ELECTRICAL SURFACE RESISTANCE OF USED VENTILATION TUBING

K.J. JUDGE AND K.J. MINTZ

MRL 88-89 (TR)

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ABSTRACT

Electrical surface resistance tests were carried out on samples of used PVC ventilation tubing from a coal mine. There was no evidence of any increase in surface resistance compared to similar new material. Hence, testing of new material appears to be sufficient to ensure safety against static electricity. This material also showed no significant change in surface resistance over the normal range of temperature and humidity. No significant difference was found between "as received" and cleaned material.

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*Technologist, **Research Scientist, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa

KEYWORDS: static electricity, ventilation materials, coal mines

RESISTIVITE ELECTRIQUE SUPERFICIELLE DE LA TUYAUTERIE D'AERAGE D'OCCASION

par

K.J. Judge* et K.J. Mintz**

RESUME

On a mené des essais en vue de contrôler la résistivité électrique superficielle des échantillons de tuyauterie d'aérage servant au recyclage des gaz de carter (PCV). Aucun signe n'indiquait un accroissement de la résistivité superficielle de ces échantillons comparativement à du materiel neuf de même type. Par conséquent, la contrôle du matériel neuf suffit à assurer la sécurité. De plus, la résistivité superficielle du matériel n'a pas été modifiée de façon importante dans des conditions d'humidité et de temperature normales.

MOTS-CLE: électricité statique, matériel d'aérage, mines de charbon

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*Technologue, **chercheur scientifique, Laboratoire de recherche minière, CANMET, Energie, Mines et Ressources Canada, Ottawa

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INTRODUCTION

In an environment containing an explosive gas, a spark generated by static electricity may be sufficient to cause a gas/air explosion. In particular, a number of explosions in underground coal mines, which often contain explosible concentrations of methane, have led many countries to require that nonmetallic materials used therein be made antistatic. The usual method employed for quantifying the antistatic property is the measurement of the electrical surface resistance.

For about 12 years, CEAL has been certifying antistatic ventilation materials on an ad hoc basis using the National Coal Board (NCB) method for flat materials (1) and a CENELEC Standard for curved materials (2). Recently, the Canadian Standards Association (CSA) has established Technical Committee M427 to develop a consensus standard for the flammability and antistatic properties of ventilation materials. A number of technical questions have arisen from the first meeting of M427. CEAL was asked to investigate the effect of wear on the surface resistance, which is the subject of the current report.

EXPERIMENTAL PROCEDURES

The Cape Breton Development Corporation (DEVCO) sent two 3-m lengths of used 60 cm diameter flexible ventilation tubing (PVC-type). Ten 190 mm x 350 mm samples were cut from each length, cleaned by scrubbing lightly with a brush, washing with water and drying. Because of the method of construction of the tubing, 190 mm was the maximum width available, with the useful width only about 150 mm, the remaining having been used for sewing around the metal

rings.

An unused sample of the same type of ventilation material was used as the reference.

An additional 10 samples were cut from each length and tested without cleaning.

The samples were conditioned and tested inside an environmental chamber set at the desired humidity and temperature.

The National Coal Board Specification (1) calls for the resistance to be measured across concentric brass electrodes (a cylinder of 25 mm diameter and a ring of inner diameter 125 mm and an outer diameter of 150 mm) placed on the material. A conducting liquid contact agent is used between the electrodes and test material. A megohmmeter is used to apply a voltage and measure the resistance. The upper limit allowed is 300 Mohm. The sample size specified is 300 mm x 300 mm; the nature of the finished product precluded the use of such a size. The actual sample was barely large enough to fit the electrodes.

The CENELEC Standard (2) uses electrodes 1 mm wide, 100 mm long and 10 mm apart which are painted on the test material with silver paint. The upper limit allowed on the measured resistance is 120 Mohm.

A digital megohmmeter, Model DMH 251A, was used for applying the voltage and measuring the resistance across the electrodes for the samples with higher resistance. An analogue insulation tester, Hitachi Type E17, was used for the resistances in the kohm range.

RESULTS AND DISCUSSION

The first set of tests was carried out to determine if the smaller than standard sample size would affect the surface resistance reading. Two reference ventilation sheetings were cut to 300 x 300 mm, 200 x 200 mm and 150 x 150 mm. At 22°C and 50% R.H., one sample remained constant at 0.3 Mohm, the other remained constant at 17.5 Mohm, regardless of sample size. Hence, the smaller test samples would not affect the test results.

