Incidence of corrosion in low voltage electrical conductor

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Abstract - This research used a salt spray booth to generate accelerated corrosion in a copper conductor, AWG 12-gauge purity of 95.95%, this caliber used in residential electrical installations according RETIE Chapter 3 Article 20 and NTC 2050 338. Additionally, to provide an enabling stage of corrosion, type mouse tail splices were made. The amount of corrosion is measured by weight loss, and incidence of corrosion in transport was evaluated from two perspectives: difference active at the beginning and end of the test power, and the change in resistance of the specimen measured at different times of the experiment. The test piece was subjected to a flow of alternating current into a low voltage system, while corrosion occurred. Using two single-phase two-wire electronic meters, the rate of power supply circuit test was recorded, to check for changes in the energy carried from exposure to the corrosive environment wire. The data collected showed that exposure times of the samples in the salt spray chamber involvement was not very noticeable copper wire, highlighting small corrosion spots. Similarly, the energy no changes were observed to induce corrosion, however, the resistance of the wire showed a total change of up to 2.4 [milliohms]. The data collected showed that exposure times of the samples in the salt spray chamber involvement was not very noticeable copper wire, highlighting small corrosion spots. Similarly, the energy no changes were observed to induce corrosion, however, the resistance of the wire showed a total change of up to 2.4 [milliohms].

1. Introduction
For the distribution of electricity above two basic steps to this, which are the generation and transport are needed [1] [2].In transport and distribution electrical conductors are needed, which are the main elements to conduct energy. These wires being exposed outdoors and often extreme conditions undergo alterations that cause damage to it causing power loss to the electrical system by corrosion effect on the driver.
Importantly in relation to wear from corrosion materials used in electrical systems in general they have been raised research focusing on the one hand to define the factors that influence corrosion of these materials and in another perspective fault analysis in electrical equipment caused by corrosion. Although, we evaluated the incidence of corrosion drivers employed in medium voltage systems, however, wear on drivers and joints due to corrosion in electrical low voltage installations is noticeable in the residential splices, boxes outlets and switches and electrical protection boxes. [3] [4] [5] [6]

Considering the above, this paper presents a study on low voltage, in order to establish the incidence of corrosion of the conductor in electrical characteristics (resistance-Transport power). For this type rat tail splices in the conductor connecting to an AC source and a load of 300 [W] nominal was used, and power were evaluated at different time instants. Then, the materials that were used and the methodology used to assess the changes in driver characteristics are described.

2. Materials and methods

2.1 Materials

To carry out tests cabin salt spray in the lab Technology unit Santander which has control for temperature and dosage of Sodium Chloride (NaCl) was used, and to moisture at room temperature 22 ° C. In Figure 1. Salt spray booth (CNS) used is presented.

![Employee Salt Spray booth at work.](image)

**Figure 1.** Employee Salt Spray booth at work.

HIKING class 1.0 wattmeters were used imitating the measurement system of the electric power distributor in the locality, which is in kWh, like the one shown in Figure 2 measuring the power consumption at two different sites before the cabin Wattmeter 1, and after the cab, Wattmeter 2 as shown in Figure 3.
PM6306 impedances meter Fluke mark which has a measuring range 0.00005Ω to 50MΩ at ambient laboratory temperature of 22 °C was used for resistance measurements. A scale model OHAUS PIONEER PA2014 0.1m was used [g] resolution for weight measurements. For loading three luminaires 100 [W] nominal was used, and the selected specimen was one AWG gauge number 12 copper since according RETIE chapter 3 article 20 and NTC 2050 section 310 and 338 it is convenient for electrical installations residential.

