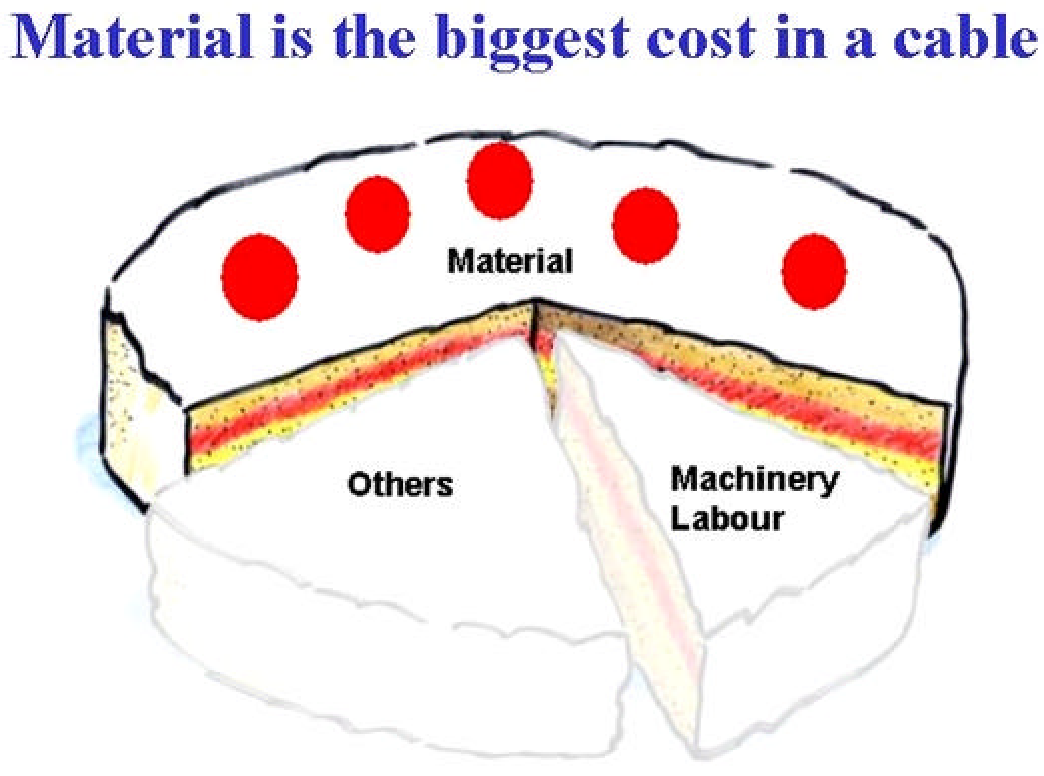
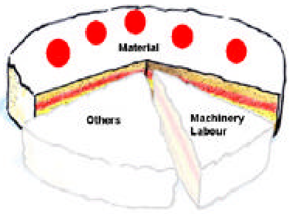
PRESENTATION made at INTERWIRE Atlanta May 2003

Control the Resistance and reduce cost

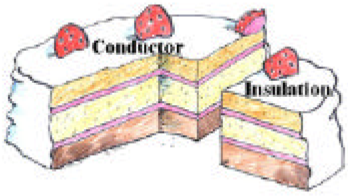
The dimension of the conductor is not the main parameter, it is the Resistance or actually the conductivity. This study analyze the variations of the Conductivity (Resistance) for some important Cupper Wire and Strand dimensions and the possible saving due to this better know how.
Since the material cost in the cable is the without discussion the major cost, approx. 55-80% of the cable were metal is around 2/3, is it very important to know what is happening in the different process steps. Also related to different areas.
A common method to measure conductivity has been the weight method. By cutting a defined length of the product and measure the weight. The main problem with this method is the uncertainty of the length. Variations of 2-3 % are normal and this gives an uncertainty finally resulting big over dimensional costs.



Materials are without doubt the dominating cost factor in a cable today.
Their proportion is
50 to 75% of the total cost.



The conductor is approx. 2/3 of the material cost thus being 35 – 50 % of the total cable cost



Cable factories do not sell metal, they sell conductivity.

