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Title	Insulation resistance characteristics of solid cable under the D. C. high voltage impression
Sub Title	
Author	森, 元吉(Mori, Motokichi)
Publisher	慶應義塾大学藤原記念工学部
Publication year	1952
Jtitle	Proceedings of the Fujihara Memorial Faculty of Engineering Keio University Vol.5, No.19 (1952.) ,p.81(8)- 99(26)
JaLC DOI	
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Notes	
Genre	Departmental Bulletin Paper
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO50001004-00050019-0008

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Insulation Resistance Characteristics of Solid Cable under the D. C. High Voltage Impression

(Received June 29. 1953)

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Abstruct

This research aims to study the insulating resistance characteristics under D.C. high voltage impression and to show a result that the detection of the D.C. insulating resistance characteristic is more promising than the other methodes to examine the deterioration of insulator which has raised a question lately in the point of view of insulation protection of the electrical machines.

This report states that D. C. insulation resistance methode is rather connected with the dielectric strength of insulator, besides, the degree of deterioration is able to be showned in quality by so-called fault-ratio.

I. The Motive of Research

For many years so called meggering method has been accepted as only one test methode to inspect on the insulators in the various kind of electric machines. Of cause, this methode has been regarded as being not sufficient in the view of conservation of electric machine.

Now let us consider why this methode has been able to exist still.

We find out there are several reasons that the megger has suitable or for using in field tests and meggering was able to aware of the unfavourable states of insulators which may frequently happen in the course of conservation of the electric machine.

Anyhow, meggering methode is undoubtedly not perfect to examine the deterioration of insulator which is related with the life of insulation and the deterioration by the supperannuation of insulator becomes an important problem. The testing voltage by this methode is generally lower than 1000 volts, and as it is too low to test the insulation of electric machines running at very high voltage. It may be doubtful to analogize the characteristics of the insulation at high voltage condition from ones at such a low test voltage. The dielectric strength of a deteriorated insulator may decreased compared to initial state.

It is also easy to consider that the characteristic of the insulator may be varified the impressing voltage. Therefore the change of charactristic difference of a supperannuated insulator by impressing voltage may be more appeared than

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that of a sound insulator.

Accordingly, it is considered to be an influential key to make the grade of deterioration, that is to say, to be obtain from the variation of the characteristic of the insulator. The life of an insulator depends on it's dielectric strength which is decided by the localized weak point in the insulator and so a methode which tries to get the localized most unfourvarable weak point of the insulator is more desirable one compared to other methode measuriug general charactristic of the insulator.

At such a stand point we tried first to get the voltage characteristics by means of D. C voltage impression, second to make the charactristics clear, analyzed, and last to discuss them compared with tan δ characteristics.

II. Experiments on the Test Pieces. The Perforated Insulators

(a) Experiments on dry test pieces.

Now let us consider the small part of a dielectrics due to the localized damage of the insulator so called break-down and etc., for example, the air gap appearing in the insulator by the partial perforation or deterioration. This variation in quality correspondes to the partial one of the whole dielectrics and so it is assumed that such a variation, in case of containing very small quantity of some different impurities, does scarecely influence upon the value of tan δ of the insulator measured with Schering bridge methode or the others.

The test piece is a solid paraffin disk which is mixed very few graphite powder to increase the conductivity and to imitate a deteriorated insulator.

After melting, paraffin was solidified in vaccum chamber to avoid the intermixture of air bubbles.

Fig. 1 shows the form of the test-piece used in our experiment.

