The Ω-CHECK® Users Guide

This User's Guide provides the requirements and recommendations for the setup and operation of the **Ω-Check®** to ensure that accurate, reliable, and repeatable test results are gathered. It does not replace the Operators Manual that comes with the instrument but supplements it with additional information. **The OM should be read thoroughly and referenced when setting up the instrument.** There are connections that must be made properly and to the correct locations for the instrument to function. It is best if the user reads and learns the operational requirements and understands the theory of operation before energizing the set. The operator must also know the specifications for the cable being tested to enter the correct data to permit the instrument to return meaningful and accurate test results. Following are further detailed instructions in the use of the machine to help users gain its fullest capabilities and be confident of the test results. Included are technical explanations offered that will help you to better understand how the instrument works, alternative methods of use to apply the instrument in ways and situations to extend its effectiveness, and several "Tips and Tricks" are offered to enhance your efforts in using this instrument.

The Ω-Check® - Tests Neutral Corrosion with Cable Energized

Find and Replace Bad Neutrals

Also use the Ω-Check® for: Substation Ground Cable Integrity Testing

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To make best use of your time and the capabilities of the **Ω-CHECK®**, be prepared for your testing. There are several functions that should be performed, and cable data gathered before leaving the shop to test. Below are several recommendations to help make your testing efficient and accurate.

Be Prepared Before You Test – Steps To Help Improve Your Success

Prior to testing any cables, first learn what is needed to help make your work successful. Do not approach the test with little knowledge of how the connections are made, how the product functions, and the conductor and neutral wires specifications. Know how the instrument works to determine the condition of the neutrals, the test leads and connections made from the instrument to the cable, the physical and electrical specifications of your neutrals, and what to expect from the test results. From pre-test calculations made, know what to expect before testing to help ensure the equipment and connections are correct and the results reported seem reasonable. Watch the units of measure. For example, the **Ω-Check®** reads R/100' (or Ohms/100') while most cable charts list Ohms/1000'.

Know The Instrument Is Working Properly And All The Parts Are Present

Perform the pre-use checks detailed in the Operators Manual. Verify the meters and LCD display read correctly.

Verify all the cables and jumpers needed are contained within the HVI auxiliary equipment bag.

Have your AWG wire measuring gauge or some other means of measuring the diameter of the neutral strands.

Have The Data For The Cables To Be Tested, Ready, Most Notably:

The wire size of the neutral strands. Use the wire size measuring tool provided, or a micrometer, to measure the actual diameter of the neutral strands and the conductor. The AWG (American Wire Gauge) chart is included within the manual. (**Caution:** some cable produced outside of the US does not strictly follow the sizing chart from the AWG for physical size and resistance. Measurement of the wire diameter may be necessary, followed by the interpolation of its resistance between two other wire sizes from the chart.

The number of neutral strands. An accurate count of all strands including any drain wires that are still part of the neutral bundle carrying the test current from the **Ω-Check®**.

The length of the cables to be tested (including unseen extra cable loops in vaults or manholes).

Calculate the Expected Data to Verify the Reasonableness of Results

Know the R/L (Resistance/100 of the neutral when new to compare to that measured in the future.

Know the RES (Resistance of entire neutral) when new for benchmark when reading field test data.

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This section will explain the several data input parameters the users must meet to ensure the accuracy and dependability of the test results. Prior to using the machine, the operator must enter data about the cable neutral under test. The quality and accuracy of this data entered will determine the same of the test results gathered. Enter complete and accurate data.

⚡ **Accuracy of the Test Results is up to the Accuracy of the Operators Data Input**

The physical specifications of the neutral wires to be tested must be known to perform the test properly. The accuracy of the output data reported from the instrument after a test will only be as true and reliable as that of the data entered before the test. The instrument measures and calculates the integrity of the neutral thru analyzing the voltage and current through it, calculating its resistance, and comparing the results to a similar cable in perfect condition: comparing the real to the ideal. The ideal is determined by the input data entered prior to the test.

Three parameters to enter:

1. **# Of Wire Strands** comprising the neutral, usually **12, 14, 16,** etc. The neutral is assumed to be round copper.

2. **AWG Wire Size** (American Wire Gauge standards)

3. **Length** of the cable

```
NO. STRANDS:   20
STRAND SIZE:   14 AWG
CBL LENGTH:    0000 FT
TEST NO:       0012
```

Data Entry Screen

Of Wire Strands

It is vitally important to accurately count the number of wire strands comprising the neutral. Also, inspect to see that all strands are together as one neutral bundle going down the cable. On many cable terminations, one neutral strand is used as **drain wire** for the cable termination to provide a ground point to eliminate and buildup of electrical charge that might occur while the cable is operating. If this is not connected to the rest of the neutral strands, it may not carry the test current. In this case, the test results would indicate that this strand is open, when in fact it may not be. Since this can occur on different strands on each end of the cable, two strands may not carry test current.   This may yield overly pessimistic results. If possible, ensure that all neutral strands are twisted together so that the test current passes through all strands. In many instances, a short length of wire with alligator clips is useful for bonding stray strands to the bundle of neutral strands. *For more on the Drain Wire, refer to the next section of this manual.*

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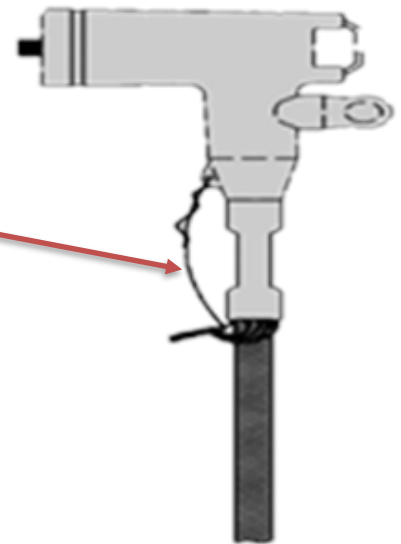
AWG Wire Size