It is of coerce more easy to calculate with weight since cable factories are buying all their raw materials in weight. But the customer need the cable from one point to a other = feet or meter.
So the more feet (meter) they can make out of the pounds (kilos) we are buying the more profitable they will be. But it is easy to say halleluiah but more difficult to do. One thing is clear, to optimize a process to be narrow to the specification boarder lines we must measure a lot with high repeat accurate.

The economics to measure with high repeat accuracy has been proven in earlier presentations regarding saving of insulation materials using automatic off-line measuring of cable walls.

KSM Off line measuring unit

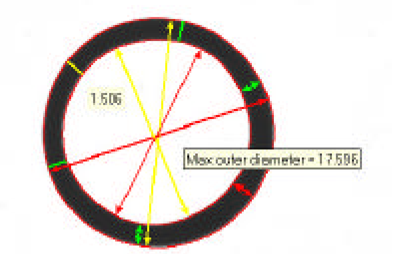
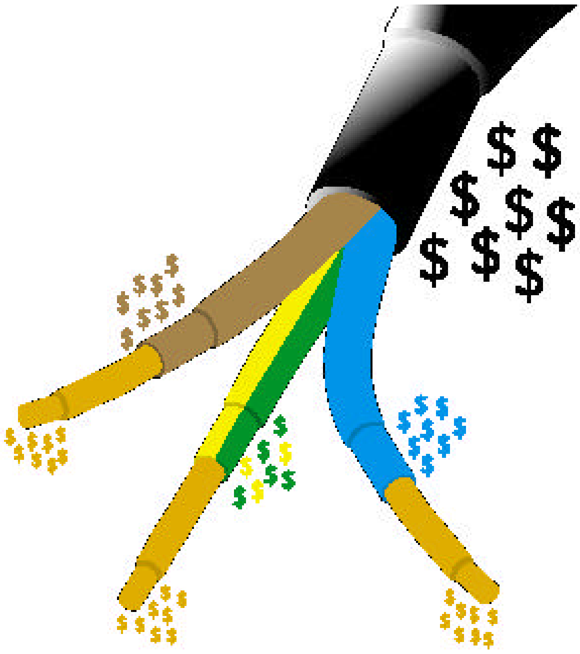


Image of a Cable sample measured as per the European spec

KSM automatic measuring system takes 1 million measurements into its calculations, with a repeat accuracy of typically 0.01 - 0.02 mm (0.4 – 0.8 mils).

More time has been spent to control the cost of the conductive part in the cable due to its higher cost per pound (kg) then on the insulation thickness. Over dimensions cost on the conductors are therefore not as high as for the insulation side but on the other hand, the price of Copper is higher than PVC or PE. Adding to the savings on the conductor also the need for insulation around the then smaller conductor is reduced. In the same % or actually somewhat more since it is the outer part not needed. The very same apply in the next steps for filler and jacket giving a nice serial reaction.



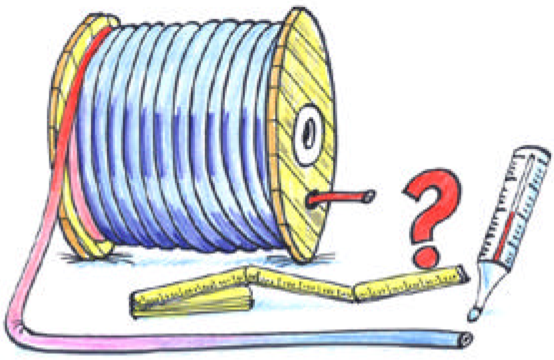
When the size of the conductor is reduced less insulation, filler and jacket material is needed

As said before you must firstly measure very accurate too know were you stand and how the processes are varying within your manufacturing unit.
We will here mainly present different method to measure resistance but it is known that the method of controlling a sample by weight has it's instability.