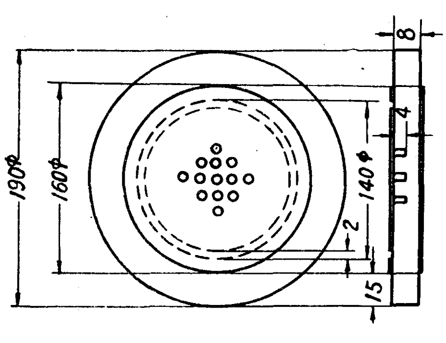


Fig.1 Sample for dry type

The test piece has an imperfectly perforated small-holes made artificially and sometimes these holes are filled up with water to imitate the intermixture of a various impurities. Fig. 2 illustrates the tan δ value and the equivalent capacity of the test-piece above mentioned by Schering-bridge A is an uninjured test-piece, unholed one and is not made with pure paraffin but with one in which few fine graphit is intermixtured beforehand, and so tan δ value of A increases with the impressing voltage as shown. B is a test-piece which has five small holes, 5 m/m in diameter and depth, perpendicular to the surface and remains non perforate part 3 m/m in thickness to the under side.

The tan δ value increases a little with the voltage. *C* is the one which has 20 holes the same above mentioned, The tan δ value increses at high voltage.

D is the one which has the same holes with *C* filled up with water.

The tan δ value is similar to that of *A*. Fig. 2 shown also the comparison of equivalent capacities of *A*, *B*, *C* and *D*. These differences are able to be explained by ionization phenomena. The equivalent resistance values of *A*, *B*, *C* and *D* are illustrated in Fig. 3. When the equivalent resistance values of holed test-piece *B*. *C* and *D* which the holes are filled up with water are compared with that of sound test-piece which is estimated at a

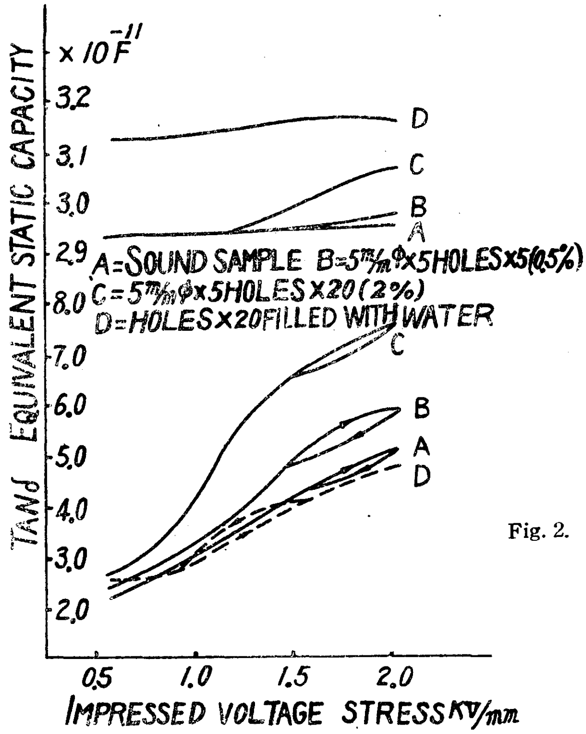


Fig. 2.

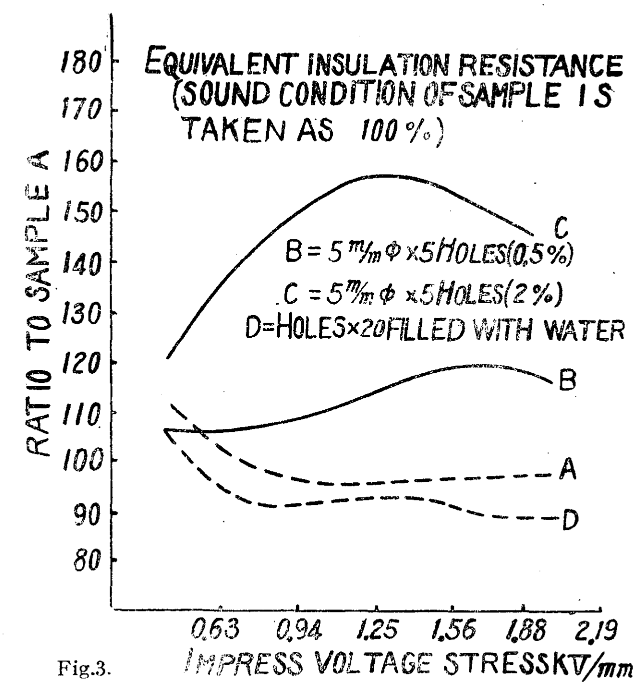


Fig.3.