The AWG (American Wire Gauge) size of the neutral wires must be determined. To aid in this effort, a wire-sizing tool is provided with the Ω - C h e c k ®, attached to the underside of the lid. Use the slots labeled for many wire sizes to determine the size of your neutral wire. **Caution:** It is not uncommon for the wire size used to be specified and labeled by the vendor as, say #16, when it is slightly smaller but not #17. The diameter of the neutral wires may not be exact to the textbook design based on the AWG. Use your judgment in determining the correct size. If the size is between two numbers, then either enter in fewer of the next smaller size or more of the next larger size, whichever would yield a similar ohms/100' of wire.
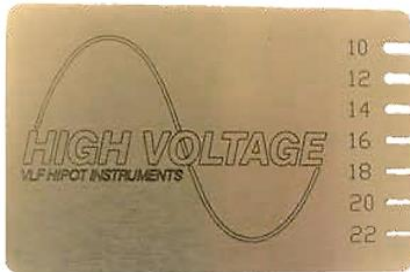

AWG guide to help select wire sizes can be found in the instrument lid.

It is very helpful to have a wire chart with the machine to help enter the equivalent number of strands into the data base as would be made up by the next size wire, similarly to what is done when aluminum, not copper, neutral wires are used. Their resistance is different, and that correction must be made to enter accurate data, in terms of Resistance/ft. or meters. AWG measuring tools are readily available from many on-line merchandise sites. Note: Since some wires are not true to their specified size, use a micrometer to get the dimension exactly if it is necessary to interpolate the resistance between two regular sizes.

Length Of Cable

How long is the cable? This must be entered into the machine. Hopefully the underground maps are accurate, but if not, then a distance wheel will have to be used to determine the length of the cable(s) to be tested. In addition, if there are locations where several turns of cable are coiled in a vault or enclosure, their length must be included. Errors in entering the correct length will cause proportional errors in the test results.

Whatever is entered for the length of the cable, an extra 10% is automatically added to the final number used in calculations due to the **"Lay Factor or Lay Length"** of the neutral, or the extra length of the neutral compared to the conductor due to its helical wind around the cable insulation. Read more about the Lay Factor in the next section.
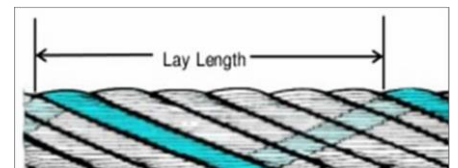
Lay Length: the longitudinal length of the neutral required to revolve around the diameter of the cable one time
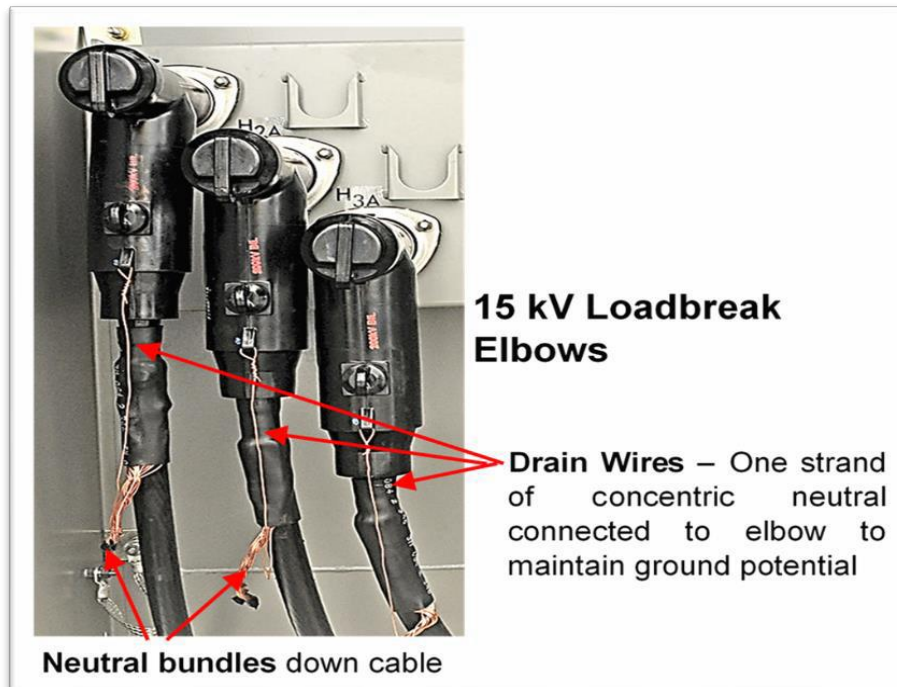
> ⚡ **Lay Length or Lay Factor**
>
> **Lay length** is defined as the distance required completing one revolution of the strand around the diameter of the conductor. The conductor is straight. The neutral wires helically wind around it from end to end, so a strand of neutral wire is longer than the cable conductor. We are measuring the neutral integrity, not the cable. The extra length of the neutral strands must be accounted for. This is referred to as the Lay Factor. For a cable manufactured in accordance with ICEA S-66-524, the lay factor could result in neutral lengths from 1.05 to 1.13 times the cable length.

The **Ω-Check**® calculates the neutral resistance based on a lay factor of 1.10. If the actual lay factor for the cable being tested is higher than 1.10, the calculated % of New would be less, as the length of the neutral is longer than expected from the data entered prior to the test.

For example: A 200' cable is being tested. The instrument, using its preprogrammed Lay Factor of 1.10 for 10% extra neutral wire length, expects 220' of neutral length and uses the resistance of that length in its comparison and evaluation of the neutral quality.

Drain Wire

The Drain Wire is one strand of the concentric neutral that is unbundled from the rest and connected to the Drain Wire position or tab on the elbow, termination, etc. Without the drain-wire, it is possible to build up charge on the elbow. This charge may discharge gradually over time to the well or elbow in which case there may be erosion/tracking. The charge may also discharge rapidly if contacted by a grounded item. In this case, bodily injury or equipment damage may occur. This wire should rejoin the others and continue down the cable. The routing of this wire and its connection to the bundle must be correct to be fully effective and included as a wire of the neutral. There is one on each end of the cable and they probably are not the same. If these are not connected properly, they may not be included as part of the neutral. In entering the # of Strands, this data must be included.