Resistance Measurements vs. Weighing Technique

There are sensible measurements errors made when using the weighing technique to determine the resistance of a conductor. For example, there is always an uncertainty on the conductivity of the material to be measured. The weighing technique can not take into account this parameter while a resistance measurement will measure the presented material, whatever its real conductivity. Another disadvantage of the weighing technique is linked to the fact that at equal weight, a solid conductor has a different resistance than a stranded conductor, due to the lay length and the compacting factor. By using the weighing technique, there is uncertainty on the sample length, this obviously having a direct impact on the weight, and therefore, after calculation, on the effective resistance value. With an electrical resistance measurement, this problem does not exist. It should also not be forgotten that the weighing technique compared with in line measuring need samples to be cut, this generating scrap. Therefore, to reduce to the minimum the material consumption, it is very interesting to be in position to make resistance measurements. For small conductors as described in this presentation using samples and for power cables also directly on the stranding line. As a general consequence and by taking into account the above mentioned points, it is very common for the cable manufacturers using the weighing technique to put extra material on their strands in the range of 1 to 4% !!!

The most important points measuring Resistance is a known length and temperature.
Often the loop resistance methods are used to measure on delivery reels. This a very uncertain method, especially with to days used "just in time" deliveries when the reel shall be on the truck some hours after manufacturing.
Firstly the temperature vary through the reel making it impossible to find the correct temperature to be used for calculation to 20 or 25 degree reference. Mistakes of 5 degrees are not uncommon. The temperature coefficient for Cupper is 0.389 %/degree Celsius thus making errors up to 2 % common!
The length measuring technique in the cable plants are not very accurate and if you have a delivery reel with 500 meter of cables it is often in reality 510 m. Then you measure on 510 meter but calculate with 500 m giving an additional 2 % error.
Adding to this are the 2 % extra length delivered completer cable not paid for.



Temp and length difficult to define using loop resistance measuring directly on a reel

The conclusion is that it is very uncertain method to measure the loop resistance if you want to keep a control of the biggest cost in the plant, material. The only way to measure accurate is by using non destructive in line measuring or samples in a good quality measuring bridge.

In line measuring can only be achieved for non insulated bare conductors, using for example AESA Resistance unit type 8130 measuring directly in the stranding line. This mainly apply for bigger products such as 1 kV power cables and HV cables. There the resistance in the stranding line is close to the final resistance on the delivery reel.

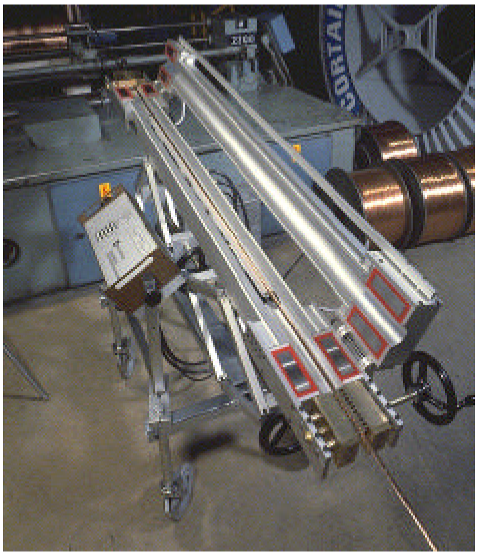


Photo showing unit 8130 measuring heavy strand by the courtesy of AESA Cortaillod

Here we are however concentrating on small bunched wires were the saving potential are the greatest. We used samples for measuring and also studied which method should be used.

Many sample methods to measure the Resistance are unstable due to its design.
A study made comparing a milliamp meter did result in a variation of 0.32 %. This was a case were only one person made the measurement trying many times for each sample to have a stable value. For normal cases were different people measure an spread of up to 1% is not uncommon.
The main problems with this type of method are
a) The temperature probe is located in the air thus sensible to movements in the air when someone is walking by or a door is opened.
b) The measurement is based upon a fixed length typical 1 meter.
Difficult to manufacture and check.
c) Contact point to the strand is not very defined and unstable.