* Fig. 2. Dielectric characteristics of injured samples
Fig. 3. Comparison of eqiuvalnet insulation resistance in the case where samples was injuired

standard rank 100%, they are all under the rank 100% as shown in Fig. 3. Each ratio of the volume of the hole of B and C to the total volume is 2.5% and 2%.

Fig .4 shows comparatively the insulating resistance values of test-piece A and B. The polarity of this experiment is negative. There is no difference between each resistance value of A_5 and B_5 in the case of impressing $5kV$, but some difference at $10kV$ and $15kV$.

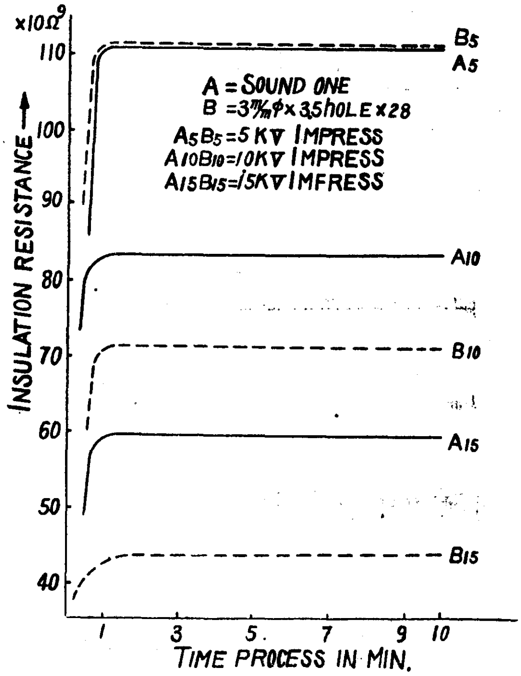


Fig. 4. Insulation resistance process in the case where negative D C voltags applied.

Table 1 illustrates the fault-ratio that means the ratio of insulating resistance at $5kV$, $10kV$ and $15kV$.

We find out the fact that the more the number of hols in the test-piece are the higher the insulating resistance ratio at each impressing voltage is.

Table 1. Fault ratio

$\frac{A_5}{A_{10}} = 1.13$	$\frac{B_5}{B_{10}} = 1.15$
$\frac{A_5}{A_{15}} = 1.86$	$\frac{B_5}{B_{15}} = 2.56$

As the results of the experiments above mentioned, we can see the fact that the direct current insulating resistance value has a considerable ability to show the most weak point of an insulator at high voltage and is better rather than the tan δ methode to the purpose.

b). Test on the holed test pieces of 3000 volt cables.

About the effects of the wounds in insulators to the charactristics of the insulators, the same experiments on cable test-pieces with the experiment on the dry insulators above mentioned were tried. Tne test-pieces, 3000 volt cables which are not new ones have the dimensions shown in fig. 5 and are soaked in an Cable Compound oil to suppress the corrona extension which may start from near the end.

The lead sheath of the test-piece was drilled to yield a wound, a hole 1 m/m diameter, while the internal insulator was treated not to be injured as possible.

The position of the hole is illustrated in Fig. 5.

