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INSULATING PROTECTIVE COVER FOR LIVE WORKING: MAIN CAUSES OF REJECTION UNDER LABORATORY CONDITIONS

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ABSTRACT

Insulating covers are collective protective equipment widely used in the maintenance of energized aerial electrical networks. The insulating covers can be divided in rigid or flexible. Using them along with other insulating means they allow carrying out repairs without interrupting the electric service. The present work relates essential aspects established in the international normative to achieve the adequate performance of rigid and flexible insulating protectors. It describes the experiences obtained in the individual electrical laboratory tests carried out in the CIPEL High Tension Laboratory in a measurement period of five years. As a result, the main insulation rigid and flexible covers used in Cuba and causes of rejection are identified at the laboratory level and measures are proposed that, in the authors' opinion, can improve the good condition of the protective element and increase its useful life, which represents an increase in operator safety and an improvement in the quality of the executed works.

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I. INTRODUCTION

The generalization of the work technique with energized power lines has been possible thanks primarily to the constant improvement of the operator's safety conditions when using materials and equipment with better characteristics and insulating qualities and also for the use of new technologies.

In recent times there has been an increase in the execution of energized power lines in Cuba. This is due to the benefits offered by this technique in terms of economic savings and positive social impact. These works are executed using individual and shared insulating protective equipment, including the rigid and flexible conductor covers which are the subject of this work [1].

As an importer of these protective elements the experimental work of high voltage laboratories is oriented to the realization of individual tests. These tests allow to comply with the annual quality certification of the equipment and "live" work tools guaranteeing the security of the energized work brigades of the UNE.

Insulating cover, including new ones, can't be used if it has been longer than twelve months after its last test. And when behaviours that may indicate loss of the insulating qualities of the cover are detected, it has to be sent immediately to a certified electrical laboratory [2-3]. This practice and work dynamics have closely linked the specialists of the CIPEL High Voltage Laboratory and the technicians of the different companies responsible for enforcing the annual checks established by the UNE.

The analysis and interpretation of the results obtained in the experimental work carried out under laboratory conditions for three years will allow identifying the main rejection criteria detected in each type of cover.

II. GENERAL CHARACTERISTICS AND TECHNICAL REQUIREMENTS OF RIGID AND FLEXIBLE CONDUCTOR COVERS

For a better understanding of the work done below, the definitions of rigid and flexible cover respectively [2-3] are presented:

Rigid covers: electrically insulated enclosures designed to be temporarily installed on various types of irregularly shaped equipment in order to protect personnel and equipment from accidental electrical contacts.

Flexible conductor covers: electro-insulating flexible tubes made of different materials such as elastomers, plastics or a combination of both. They present a longitudinal incision and are installed temporarily in electrical conductors to avoid accidental contacts when performing works on energized power lines.

The insulating covers can be classified according to their class depending on the electrical limits they support by design and according to their use depending on the shape of the element to be protected.

II.1 CLASS

Different manufacture insulating covers can be found internationally. In the CIPEL High Voltage Laboratory all certified insulating covers meet the criteria of the ASTM standards [2-3]. Rigid and flexible conductor covers are divided in classes according to their electrical limits according to the criteria shown in Table 1.

Table 1: Classes of rigid and flexible conductor covers according to their electrical limits.

Class	Rigid covers Phase to phase voltage (kV rms) [1]	Flexible conductor covers Phase to phase voltage (kV rms) [2]
0	-	1
1	-	7,5
2	14,6	17
3	26,4	26,5
4	36,6	36
5	48,3	-
6	72,5	-

Source: [2-3].

In Table 1 it is observed that for both the rigid and the flexible conductor cover their operating voltage for the common classes does not considerably vary. However, there are differences in the classes that are manufactured.

Due to the predominance of electric networks with nominal voltage from line to line of 15 and 33 kV in Cuba, the most commonly used insulating covers are class 2, 3 and 4.

II.2 UTILIZATION

There is a wide diversity of insulating covers depending on the energized elements to be isolated from the operators. The most used rigid insulation covers in Cuba are shown in Figure 1.

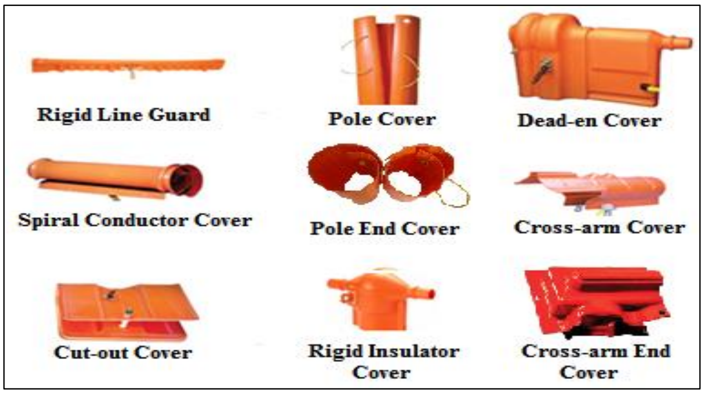

Figure 1: Rigid insulation covers most used in Cuba.
Source: [4-5].