2.2 Methods
The research has two objectives: In the first instance define what type of connection cable corrosion is favored, if the simple connection (without joints) or complex connection (with connections) additionally if corrosion has any influence on the electrical characteristic’s driver (Transmission power and resistance). Taking into account the above, research is descriptive because it attempts to measure the characteristics of
the driver before a principal factor such as corrosion. Also, to establish the relationship between corrosion and electrical characteristics of the driver based on linear regression model is used [7] [7] [8]. In order to determine which was the type of connection where greater influence of corrosion is presented an experimental design was proposed treatments. 1. Type of connection and 2. Exposure time: Thus two factors are established. In this respect tests were performed with simple connection 8 hours exposure and 16 hours of no exposure to salt spray and the complex connection 8 hours exposure and 16 hours of non-exposure, completing this four treatments in which the amount of corrosion, the energy transmitted and the strength was measured. 5 repetitions is recommended for experimental design with two factors were performed, as is the case in the present study; tests were realizadas in a period of 120 hours for each factor. It should be noted that the time intervals were chosen in this way because for making measurements, these should be made during working hours. [8] [9]

3. Works development

The tests were conducted in two stages with 12 AWG gauge copper number as according RETIE and NTC 2050 is suitable for residential electrical installations.

The first step was to expose completely smooth wire (single connection) to saltiness using the Salt Fog Cabinet (CNS) of Figure.1 which provide a special atmosphere to accelerate corrosion. The (CNS) is added a solution composed of 5 parts of sodium chloride (NaCl) and 95 parts of natural saline water, as indicated by ASTM B117 (ASTM B117), under the supervision of the CIC. To this was connected a completely resistive load of 300 [W] which is an average load of a joint or driver in a switch or home outlet, the supply of electricity from a source of 120 [V] AC. This step was performed in cycles 8 hours and 16 hours deenergized energized per day for 5 days, giving a total of 120 hours testing since the tests were done in days and working hours only. Also, the weight of the specimen after each cycle was measured and the electric power consumption in watts kilo-hour (kWh), in the entrance of the specimen as its output, as shown in Figure.3. Similarly, resistance in ohms (Ω) immediately terminated each cycle, the driver being at room temperature as it was not in overload was measured.

In test 2 the above procedure was replicated, but using complex connection, for this type joints used mouse tail as shown in Figure.5 and Figure.4.

Figure 4. Load energy measurement and joints.
Figure 5. Rat Tail Silice.

4. Results

To test 1 with the driver unsliced data obtained are shown in Table 1. The cycles are due to the possibility of laboratory measurement, cycle 1 being the initial state in the first test day. Is Day 1 Time 10:00 a.m. cycle 2 corresponds to the first day when they have passed 8 hours of operation and exposure is day 1 at 6:00 pm cycle 3 we correspond to measurements made past 16 hours, that is to second day 10: am, the fourth cycle is reading the same day to spend 8 hours and so on.

Table 1. Weight readings, energy in each meter and resistance in test 1 (connector without joints)

| CYCLE | WEIGHT |
|-------|--------|
|       | [G]    |
| 1     | 55.3210 |
| 2     | 55.3210 |
| 3     | 55.3210 |
| 4     | 55.3210 |
| 5     | 55.3210 |
| 6     | 55.3210 |
| 7     | 55.3210 |
| 8     | 55.3210 |
| 9     | 55.3208 |
| 10    | 55.3205 |

|               | W1 [KWH] | W2 [KWH] | RESISTANCE [Ω] |
|---------------|----------|----------|-----------------|
| 1             | 1.2      | 1.4      | 0.0154          |
| 2             | 3.2      | 3.4      | 0.0154          |
| 3             | 7.2      | 7.4      | 0.0154          |
| 4             | 9.2      | 9.4      | 0.0155          |
| 5             | 13.2     | 13.4     | 0.0156          |
| 6             | 15.2     | 15.4     | 0.0157          |
| 7             | 19.2     | 19.4     | 0.0157          |
| 8             | 21.2     | 21.4     | 0.0158          |
| 9             | 25.2     | 25.4     | 0.0163          |
| 10            | 27.2     | 27.4     | 0.0177          |

In Figure 6 it can be seen the behavior of the resistance in the measuring time, which increases minimum values being assumed to microbiological corrosion, and in Figure 7 behavior driver's weight.
Similarly, in Figure 8 energy profiles are shown in both power consumption meter readings where w1 is the bottom line and reading w2 is the top line.
To test 2 with the conductor splices using data obtained are shown in Table 2. The data presented there obey the procedure used for test 1.