15 kV Loadbreak Elbows

Drain Wires – One strand of concentric neutral connected to elbow to maintain ground potential

Neutral bundles down cable

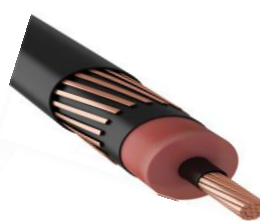## What Kind Of Cables Can Be Tested And Which Cannot?

| USEB90 Secondary Concentric round wires	XLPE w/Tape Shield	EPR w/Concentric Cu round wires	EPR w/Concentric Cu flat wires	EPR w/concentric neutral and spiral tape
Yes	**No**	**Y**	**Y**	**Y & N**

Most power cables have some form of metallic shield around the insulation surrounding the main conductor. This "shield" can be made from different metals and be of various physical designs, as the photos above illustrate: individual round wires, flat wires, continuous wrapped foil, and combinations of these. Each design

> **The Ω-Check® is designed to test concentric neutrals of medium voltage power cables designed using multiple round, flat, copper, or aluminum wire strands, usually tin plated.**
>
> **Unjacketed Concentric**

serves its specific purpose. Most of the power cables installed in North America starting in the 1960's and continuing to this day are designed with a concentric, individual wire stranded shield, or neutral. Concentric meaning the group of strands is wound around a common center point, in this case the conductor and its insulation. These strands are helically wound around the insulation to form a more complete wire "cage" or "shield" surrounding the insulation, providing a uniform ground plane to minimize the voltage stress fields around the cable.
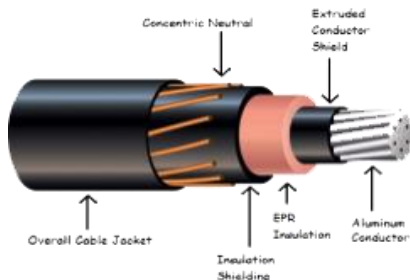
XLPE insulated medium voltage cable

The image *(left)* shows an XLPE insulated medium voltage cable with the typical concentric neutral design, using possibly 16 individual **round** copper wires helically.

The **Ω-Check®** is designed to test cables with **"concentric neutrals"** like shown above, neutrals comprised of multiple strands of round copper wires helically wound around the conductor insulation. **The library of wire sizes and their resistances stored within the instrument are for round copper wires.** However, the unit can perform tests on other types of neutrals with flat copper wires, flat or round aluminum, even combinations of wires and foils. To test these other types of designs requires the user to learn their resistance per unit length and find the equivalent spec for copper and enter this type of copper neutral wire into the machine.

Cables using foil wrapped neutral shields or full screen, coaxial shielded, types of cables are not well suited for the **Ω-Check®**. Partially corroded foil or full tape shields cannot be accurately measured by the **Ω-Check®**

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unless a long portion of the neutral is in a severely corroded condition. If only small portions of a tape shield neutral is corroded, these short distance, yet high resistance locations along the cable are not significant when measured with the entire cable length. Perhaps 2000' of cable neutral is good but 20' somewhere in the middle is almost corroded open. This small area will not significantly impact the overall resistance reading of the cable. Possibly a TDR (radar) instrument or above ground earth gradient measurement tools could locate this problem. A combination of TDR and an **Ω-Check®** unit is the ideal setup for neutral testing, with the **Ω-Check®** being the more accurate and easiest to interpret of the two.

Jacketed Or Unjacketed Cable: Does It Matter?

The test set-up and operation are the same in both circumstances. However, the interpretation of the results may be more complicated and less accurate when testing unjacketed cable. Unjacketed cable has all its neutral wires exposed on the outside of the cable, open to the environment around them. Generally, they will corrode faster than the neutral wires of jacketed cable where they are more protected from the elements of dirt, water, corrosive chemicals in the surrounding soil, and physical damage during and after installation. Also, in most cases, three cables of a three phase system are placed in a common trench or conduit and touch each other along the path of the cables. With the neutral wires of one cable possibly shorting out those of another or bridging an open gap in the neutral of one cable or more, the readings are often less obvious to interpretation. The decision to replace the cable may come down to what the neutral is used for in that case. In some cases when all three are tested together it is found that an adequate path for return currents is present from one end of the cables to the other. Whether it is evenly divided among the three cables or all on two with one cable neutral gone, it may not matter depending on the system's design.

Is A Minimum Cable Length Required, Or A Minimum Voltage And Current Needed?

Yes: A cable whose length requires a minimum voltage of 300 mV across the neutral with a minimum current of 1 ampere thru the neutral is needed. The length will depend on the neutrals resistance.

The **Ω-Check®** is designed to measure the resistance of the concentric neutral in typical shielded power cables of some length, usually at least 100' (30m) long. From the instrument, an AC current is injected through the neutral. The current thru and the voltage drop across the neutral are measured, the power factor calculated, and from these numbers the several data facts about the cable's neutral are reported. To meet the accuracy and resolution standards required for the instrument to calculate the cable neutrals total resistance, R/100', power factor, and % of New remaining, the analog signals received from the voltage and current connections must be of sufficient levels to be accurately converted to digital signals before the data is manipulated and reported.

The minimum length is better expressed as that length that will require **a minimum amount of voltage drop** needed for measurement accuracy purposes. So, the minimum length really depends on the resistance of the cable's neutral. A sufficient resistance is required so the **output voltage drop across the neutral is at least 300 mV**. If the resistance is very low due to a very short cable, 300 mV will not be reached before the load will draw the maximum current. **Generally, at least 40' – 50' (12m – 15m) of cable length is needed,** assuming an average size 15 kV power cable with concentric shielding.

