Previously, eddy current testers were nothing more than comparison tools. The M4900C offers a new level of precision to the industry, provides wide range temperature compensation, and a new digital output capability. We envision the metallurgical and quality control personnel with a powerful new tool. If you find an unusual application, have any difficulties, or are just plain happy with the instrument, please call or write to let us know. We will gladly answer questions and spread the word about your application, or help you invent new ones whenever possible. Feel free to contact us at:

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