Fig. 6. shows the results of measuring the loss angle of the test cables at both

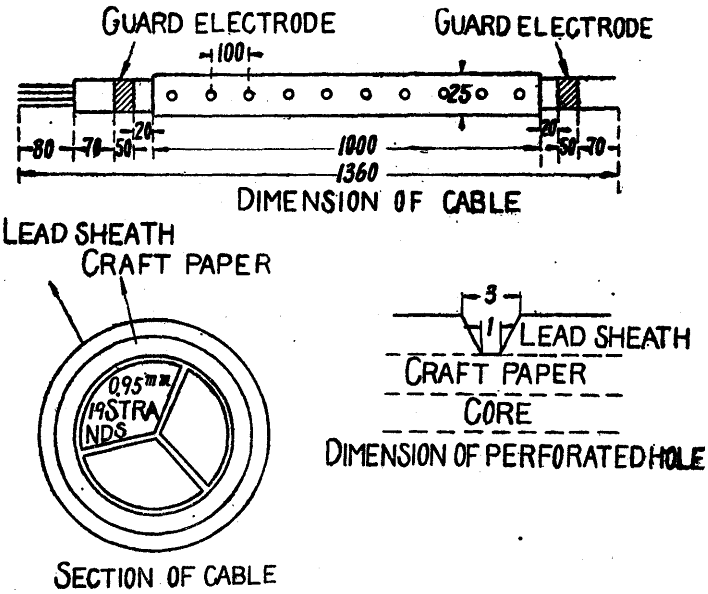
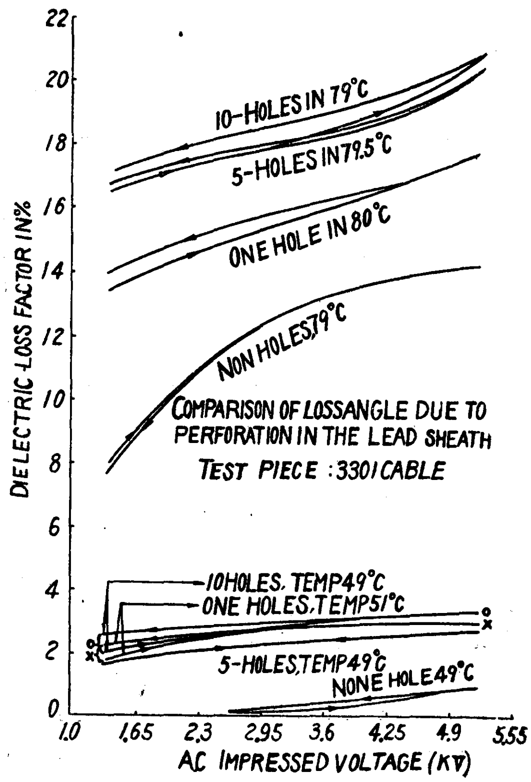


Fig. 5. Sample Cable (3301)



high ai d low temperature in the both cases that a test cable's lead sheath is holed and the other one is not wounded. Generally speaking, the higher the temperature is, the more distinctly the effects of the wound appear.

Fig. 7 the various resistance values due to the existence of wounds at different voltage, high and low.

The higher the temperature is, the more the D C. resistance value generally decreases. Comparing the insulating resistance values at both high and low voltage at the same temperature, the

* Fig. 6 Variation of Dielectric power factor due to perforation in the lead sheath

resistance increased with the vcltage. In the case that the lead sheath is injured, the insulating resistance decreases at the same temperature and voltage.

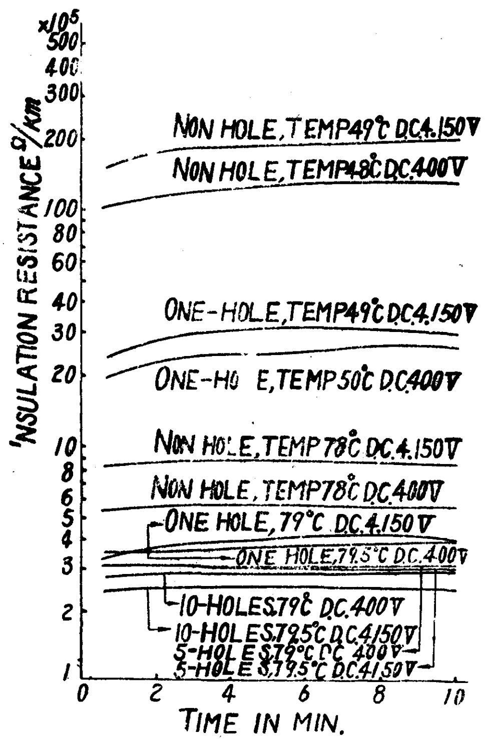


Fig. 7 Comparison of insulation resistance under the high and low D.C. voltage stress

Table 2 shows the fault ratio which means the ratio of an insulating resistance mesaured after 10 minuite's voltage impression at low voltage to the one at high voltage.