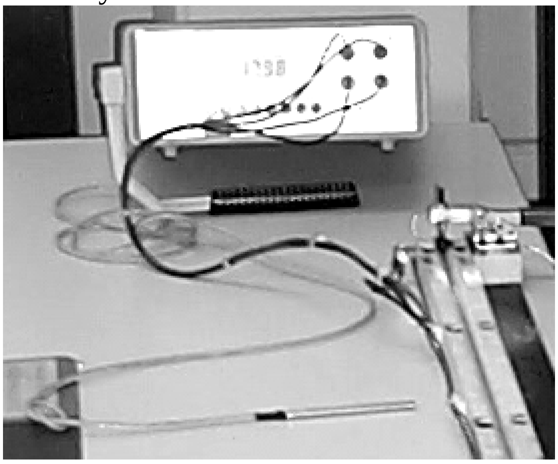


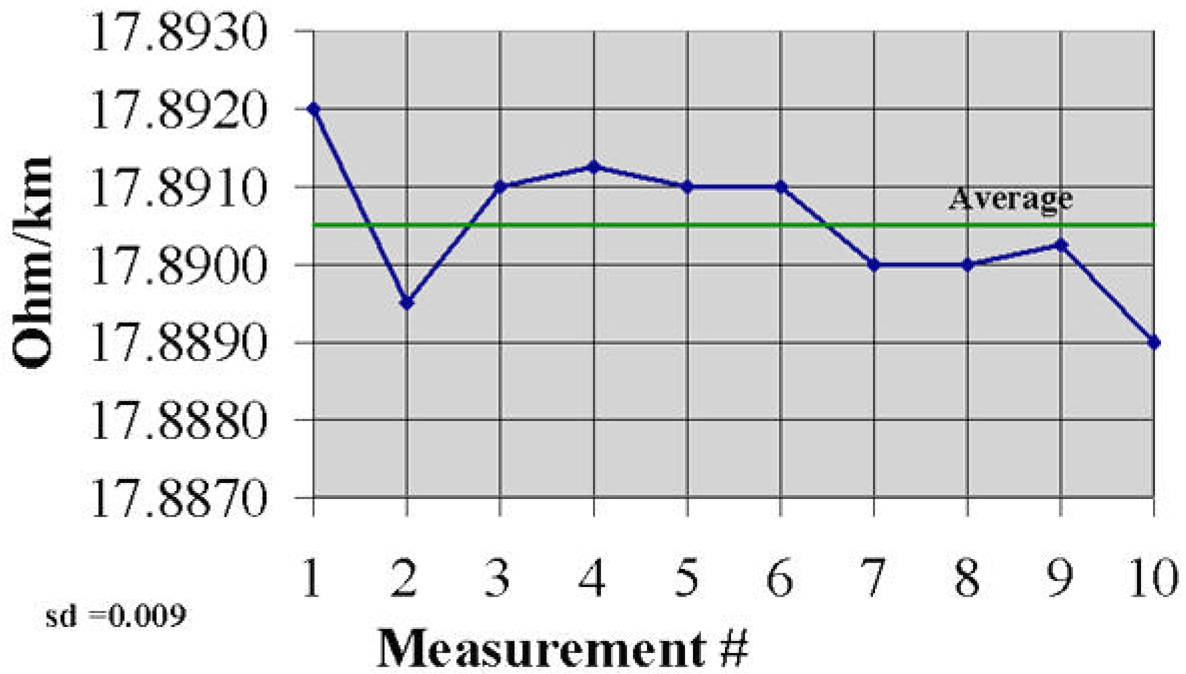
Photo showing a measuring station with mill amp meter

Comparing the stability of a AESA measuring unit type 7195

Photo showing strand measuring unit 7195 by the courtesy of AESA Cortaillod

a) The temperature probe is located inside the bended aluminum rule of the resistance bridge. The contact point of the strand is made over the distance of the massive aluminum rule. Its bended geometry allows to have an efficient contact between the sample under test and the resistance bridge, this allowing to quickly equalize the temperature of the sample and consequently provide highly accurate results.
b) The measurement is not based upon a fixed length but is typical 1 meter. Each unit is individually calibrated according to its exact mechanical length by measuring a certified standard which allows to exactly calibrate the resistance bridge.
c) The power supply to the stand is mad over long jaws securing an even distribution of the current in the strand. The resistance (voltage drop) is measured thru very fine spring loaded knives giving a very good measuring reparability.

A practical test with repeat measuring on a 1.00 mm2 strand gave the following curve.