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Summary: A minimum current of 1 Amp must be injected through the neutral under test for a reliable test result. That is 1 amp indicated on the **LCD display** as the current thru the neutral under test (where the clamp-on current meter should be positioned). The machine can output up to 30 amps, as shown on the **analog current meter** on the front panel, but with many parallel ground paths in most situations, much of it goes elsewhere and not thru the neutral tested. The LCD display for the Current (I) thru the neutral under test should be at least 1 ampere.

Test Minimums: V > 300 mV &   I > 1 amp

What If Many Cables Are In A Common Trench And Unjacketed?

Often distribution systems are constructed with multiple primary cables in a common trench. In this situation, contact between the neutral being tested and the neutrals of other cables in the trench are unavoidable. In some cases, these incidental contacts may allow a portion of the test current to flow in the adjacent neutrals, resulting in a lower resistance measurement. This possibility should be kept in mind when interpreting the final results. Testing each cable individually and then all three at once is best to determine the real resistance of the neutral.

Ground soil is usually a poor conductor. Neutral currents are not going to flow from an open neutral wire, or wires, through the dirt for many feet to then be picked up again by the remaining good neutral wires

Maybe some, but not many. The possible scenario where unjacketed cables can be highly corroded with some open but be masked by the wires of one phase shorting out the corroded wires of another, or, the neutral currents being carried for short distances through the earth and meeting up with the same neutral wires further down the cable, is not likely. The possibility of strands 1 – 6 of cable A being open, only to be touched by wires of another cable that then touch those wires of cable A further down is not reasonable to assume. Even if this occurred, the earth is a poor conductor, compared to copper or aluminum. Also, depending on the current being carried to balance the three-phase system, those broken wires may not even be needed. Remember, what is this neutral designed for? How much is needed, is there a separate bare conductor in the run to carry balancing currents, etc. Again, but put differently, does it matter? If all you are after is to find out if there is an adequate neutral path for the return current to get back to the source from point A to point B (and depending on the extent of phase current imbalances), it may not matter if it is evenly divided among the three cables or 50% on two or 100% on one? Of course, you may not have the ground shield around each cable needed to safely handle fault currents, but again, that goes back to what your neutral is designed to do.

Is There Interference Or Induced Voltages And Currents From Nearby Live Cables?

The operation of the **Ω-Check**® effectively mitigates the induced effects from system load current. However, induced effects are possible from the test current flowing in adjacent paths parallel to the cable being tested.

This effect is particularly apparent when testing three phase cables since a large portion of the test current flows in the neutrals of each phase. When testing cables known to be in new condition, readings above or below 1.00 are obtained when the phases are tested individually. When all three phases are tested simultaneously, more accurate readings are obtained. Induced effects from the test current are most apparent in cases where the test current is high, the test voltage and power factor are low. In these cases, small changes in the voltage magnitude or phase angle can result in significant errors in the calculated resistance and ratio.

Can More Than One Cable At A Time Be Tested?

Yes, a single cable can be tested, or all three cables of a common three-phase circuit, can be tested. To set-up the three cable test, one must do the following:

1. Place the clamp-on current meter around all three neutral bundles at once.

2. Enter into the machine the total number of neutral strands of all three cables. The same method and calculation will be made and displayed as usual but represent the entire bundle tested.

Can Both Energized and De-Energized Cable be Tested?

Yes. The **Ω-Check®** can be used to test a cable either on-line (energized) or off-line (de-energized). Although the instrument was developed to permit the user to test the neutral integrity without de-energizing the cable or disconnecting the neutral from ground, there are times when a test of a disconnected, isolated cable, or a full cable reel, are necessary. Test results are usually more accurate when a cable is de-energized, as there is little affect from induced voltages or currents from load currents or adjacent cables. **Warning:** if the cable is short and isolated from ground, all the test current from the set will flow in the neutral with none splitting off to typical underground neutral networks. **Watch the current meter while turning the voltage knob** to apply the voltage that induces the current flow. You don't need 30 amps in one cable neutral of short or medium length to get a good measurement.

Can I test a full reel of cable?

A full reel of cable can be tested, assuming the start of the cable is accessible. In this case, the cable length should be known precisely, offering a good opportunity to precisely measure, and benchmark, the resistance per unit length of the cable. If the same cable installed is also in stock on reels, it is a good opportunity to measure and record the exact number for future reference when comparing the ideal cable resistance to the actual when field testing.

Section 3 – Performing the Test

The following suggestions for testing are based on experience gained during development and subsequent field application of the instrument. These suggestions may be helpful in resolving some of the problems that may be encountered in using the instrument and unlock the nuances enabling it to test unusual applications.

Check for missing strands

Count the number of strands running down the cable to be sure they are all there. Perhaps some broke off or were cut during installation at the threshold of the sheath cut. Also, one wire may be used as a drain wire to ground the elbow or whatever termination may be used. Usually this drain wire is pulled from the bundle of all the wires but still twisted together with the others and on down the cable. In this case it is still part of the bundle and counts. There is usually a drain wire on both ends and it is usually a different strand. Make sure the number of strands that are carrying the injected current are known and programmed into the machine. Check both ends of the cable.

Connecting The Test Leads

It is important to ensure that the test leads make good contact with all the strands of the neutral. Where the neutral strands are tightly twisted, this is generally not a problem. Where the strands are loosely twisted, it can be difficult to make contact between the test lead clamp and all the strands. If necessary, manipulate the strands into a tight bundle, clean the strands of any debris that may impede a quality connection, and tighten the clamp firmly.

Place clamp-on current meter in the correct location.