**Table 2.** Weight readings, energy in each meter and test Resistance 2 (connector joints)

| CYCLE | WEIGHT [G] | W1 [KWH] | W2 [KWH] | RESISTANCE [Ω] |
|-------|------------|----------|----------|----------------|
| 1     | 57.8265    | 27.2     | 27.4     | 0.0175         |
| 2     | 57.8265    | 29.8     | 30.1     | 0.0175         |
| 3     | 57.8265    | 35.0     | 35.3     | 0.0177         |
| 4     | 57.8265    | 37.6     | 37.9     | 0.0178         |
| 5     | 57.8263    | 42.8     | 43.1     | 0.0179         |
| 6     | 57.3260    | 45.4     | 45.7     | 0.0179         |
| 7     | 57.3258    | 51.0     | 51.3     | 0.0180         |
| 8     | 57.3253    | 53.6     | 53.9     | 0.0181         |
| 9     | 57.3248    | 58.8     | 59.2     | 0.0183         |
| 10    | 57.3240    | 61.4     | 61.8     | 0.0199         |

In Figure 9 shows the behavior of the resistance along the test used 2 to 3 rat tail splices the same author. Also, in Wright Figure 10 behavior occurs.
Similarly, in Figure 11 behavior of power transmission by reading W1 and W2 the upper curve the lower how.
Figure 11. Behavior of energy transported in test 2. Source: authors.

From Figure 6 to 11 can be highlighted several observations. The first is that as shown in Figure 7 and Figure 10, the weight loss was very small both in test 1 and the prueba2. Additionally, in Figure 6 as in Figure 11 readings wattmeter 1 and 2 are very similar for each test. This indicates that exposure to corrosive environment did not allow a substantial material wear and did not affect the transport of energy. However, the conductor resistance in test 1 showed a total change of 2.3 milliohms and in test 2 2.4 m [Ω]. Whereby a linear regression model trying corrosion, represented by weight loss, as an independent variable and the dependent variable resistance in each of the tests sought.

For test 1 the model that best fits is an exponential model as shown in Equation 1.

\[
R(t) = a \cdot p(t)^b + c
\]  

Where:

R (t): Tensile test along
P (t): weight throughout the test
a: constant adjustment (-47.46)
b: adjustment constant (0.54689)
c: constant setting (426.1)

To validate this model the experimental data with the data model results were compared. The data are shown in Table 3.
Table 3. Validation data for the model resistance test 1 (driver without joints)

| CYCLE | WEIGHT [G] | R MODEL OH | AS R [Ω] | ERROR % |
|-------|------------|------------|----------|---------|
| 1     | 55.3210    | 0.0144     | 0.0154   | 6.9515  |
| 2     | 55.3210    | 0.0144     | 0.0154   | 6.9515  |
| 3     | 55.3210    | 0.0144     | 0.0154   | 6.9515  |
| 4     | 55.3210    | 0.0144     | 0.0155   | 7.6460  |
| 5     | 55.3210    | 0.0144     | 0.0156   | 8.3405  |
| 6     | 55.3210    | 0.0144     | 0.0157   | 9.0350  |
| 7     | 55.3210    | 0.0144     | 0.0157   | 9.0350  |
| 8     | 55.3210    | 0.0144     | 0.0158   | 9.7294  |
| 9     | 55.3208    | 0.0152     | 0.0163   | 6.9449  |
| 10    | 55.3205    | 0.0165     | 0.0177   | 7.2393  |

To test 2 the same analysis was performed and the same model of equation 1. But with values \( a = -0.004401 \) was obtained, \( b = 0.6787 \) and \( c = 0.08679 \). Validation data shown in Table 4.