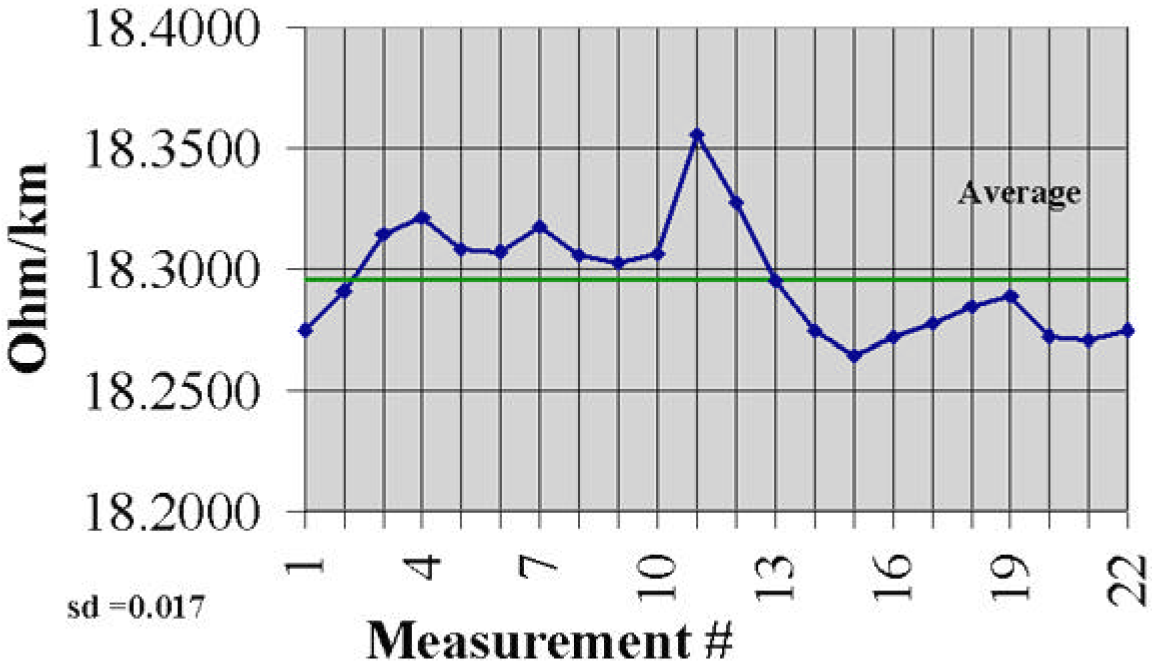
The spread (repeat accuracy) was less than 0.02 % and the standard deviation 0.009 thus verifying it as a very stable method. This method was selected to be used for the trials.

Stability of a AESA measuring unit type 7197 with knives cutting through the insulation

Photo showing insulated wire measuring unit 7197 by the courtesy of AESA Cortaillod

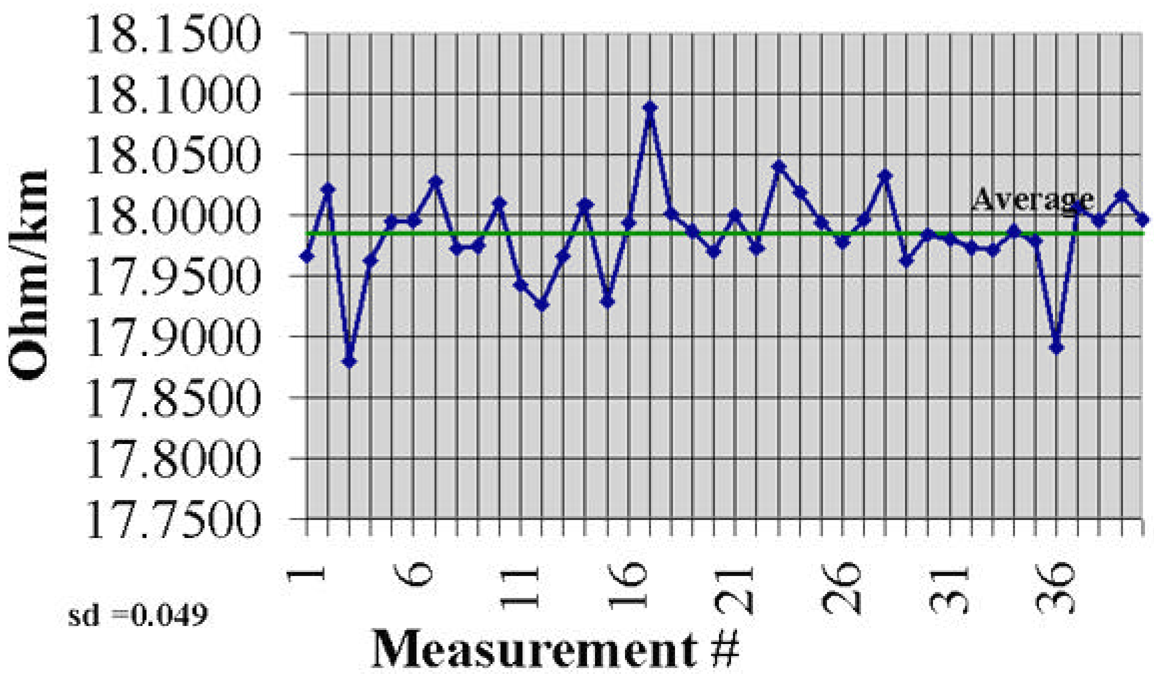
The basic design is the same as for 7197 only the clamps are exchanged for knives cutting through the insulation . Check were made and the stability also for this unit was very good.
Decision was made to use this unit for the follow up of resistance after insulation.