The CT must be placed on **the cable side of the voltage clamp** connection to read only the current traveling down the neutral under test.
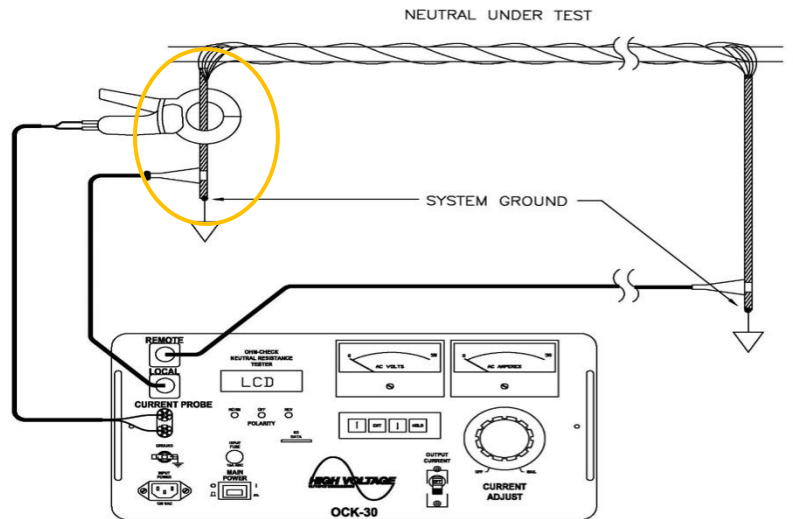
Unroll The Ω-Check® Test Lead Off The Reel

Testing with the instrument's test lead on its reel will provide inaccurate results due to uncompensated parasitic inductance from the 500' coil of wires. Always unroll the test lead from its reel, just to the next connector (if Reel B) and open the cable at the connector to connect to the instrument. This is one of several methods of testing that should be experimented with by the user. Try a test both ways, test lead reeled and unreeled, and compare the results.

Testing Three Phase Cables

When testing three phase cables, the most reliable results are obtained by placing the current probe around the neutrals of all three phases and measuring the resistance ratio based on the total number of strands in all phases. For example, a three phase circuit of cables with 8 no. 14 AWG neutral strands would be entered as 24 no. 14 AWG strands. Measurement of the phases individually can provide an indication of the integrity of each phase, however contact between the strands of adjacent cables and the effects of test or actual neutral currents flowing in adjacent neutrals may provide unexpected results. It may be advantageous to test all three phases at once and then each individually to learn more precisely how the test current splits down each cable and other possible ground paths.

Testing different types of neutrals

1. **My neutral wire is aluminum, not copper. What do I do?**

This is one of several circumstances where the operator of the machine must alter the input data to fool the machine about the make-up of the neutral. The library of wire resistance data programmed into the machine is for round, uncoated copper wire. If the neutral tested is made from aluminum wire, then the equivalent

number of strands and/or wire size of copper wires must be selected and entered into the machine to duplicate the Ohms/100' of the actual aluminum wire. The machine is then looking for the proper resistance value of the actual neutral regardless of whether it is AL or CU. It doesn't know the difference.

For example: An aluminum neutral has 16 strands of 14 AWG wire, with a strand resistance of 0.414 Ω/100', for a total resistance of **0.414 Ω/16 strands = 0.0259 Ω/100'**. Now, using copper wire data that the machine is programmed to manipulate, we must come up with a strand count and wire size that will be nearly equivalent to the 0.0259 Ω/100' of our actual aluminum neutral. Looking at the wire charts for copper wire, we see that 16 AWG copper wire has a resistance of 0.402 Ω/100', nearly the same as the 14 AWG aluminum wire. A copper neutral with 14 strands of #16 AWG wire has a neutral resistance of **0.402 Ω/16 = .0251 Ω/100'. Result:** We enter into the machine a neutral containing 14 strands and a wire size of 16 AWG. We are fooling the machine about the actual neutral design, but it is now looking to compare the measured resistance against the resistance of the actual aluminum neutral when new.

Aluminum wire: 14 AWG = 0.414 Ω /100'. With 16 strands in parallel 0.414 Ω /16 strands = <u>**0.0259 Ω /100'**</u>

Copper wire: 16 AWG = 0.402 Ω /100'. With 14 strands in parallel 0.402 Ω /14 strands = <u>**0.0251 Ω /100'**</u>

Another way to manipulate the data to enter unusual neutral designs, is to use the standard strand sizes but alter the cable length to make the total resistance of the actual neutral under test equal to that of a known wire size. If the resistance of your neutral is twice that of a known size, then use that size but double the cable length entered.

Review: The instrument and its database were designed for testing round, copper wire concentric neutrals. To test other types of neutrals, it is necessary to determine the resistance per 100 feet of a new neutral of that type. This can be done by calculation, reference to manufacturer's data, or by measuring the resistance of a 100' length of cable neutral using the **Ω-Check®.** The **Ω-Check®** provides test results in resistance per 100 feet (R/L') and the resistance ratio can be calculated manually. It is also possible to determine the number and size of round concentric wires that will provide a resistance that is equivalent to the neutral being tested. The **Ω-Check®** calculates the reference resistance as follows:

$$R_{ref} = \frac{Resistance\ of\ 1\ strand\ \ (1.1)}{Total\ no.\ of\ strands}$$

(The constant of 1.1 is a lay factor that accounts for the increased neutral length due to the spiral wind of the concentric neutral around the insulation covering the conductor. Once the equivalent neutral size is calculated, it can be entered as test data and the measured resistance data can then be read directly. Using this method, the **Ω-Check®** can be used to test virtually any type of concentric neutral.)

The strand resistance per 100 feet used by the Ω-Check® are:	
AWG:	**Ω/100 feet**
10	0.0999
12	0.1588
14	0.2525
16	0.4016
18	0.6385

2. My neutral uses flat wires, not round

The instrument is programmed assuming round concentric neutral strands. However, calculations are made using the resistance of the strands AWG size input. The ohms/100' of the neutral under test must be determined. Once known, the user can input to the instrument a wire size of round wires that is equivalent to the resistance of the flat wires under test. The proper resistance in total and R/L will then be displayed directly on the LCD. Using a similar R/L, essentially the machine is being fooled to think round wires are under test.

3. My neutral is a foil wrap or shield all around the insulation, not concentric wires.

The **Ω-Check®** can accurately test how many strands of a concentric neutral are open. When one of, say, 14, wire strands open, it produces a very measurable and predictable change in the total resistance of the neutral. When a foil wrap or wire shielded cable (like coaxial cable) is partially degraded, it is difficult to measure the degree of corrosion. Also, one short length of a foil shield can be corroded to near zero remaining, yet that localized point of high resistance is not noticeable when part of the overall measured resistance of the entire length. Other methods can be tried to find such an occurrence.