Half of the 10 samples of each length (designated "A" and "B") were tested on the inside surface and the other half used for testing on the outside surface. The mean values of each set of 5, along with their standard deviations, are shown in matrix form in Tables 1 - 10.

All the surface resistance values were quite low, about four orders of magnitude below the maximum allowed values.

Sample B had a lower surface resistance than sample A. The difference, however, can be attributed to normal batch-to-batch variation. Since we do not have the history of these samples, no conclusions can be drawn as to whether this is, indeed the cause of the difference. The resistance of the reference sample was close to that of sample A.

The inside of the duct might be expected to wear much more than the outside, due to the high velocity of air travelling through it, and thus might be expected to show a greater change in surface resistance. Both surfaces of the material exhibited little wear (once they had been completely cleaned). The surface resistance data indicates that there is no significant difference between outside and inside surfaces.

Comparing Tables 1 and 2, it can be seen that the NCB method yielded values 3 - 6 times greater than the CENELEC method. Previous studies on

conveyor belting yielded ratios of 0.7 - 1.5. The higher ratio in the current study may be due to the lower resistance values involved.

The effect of humidity (at a constant temperature of 22°C) on the surface resistance can be seen by comparing Tables 2 - 6. Both surfaces of both lengths of tubing, as well as the reference sample, showed no detectable change in resistance over the accessible range (32% - 90%). Our previous study on conveyor belting (3) indicated that the surface resistance of PVC-type belting was essentially constant in the 10 - 80% range, but decreased sharply above about 85%. No such decrease was observed for the ventilation materials. The cause of the decrease was suspected to be adsorption of water on the surface, which would be a function of the entire formulation.

The effect of temperature on the surface resistance can be seen by comparing Tables 2 and 7 - 10. The relative humidity could not be maintained at the 48% value at the extreme points because of the limitations of the environmental chamber. Since the effect of humidity was shown not to have a detectable effect, this limitation is not a problem. Both surfaces of both lengths of tubing as well as the reference sample showed no significant change in resistance over the accessible range (6 - 40 °C). This is in marked contrast to the PVC conveyor belting (3), for which the resistance increased very strongly with decreasing temperature. Note, however, that a nitrile rubber belting had only a mild dependence on temperature and two rubber belts had no significant change with temperature. These three belts had very low surface resistances; it is possible that only materials which have already a substantial resistance to the flow of current might exhibit a strong dependence on temperature. Alternatively, the difference in temperature-dependence may be attributed to the means of achieving the

anti-static property. The conveyor belting uses an antistatic substance impregnated into its cover; perhaps decreasing the temperature decreases the mobility of the antistatic substance and thus decreases the conductivity. On the other hand, the ventilation material uses a coating of the antistatic material and thus may not be affected by any mobility problems.

As can be seen from the data, the measured surface resistance is quite variable even on samples taken from the same sheet. This variability is not due to limitations of measuring instrument or electrode placement, but is probably due to the sensitivity of surface resistance to very small variations in surface composition. Hence, a minimum of three tests should be carried out on each side of each product to be certified, or tested in a quality control program. In addition, manufacturers should take into consideration this variability when formulating a new product. Although it may be desired for economic or product performance reasons to have the surface resistance close to the upper allowable limit, a risk would be taken that a product may fail either the certification or quality control tests.

There is always a certain degree of arbitrariness when a limit on some property is decided upon for safety reasons. From the discussion above, this is especially true for the surface resistance. In our earlier report (3), we had recommended that an upper limit of 200 Mohm be used with the CENELEC method in order to achieve approximately the same degree of safety as the 300 Mohm upper limit of the NCB method. Although the results here indicate that the CENELEC method sometimes yielded values much smaller than the NCB method, they also indicate that for the higher resistance values, which are of most interest with respect to safety, the two methods yielded values fairly close together. Therefore, the earlier proposal of 200 Mohm as the upper limit remains reasonably valid.

Tables 11 and 12 show the results of testing the used ventilation material as received (without cleaning). Considerable coal dust and other materials were stuck to the surface. It was rather difficult to apply the electrodes without disturbing this coating. Not surprisingly, the scatter of the data is much greater than that on the cleaned surfaces (compare the standard deviations). Nevertheless, of the eight comparisons that can be made between the data in Tables 11 and 12 and the corresponding data in Tables 1 and 2, only one is statistically different at the 95% confidence level, using the method of Pearson and Hartley (4). That one, the inside surface of Sample B using the NCB method, has lower resistance for the non cleaned sample than the cleaned; hence, the cleaned sample is the worst-case. The reason for the similarity of values probably can be attributed to the porosity of the deposited materials (with respect to passage of electrical charge), otherwise, one would have to assume that the deposited coating had about the same electrical conductivity as the ventilation material.