The flexible conductor covers are used according to the styles shown in Figure 2.

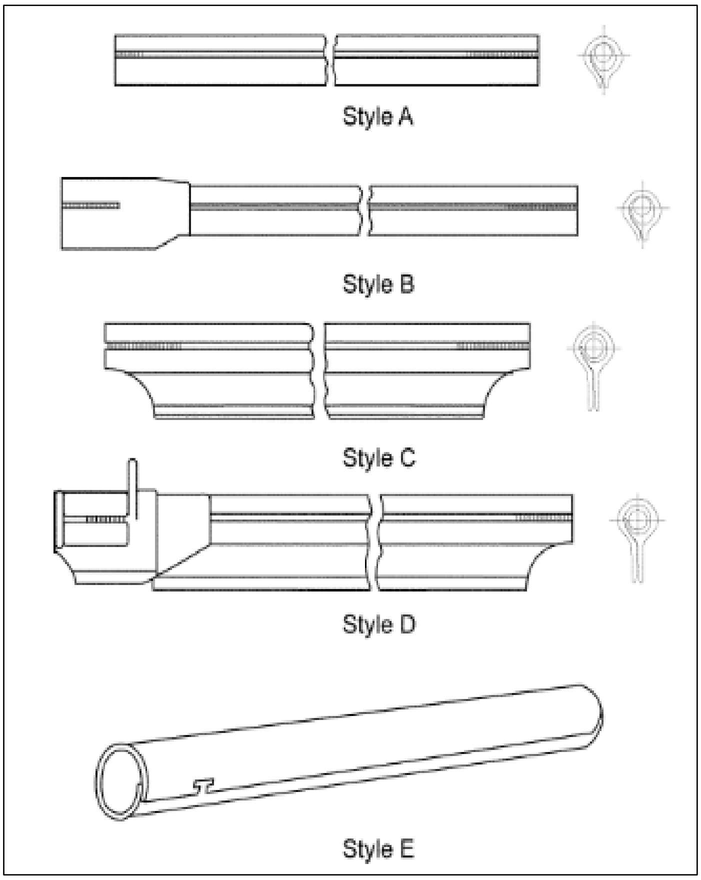

Figure 2: Different styles of flexible conductor covers.
Source: [3].

From Figure 2, the type A cover (short-lip) is the most used in our country for energized work [4-5]. Class 2 is the only one used for this type of cover. Other important aspects to keep in mind to maintain the quality of the sample in the processes of laboratory tests are: cleaning, drying, storage and transportation.

II.3 CLEANING AND DRYING

Each protective element must be inspected and cleaned in the field or laboratory conditions before being used. To fulfil this task, the following aspects must be taken into consideration [2-3]:

The cleaning of both types of insulating covers must be done with soap or light non-bleaching detergent or with a cleaner recommended by the manufacturer to prevent degrading of the insulating qualities of the cover [2-3].

Drying should be done by suspending each element in a way that facilitates drainage and air circulation. It is proposed that in cases where an automatic dryer is used, it should not have ultraviolet lamps, generate ozone or present interior surfaces that cut, wear or puncture the element [2-3].

II.4 STORAGE AND TRANSPORTATION CONDITIONS

Both types of covers must be stored and transported with extreme care avoiding mechanical stresses that could damage them. For storage, they should be placed in containers, boxes, or appropriate bags in cold, dry and dark places. It is important that the areas near the storage areas are free of ozone, chemical agents, oils, vapours, electrical discharges and heat sources [2-3].

III. INDIVIDUAL LABORATORY TESTS

In the 2014-2019 periods up to a total of 1026 rigid insulating cover and 452 flexible conductor cover belonging to different companies in the country were tested in the CIPEL High Voltage Laboratory [6-7]. The insulating covers subjected to tests are manufactured by CHANCE, SALISBURY, KEARNEY and RITZ (ASTM standards) [8-10]. All of them have different types according to their use and belong to classes 2, 3 and 4. A summary is shown in Table 2 of the technical data of the insulating covers subjected to tests.

Table 2: Technical data of the insulating covers subjected to individual electrical tests.