Very Low Neutral Test Current and/or Test Voltage

When the neutral test current is very low (less than 1 Amperes), reliable resistance measurements are not possible. When the neutral test current is very low, particularly when accompanied by high neutral voltages, it is a positive indication that the neutral is open or nearly open. In this case the neutral should be presumed open and the LCD results will often be disregarded. Conversely, if the neutral current is very high and the voltage across the neutral is very low, maybe too low to measure accurately, it can be assumed that the neutral is in good condition. **Remember Ohm's Law: R= V/I**

Think about both this way: If only a fraction of an amp passes through the neutral with a high level of voltage across the neutral (20 – 40 volts), it can be safely assumed that the neutral is open or nearly open. Or, if it takes only a fraction of a volt to drive high current (20 – 30 amps) through the neutral, the resistance is extremely low and the neutral should be considered healthy.

Testing Long Cables

The **Ω-Check®** comes with two reels of test lead, Reel A is a continuous 500' length and the other, Reel B, is also 500' but with connections every 100', permitting the user to reel out only as much cable is needed by opening the cable of Reel B at the nearest connector. Additional Reels of either A or B test lead may be used to test cables longer than 1000 feet. Field experience has shown that energized cables up to 2000 feet can generally be tested with the neutral connected to the system. At lengths beyond 2000 feet, the voltage drop in the test lead will not allow adequate current to be passed through the neutral. To insure reliable measurements, **at least 1 Ampere** of neutral current is required. Considerably longer lengths of cable could be tested, once de-energized, by disconnecting the neutral from the ground system to permit all the current the machine can deliver to travel only the neutral path under test. It is also possible to test longer lengths of cable by excavating the cable near the middle and connecting the remote test lead at this midpoint of the cable and the Local at each end separately and testing the two sections individually.

Another method of testing long cable lengths is to use the **Parallel Conductor Method**. In situations where it is not practical, or the cable is too long (>2000') to use the Remote test lead from the **Ω-Check®** there is another way. This method can work very well and expedite the testing of longer cable lengths, but the cable must be de-energized and isolated.

If the phase under test and/or adjacent phases are disconnected, the conductor of one can be used to make the Remote connection between the **Ω-Check®** and the distant neutral. Rather than use the reels of test lead provided with the instrument, the Remote connection can be connected to the conductor of the cable under test or a parallel cable's conductor, and that used to reach the other end of the cable and make the connection to the neutral. The one limitation to this method is that the neutral at the far end, the Remote connection end normally, must be lifted from ground so that all the current injected into the cable returns in the neutral under test. Since this method requires the Remote connection to be made at the Local end of the cable conductor, the resistance of the cable conductor
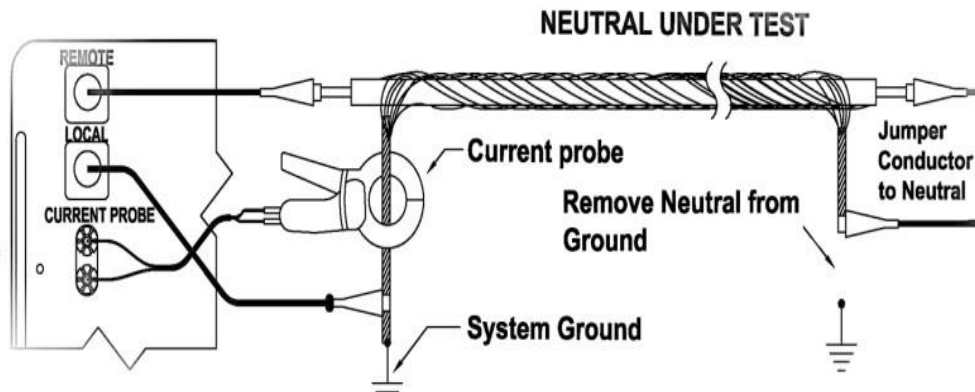
must be subtracted for the readings of the final results. The **Ω-Check®** can be programmed for the cable conductor's resistance by entering an alias cable spec (# of strands and AWG) that is of similar total resistance as the cable conductor, to permit the displayed Res and R/L to be true to the neutral being tested. Or it can be manually subtracted from the results and the resistance of the neutral tested calculated.

Testing cables with mid span taps.

It is not possible to accurately measure the resistance of cables with mid span taps because the portion of the current flowing in each cable segment from the tap point cannot be determined. However, by measuring the resistance across each of the three terminals, it often can be determined if the neutral is open or severely impaired in one cable segment. This may require moving the connections and/or the instrument from one end to the other.
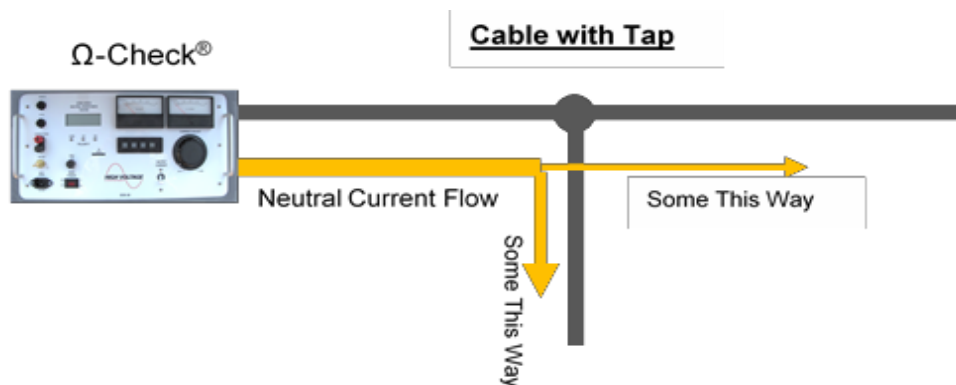
Below are two photos of the LCD front panel display. The first is the **Neutral Data** entry screen used to enter the neutral design details. The second is the **Test Results** display following a test. The displayed field definitions follow.

```
20#14 L:   10 TN:0013
V: 0.02   R/L:16.797
I: 0.01    RES: 1.680
PF:1.00 PCT NEW:   0
```

```
NO. STRANDS: 20
STRAND SIZE: 14 AWG
CBL LENGTH:    0000 FT
TEST NO:       0012
```