First test made on a bunched strand 1.00 mm^2 taken from a reel before a insulation line.



Conclusion, the strand is very stable through the reel but vary from reel to reel. The spread of the values are typically 0.5 % and the standard deviation 0.017.

The same strand 1.00 mm^2 tested after the insulation line and measured with AESA type 7197.



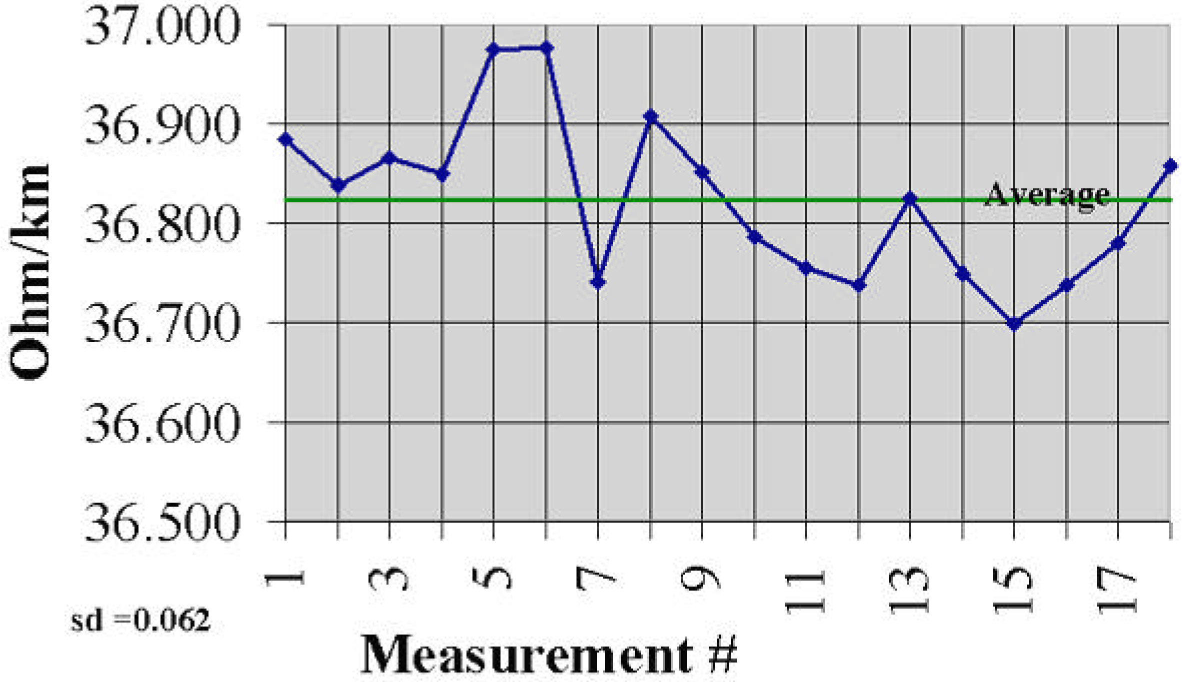
The insulated strand is also very stable and the elongation from the strand value vary between 1.5 – 2.1 % through the production.