Technical dates	Rigid covers		Flexible conductor covers
Manufactures	CHANCE, SALISBURY, KEARNEY AND RITZ		SALISBURY
Utilization	Rigid cover to: conductor, insulator, dead-en, cut-out, cross-arm, cross-arm top, pole and pole top		Short-lip flexible cover
Class	3	4	2
Operating voltage between phases (kV rms)	26,4	36,6	17

Source: Authors, (2020).

The individual electrical test of both rigid and flexible conductor insulators consists of two stages: visual inspection and dielectric test.

III.1 VISUAL INSPECTION

Visual inspection of the material should be performed to check for presence of: cracks, holes, foreign matter, cuts or abrasions. Only small depressions or bulges are accepted as long as they do not affect its operation. Cases that present some of these problems are immediately rejected.

Once the visual inspection has been successfully carried out, the insulating cover is subjected to a dielectric test to verify the state of the insulation of the material.

III.2 DIELECTRIC TEST

The test procedure consisted in the execution of the following steps:

1. An inner (potential) electrode is selected depending on the type or style of the cover as established in the corresponding regulations [2-3].
2. As an external electrode (grounding), a wet tissue blanket was used.
3. The distance between electrodes is established according to the corresponding regulations [2-3].
4. The test voltage specified in Tables 3 and 4 is applied according to the class of cover. The electric voltage is increased at a rate of 1kV/s from a value no greater than its 50%. Once the specified value is reached, the time established in Tables 3 and 4 is maintained.
5. If disconnection of the source does not occur, the voltage is reduced to zero maintaining the same rise rate.

The environmental variables during the trials were maintained within the following ranges:

Temperature: between 18 ºC and 28 ºC.

Relative humidity: between 45% and 75%.

Table 3: Voltages and test times specified for rigid covers.

Class	Test voltage (kV effective)	Duration (min)
3	24	1
4	32	1

Source: [2].

Table 4: Voltages and specified test times for flexible conductor covers.

Class	Test voltage (kV effective)	Duration (min)
2	20	1

Source: [3].

The rejection criterion established for the evaluation of the dielectric test performed to the material are:

Cover fault before the test voltage reaches its maximum value or during its application time.

- A significant increase in temperature.
- A perforation or discharge occurs.

If any of these are observed: cracks, abrasions, burns, perforations or symptoms that indicate degradation of the material once the test is finished.

If any of these problems occur, the covers are immediately rejected.

The generally used test schemes are shown in Figures 3 and 4.

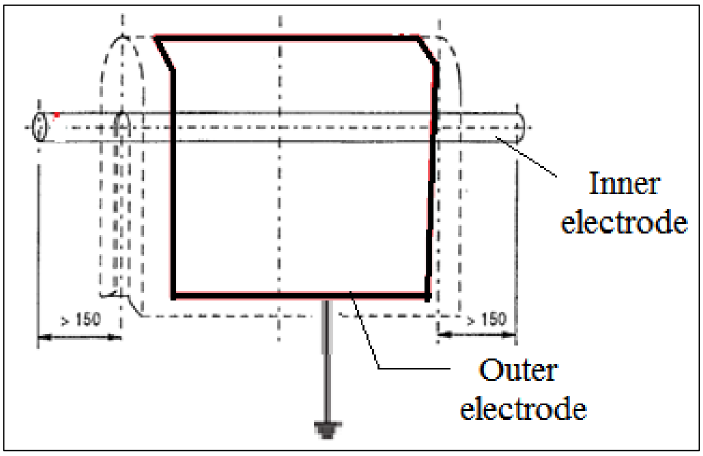

Figure 3: General test scheme for rigid cover certification.
Source: [2].

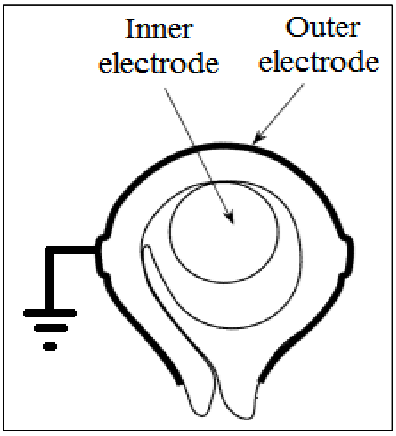

Figure 4: General test scheme for flexible conductor cover certification.
Source: [3].

IV. RESULTS AND DISCUSSIONS

Out of the 1026 rigid covers subjected to individual tests during the analysed period, 89 were rejected, representing a 8.7 % of the total. In the case of flexible covers, out of a total of 452 only 15 were rejected, representing a 3.3 % of the total. These percentages could be interpreted as general tendency of the covers to be resistant to mechanical and electrical stresses provoked by handling in field conditions.