Neutral Data	Explanation of LCD Screen Labels
L:	The cable length in feet, entered by the user
TN:	The test number entered by the user
V:	The voltage difference between the local and remote ends of the cable neutral. This voltage is measured with the voltage sense conductors in the test lead.
R/L:	The resistance of the neutral being tested in Ohms/100 feet
RES:	Total resistance in Ohms
PF:	The power factor of the neutral conductor being tested. This is determined by measuring the phase angle. [between I and V, where PF = Cos]
PCT NEW:	Conductivity ratio of measured neutral compared to ideal neutral of same length expressed as a percentage. For example, a reading of 75 would mean that the neutral has 75% of its original capacity and that approximately 25% of neutral strands are open

"The Reasonable Test"

Study the various data points measured: do they all seem reasonable in relation to each other and to what is expected? Do all the test results analyzed together, **seem reasonable**? Cross check several data points to be certain of the results consistency and believability. Several of the various data results should complement or confirm the others are correct. Use all the data returned from the test to determine the neutral's health. For example, if the PCT New reads 99 yet the R/L reads far higher than it should, one or the other is not correct. If the voltage measured across the neutral (on the LCD) is very low yet the current is very high, then it is a good neutral of very low resistance. Check that against the RES and R/L and PCT NEW results. If the Power Factor reads above 70, then the neutral is not 100% intact. Cross reference that with the other numbers. Consider all the data returned from the test before making a decision.

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PCT New: Reading >100%?

Occasionally the **Ω-Check®** will yield resistance ratios greater than 1.00, or the % of New cable remaining reads greater than 100%. In nearly all the test results reviewed in these cases, these anomalies have mostly occurred on cables where the test current is high and the test voltage is low, indicating a high quality neutral path. There are several factors that can cause this. Recheck that the test data defining the cable under test was entered correctly and that the clamp-on current meter and the voltage clamp connections are in their proper places and making good connections.

Note: The PCT New reading should not be used as the only indicator of the health of the neutral. When all the neutral data entered into the machine is accurate, all the physical clamp connections are proper, and when the correct testing procedures are followed, the PCT New reading is usually accurate. However, the other data revealed following the test should also be viewed to evaluate if all the related data makes sense with no anomalies indicated. Again, does it pass "The Reasonable Test"?
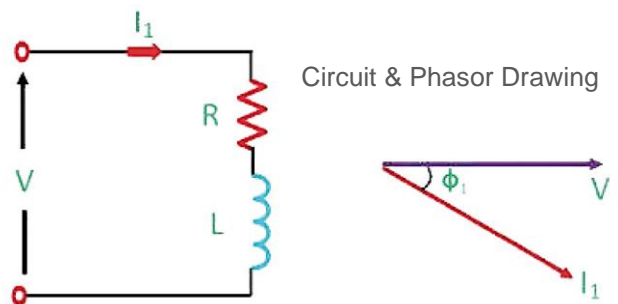
Neutral Power Factor

The Power Factor of the concentric neutral is calculated and displayed on the panel screen. Since the Ω-Check® is calculating the AC resistance of the neutral, it must measure the phase displacement between the voltage and current to find the angle Ø (Theta) between them.

Resistance = Voltage/Current if DC.   For AC calculation: R = V/I x cos Ø

A concentric neutral is a collection of perhaps 10 – 16 individual wires separated equally and consistently, and helically wound around the insulation over the conductor. It is essentially a long coil extending all the way down the cable length. As such, it has the properties of Inductance, or that of an inductor. The typical power factor of a concentrically shielded cable is from 0.4 – 0.6, out of 1.0. A pf of 10 would indicate a phase shift of 90 between the voltage and current.

Since this neutral coil is not a perfect inductor and contains resistive properties, it is not higher than around 0.6. If it were only a couple of wires that ran down the cable, not much of a coil, the pf would approach that of a resistor: it would be nearly 1 if it were pure resistance. It is a combination of Inductive Reactance (X_L = 2πfL, where L is the inductance in unit Henrys) and resistance.

Circuit & Phasor Drawing

The Power Factor reading displayed is a rough estimate of the inductive nature of the neutral. The more degraded the neutral the higher the pf becomes, as the once perfect coil is now perhaps only four or five wires running alongside the cable, which is more resistive than inductive. Alone, it is not the best arbiter of neutral integrity, but when considered with the % of New, Resistance, Voltage, and Current readings, it can be useful in confirming the validity of the other data results.

Official Standards Defining the Use of the Ω-Check®

There are two IEEE standards that are written defining the use of the **Ω-Check®:**

IEEE Std. 81™ - 2012 (Revision of IEEE Std. 81-1983). IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System.

IEEE Std. 1617™ - 2007 (now being rewritten) IEEE Guide for Detection, Mitigation, and Control of Concentric Neutral Corrosion in Medium-Voltage Underground Cables. (Under revision to be released 2019)

Other Applications For The Ω-Check®

1. Substation Ground Cable Integrity Testing

The **Ω-Check®** is an excellent **high current, low voltage ohmmeter to measure AC resistance**. It is very useful for applications where low resistance values must be read but with AC currents applied approaching **30 amps**. Many contact resistance-testing applications can benefit from the **Ω-Check®** due to its 1000' (300m) output leads permitting **voltage drop and resistance measurements to be made across the load only.**

2. Before Cable Diagnostic Testing: AC Withstand, Partial Discharge, & Tan Delta Testing

Verify neutral is intact before testing. All three tests are commonly performed on cable, but many are performed without first testing the neutral. **Before investing in the expense and downtime of PD and TD/PF testing cables,** verify that a sufficient neutral is present to create the necessary uniform ground shield around the cable's insulation to make the tests meaningful. **No neutral – no useable test data.**