Conclusion is that very interesting economical optimizations can be made
a) on manufacturing more precise Cu wire dimension in the multi wire drawing machine. In this case typically each individual wire could be manufactured in 0.002 mm less diameter. Equal to 2.0 % reduction in area. On a normal production will this result in a **annual saving of 100.000 $** buying **Cupper for only 5.000.000 $** which is a small size factory annual need. A very interesting figure.
b) To minimize over dimension the final strand each group of wires can be measured and matched together for optimum resistance. Potential savings are typical 5**0.000 $ yearly** based upon the same annual usage.
A total saving potential of 150.000 $ yearly on 5.000.000 $ annual usage of Copper.
And the additional serial effect on the insulation, filler and jacket are in the range of 100.000 $.

Giving a Total Annual savings of 250.000 $

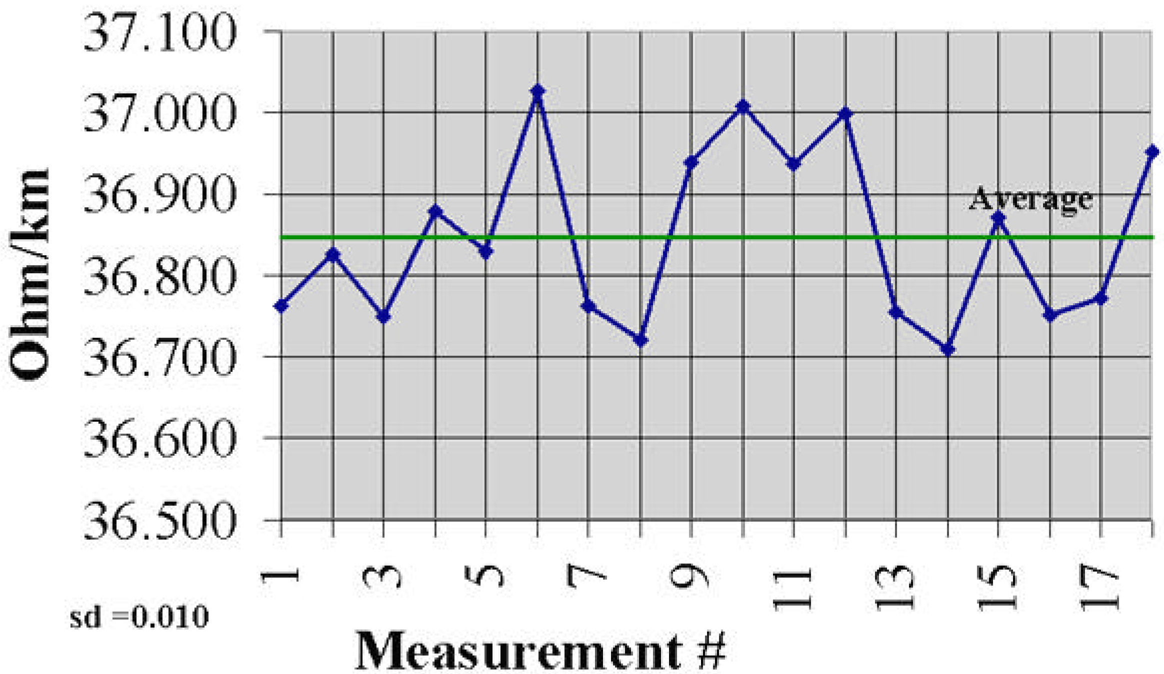
Why is the cable industry giving away so much money?

The similar test was made on 0.5 mm2 bunched strand giving similar result.
Test made on a bunched strand 0.50 mm^2 taken from a reel before a insulation line.



Conclusion, the strand is very stable through the reel but vary from reel to reel. The spread of the values for 0.5 mm2 are typically 0.2 % and the standard deviation 0.010 thus proving the same or even more stable result in giving potential savings as least as for 1.0 mm^2.

The same strand 0.50 mm^2 tested after the insulation line and measured with AESA type 7197.



The insulated 0.5 mm^2 strand is also very stable and the elongation from the strand value vary between 0.06 – 0.13 % through the production proving the stable elongation in the process.

Further investigations will be made to establish the elongation per area and insulation line.