Table 5 shows a synthesis of the results obtained at laboratory level in order to analyse which were the predominant causes that led to rejection in both cover types [7].

Table 5: Causes of rejection of insulating covers at the laboratory level.

Causes of rejection	**Quantity of rigid insulating covers rejections**	**Quantity of flexible insulating conductor covers rejections**
Cracks	71	2
Electrical perforation	18	13
Total	89	15

Source: Authors, (2020).

Next, an analysis is made of the percentage of the causes of rejection (Figure 5).

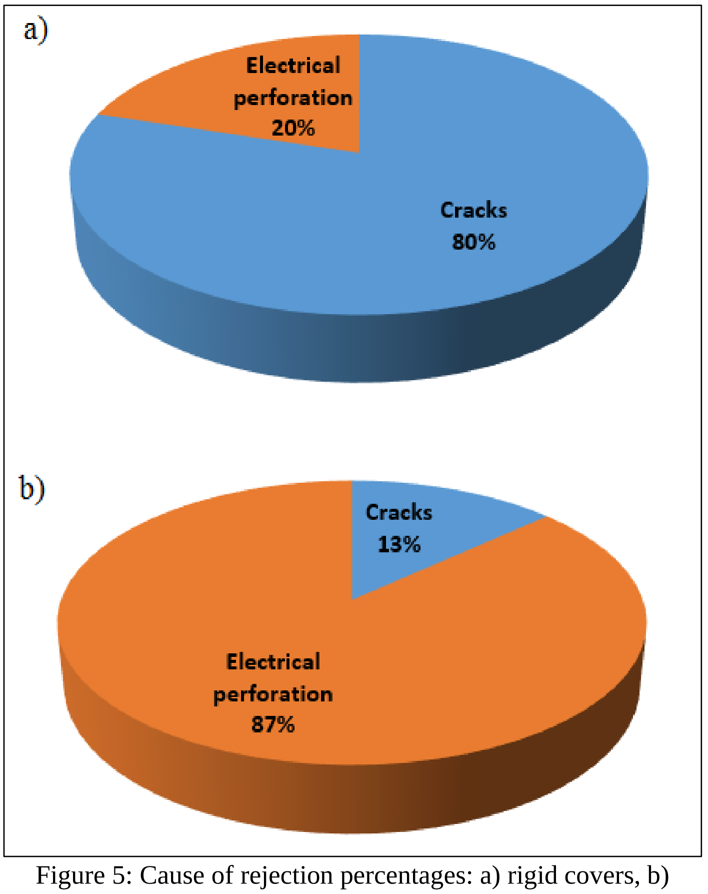

Figure 5: Cause of rejection percentages: a) rigid covers, b) flexible conductor covers.
Source: Authors, (2020).

Interpreting the behaviour of the results obtained in Figure 5 approximately 80% of the rigid cover's rejections are due to the presence of cracks and only 20% are due to the electrical perforation of the insulating material. However, in the case of flexible conductor covers, it is evident that 87% of the rejections are due to electrical perforation and 13% to cracking.

As a summary, it can be observed that the main cause of rejection of rigid insulating covers are the cracks present in the material while the main cause of rejection of flexible conductor cover is the electrical perforation of the material during the dielectric test.

The authors, based on the experience gathered working with specialists from different entities that use this type of protection, consider that these problems can be attributed mainly to deficient storage conditions, transportation and utilization conditions of the covers.

The problems related to storage, use and transportation of the covers are mainly due to lack of care owing to objective factors such as lack of material resources. Also, subjective factors such as the lack of technical culture prevent internalizing the extraordinary importance of the care that should be given to the protection means.

V. CONCLUSIONS

The main cause of rejection in the individual tests carried out in the CIPEL High Voltage Laboratory is the presence of cracks in the insulating material of the rigid covers and the electrical perforation in the flexible conductor covers. This reveals evidence of the existence of inadequate storage, transportation and handling conditions, therefor individual electrical tests have to be executed respecting the established periodicity. Also the training of the technical personnel ought to be continued and intensified through preparation courses to increase their technical culture. Furthermore, the implementation of measures by the UNE should be oriented to minimize the problems detected and increase the operator's safety and work quality.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Dr. Ramón González Guevara and MSc. Boris Alba Valle.
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Supervision: Dr. Ramón González Guevara and MSc. Boris Alba Valle.
Approval of the final text: Dr. Ramón González Guevara and MSc. Boris Alba Valle.

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