3. Cable Fault Locating: Can't Easily Find a Fault if no Neutral

When using a capacitor discharge cable fault locating device (a thumper), the internal thumper capacitor discharges it high voltage stored energy into the cable where it ideally surges, or arcs, through the fault in the insulation to the grounded neutral plane around the insulation. **BANG!** A loud noise and powerful electro-magnetic current surge from the thumper is created, easily picked up by above ground listening and magnetic impulse measuring detectors, and by a TDR/radar if used. Fault found. **NOT SO if the neutral, or part of it at the fault location, is missing.** There is no ground for the voltage arc to jump to, just the dirt surrounding the cable. Another use of the **Ω-Check®.**
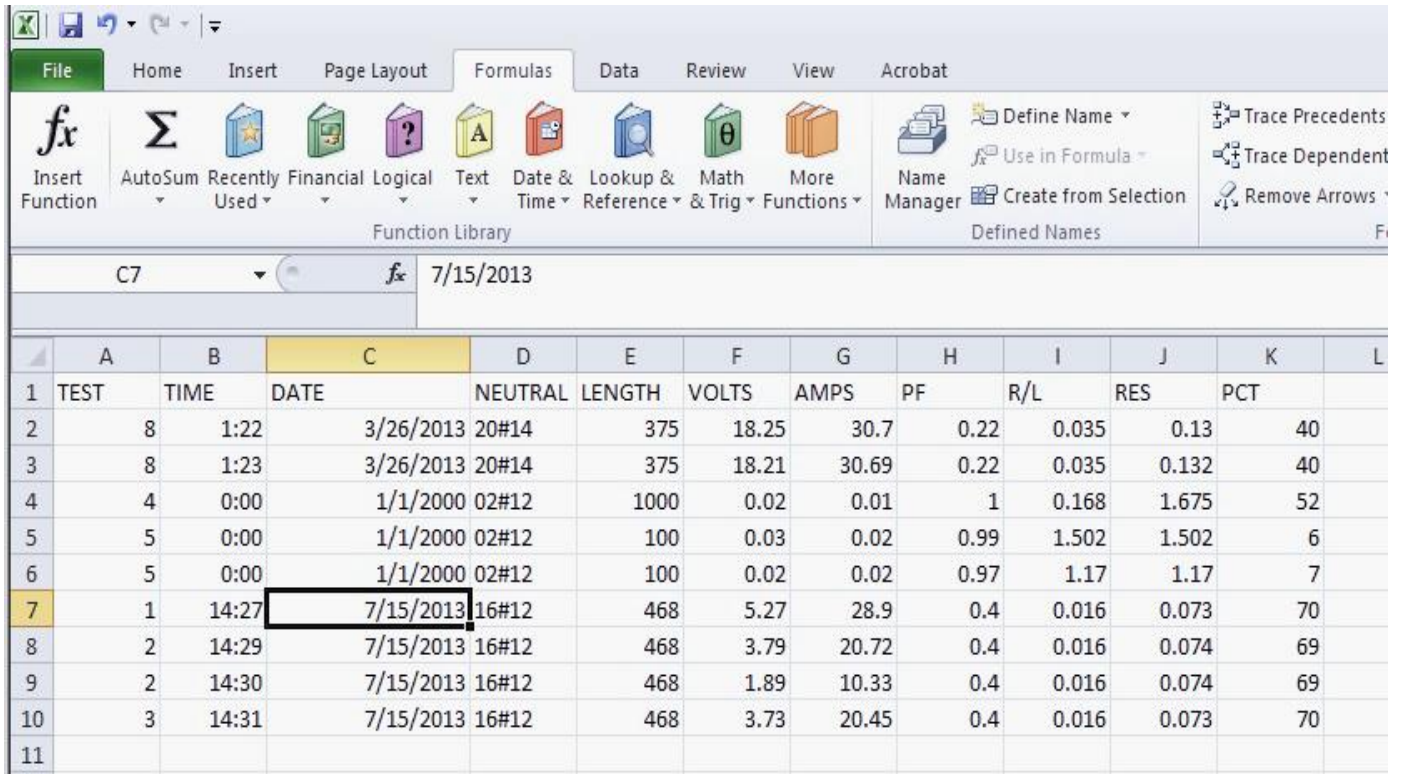
Also use the Ω-Check® for: Substation Ground Cable Integrity Testing

Consult HVI for any additional questions: sales@hvinc.com

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Data Retrieval

The OCK-30 uses an SD card to store test results and other data. Below is a look at how this data can be easily retrieved and manipulated for use. Test data stored on the SD card is saved as a tab-delimited text file (.txt) that may be retrieved using any text editor or Microsoft Excel on any PC equipped with an SD card reader.

	A	B	C	D	E	F	G	H	I	J	K	L
1	TEST	TIME	DATE	NEUTRAL	LENGTH	VOLTS	AMPS	PF	R/L	RES	PCT	
2	8	1:22	3/26/2013	20#14	375	18.25	30.7	0.22	0.035	0.13	40	
3	8	1:23	3/26/2013	20#14	375	18.21	30.69	0.22	0.035	0.132	40	
4	4	0:00	1/1/2000	02#12	1000	0.02	0.01	1	0.168	1.675	52	
5	5	0:00	1/1/2000	02#12	100	0.03	0.02	0.99	1.502	1.502	6	
6	5	0:00	1/1/2000	02#12	100	0.02	0.02	0.97	1.17	1.17	7	
7	1	14:27	7/15/2013	16#12	468	5.27	28.9	0.4	0.016	0.073	70	
8	2	14:29	7/15/2013	16#12	468	3.79	20.72	0.4	0.016	0.074	69	
9	2	14:30	7/15/2013	16#12	468	1.89	10.33	0.4	0.016	0.074	69	
10	3	14:31	7/15/2013	16#12	468	3.73	20.45	0.4	0.016	0.073	70	
11												