The authors prefer the CENELEC method over the NCB method for several reasons:

1. the NCB method cannot be applied to curved materials, such as rigid pipe;
2. there is no problem with contact of the electrodes with the surface, which can be a problem with dimpled or roughened surfaces;
3. the test sample with the electrodes can be stored for future reference;
4. tests can be done easily at different humidities and temperatures if required.

The CENELEC method has one significant disadvantage: if the material on which the silver is painted is flexed, there is a risk of tiny

cracks on the electrode which, if not detected and repaired, would greatly increase the resistance. This is, of course, a problem only for flexible ventilation materials and not for rigid materials or conveyor belting. To ensure that the sample under test does not have this problem, it is necessary only to measure the resistance along the length of each electrode, which should be no more than 500 ohm.

CONCLUSIONS

The results of this study indicate that used ventilation material does not present an increased hazard with respect to static electricity. It must be stressed, however, that this conclusion may apply only to the particular material tested. Although this product obtains its antistatic characteristic from a coating which is applied to the base non-antistatic vinyl cloth and thus, in principle, is subject to loss of the anti-static characteristic if the coating wears off, it would appear that the coating is sufficiently durable and sufficiently well-attached that this event did not occur in typical usage.

The effect of temperature and humidity on the surface resistance over the usual range appear to be small for this type of ventilation material.

The data on the "as is" samples from the mine vs. the cleaned samples indicate that the materials that are deposited on the tubing in normal usage, assuming that these tubings had been used in typical locations, do not adversely affect the conductivity of the ducting.

The authors recommend that the CENELEC method be adopted, with an upper limit of 200 Mohm.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Mr. Wayne Leblanc of DEVCO for arranging the shipment of the samples of used ventilation tubing.

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Table 1. Surface resistance (kohm): NCB method; t = 24°C, R.H. = 49%.

	A	B	Reference
inside	63 ± 14	17 ± 2	60
outside	56 ± 17	25 ± 7	

Table 2. Surface resistance (kohm): CENELEC method; t = 22°C, R.H. = 48%.

	A	B	Reference
inside	17 ± 5	3 ± 1	20
outside	13 ± 7	4 ± 1	

Table 3. Surface resistance (kohm): CENELEC method; t =22°C, R.H. = 32%.

	A	B	Reference
inside	17 ± 5	2 ± 1	20
outside	13 ± 7	4 ± 1	

Table 4. Surface resistance (kohm): CENELEC method; t = 22°C, R.H. = 62%.

	A	B	Reference
inside	18 ± 5	3 ± 1	20
outside	13 ± 8	4 ± 1	

Table 5. Surface resistance (kohm): CENELEC method; t = 22°C, R.H. = 84%.

	A	B	Reference
inside	18 ± 5	2 ± 1	20
outside	13 ± 7	4 ± 1	

Table 6. Surface resistance (kohm): CENELEC method; t = 22°C, R.H. = 90%.

	A	B	Reference
inside	17 ± 5	3 ± 1	20
outside	13 ± 8	4 ± 1	

Table 7. Surface resistance (kohm): CENELEC method; t = 6°C, R.H. = 58%.

	A	B	Reference
inside	16 ± 4	3 ± 1	19
outside	12 ± 7	3 ± 1	

Table 8. Surface resistance (kohm): CENELEC method; t = 14°C, R.H. = 48%.

	A	B	Reference
inside	17 ± 4	3 ± 1	20
outside	12 ± 7	4 ± 2	

Table 9. Surface resistance (kohm): CENELEC method; t = 30°C, R.H. = 47%.

	A	B	Reference
inside	16 ± 6	3 ± 1	20
outside	14 ± 8	4 ± 2	

Table 10. Surface resistance (kohm): CENELEC method; t = 40°C, R.H. = 38%.

	A	B	Reference
inside	17 ± 5	3 ± 1	20
outside	14 ± 8	4 ± 1	

Table 11. Surface resistance (kohm) uncleaned surfaces: NCB method;

t = 22°C, R.H. = 50%

	A	B
inside	71 ± 20	10 ± 2
outside	86 ± 37	15 ± 7

Table 12. Surface resistance (kohm) uncleaned surfaces: CENELEC method;

t = 22°C, R.H. = 50%

	A	B
inside	16 ± 8	6 ± 8
outside	13 ± 3	4 ± 2