Table 4. Validation data for the model resistance test 2 (conductor joints)

| CYCLE | WEIGHT [G] | R MODEL OH | AS R [Ω] | ERROR % |
|-------|------------|------------|----------|---------|
| 1     | 57.8265    | 0.0177     | 0.0175   | 1.0484  |
| 2     | 57.8265    | 0.0177     | 0.0175   | 1.0484  |
| 3     | 57.8265    | 0.0177     | 0.0177   | 0.0000  |
| 4     | 57.8265    | 0.0177     | 0.0178   | 0.6479  |
| 5     | 57.8263    | 0.0181     | 0.0179   | 1.2124  |
| 6     | 57.3260    | 0.0181     | 0.0179   | 1.0608  |
| 7     | 57.3258    | 0.0181     | 0.0180   | 0.5089  |
| 8     | 57.3253    | 0.0181     | 0.0181   | 0.0000  |
| 9     | 57.3248    | 0.0181     | 0.0183   | 1.1447  |
| 10    | 57.3240    | 0.0181     | 0.0199   | 9.9840  |

5. Discussion
In this work two tests were to determine the influence of cable joints in the proliferation of corrosion. Similarly determine the type of incidence of corrosion in the electrical characteristics of the driver as the resistance and energy transport. On the one hand the total weight loss driver unspliced was 0.5m [g] and the conductor splices was 502.5m [g]. From this result it follows that there was greater weight loss in the conductor joints, which suggests that the presence of splices in a conductive favors outbreaks of corrosion. Furthermore, in the power transmission of the two conductor types that no changes can be inferred because of corrosion they occurred. In contrast to this, in resistance measurements if they every test these changes were generally 2.3m [Ω] and 2.4m [Ω] for the two tests respectively perceived. It is important to note that these values are in proportion to the average strength (15.85mΩ, 18.06mΩ, for test 1 and 2 respectively) of each test 14.51% and 13.29 respectively. This indicates that although there was a change in the resistance of the conductor, no changes were noted in the transmitted energy. This result may be limited by the accuracy of the wattmeter since this is the order of tenths.
Finally, the exponential model obtained represents an average approximate 6.98% and 1.7% error for the two tests, the resistance in the conductor based on the weight of the driver. This allows predicting changes in weight and resistance when the weight has been affected by corrosion. It is important to note that changes in weight and resistance were evaluated for each test lasting 120 hours. In this sense it could be extrapolated to a longer obtaining the weight functions depending on the time and thus analytically meet resistance.

6. Conclusions
Descriptive analysis and experimental design allowed us to evaluate the incidence of two factors (connection type and exposure time) in induced corrosion in a copper conductor 95.95% purity used in residential electrical installations. The method of weight loss allowed to establish conditions altered corrosion element. With this it was possible to differentiate between the connection and without joints; latter showing further degradation by having a total weight loss was 100 times the driver without splicing. Additionally, according resistance profiles shown in Figures 6 and 9, changes manifest as time progresses test and turn corrosion; this shows that if the electrical characteristics vary with corrosion. But nevertheless, Finally, the methodology proposed by the experimental design provided results that were used to propose a model (equation 1) described with greater accuracy than 90% resistance behavior depending on the weight of the driver. It should be noted that the model parameters equation, according to this study, dependent on the structure of the conductor (with or without joints); in turn this evidence is important to adjust the parameters from experimental data if tests do to other drivers of other features such as: other calibers, other arrangements, etc. However, to achieve a generalization of the model it should be extended to a dipping process of the specimen carried out directly in saline solution and no mist; It is also presumed that longer exposure times may exhibit changes larger magnitudes according to the trend shown in Figures. 6 and 9 because the behavior of the resistance in the measuring time increases in minimum values being assumed to microbiological corrosion.

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