We can see the fact that cables have generally fault ratio lower than 1 and the fault ratios increase by the wounds as in the foregoing experiment (a), and then it is desirable to be measured at high temperature.

As the results of the experiments above described, it is found that the insulating resistance characteteristic is supperior to the power factor characteristic of dielectrics to the purpose of indicating the weak points of the insulators. These facts made us to promote the experiment on the insulating resistance characteristics.

Table 2 Variation of Fault ratios

	Fault raotis			
temp (°C)	non hole case	one hole case	5 holes case	10 holes case
high temp.(79∼80)	0.65	0.988	1.03	1.19
low temp (48∼49)	0.655	0.874	—	—

(C) Influence by perforation in the case where an insulator's conductivity increases.

The test piece attached with guard-ring have the same size with the one illustrated in Fig. 5. Fig. 6. shows the results of the measurement of tan δ v. s. temperature charactristics.

The spare cables, 3000 volt three phase ones, 14 *m/m* in cross area 1.6 *m/m* strand were surviced by Tokyo Electric power Company. Some of them are perforated artificially as shown in Fig. 5, and the others are not. Fig. 6 shows the results of the measurement for the cables in oil. Deciding from, we are able to recognize the fact that the effects by wound apt to appear at high temperature and rather independent on the value of impressing voltage. Fig. 7 represents the *D.C.* resistance *v.s.* voltage characteristic of the same test-pieces. The characteristic differences between injured test pieces and unjured ones appear more distinctly campared with tan δ characteristic of them.

The insulating resistance of sound cable is high in value and increases with impressing voltage, while that of injured cable decreases at over 3000 volts.

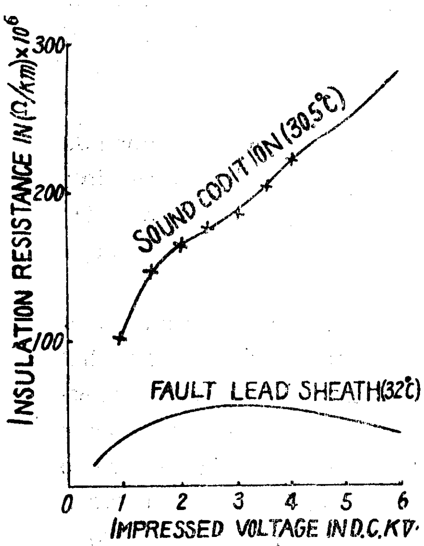


Fig. 8 Changes of insulation resistance for lead sheath fault of 3000 v cable.

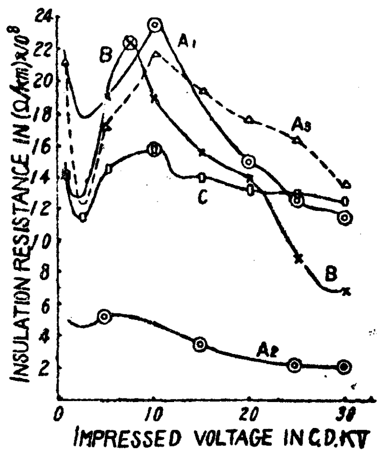


Fig. 9 Relation between insulation resistance and impressed voltage of 20kv SL cables

Fig. 8 shows the direct carrent resistance voltage characteristic of deteriorated three phase cables, 3000 volts 0.95 *mm*/19plys (manufactureing date and the name of factory are un known). The *D. C.* resistance *v. s.* voltage characteristics has a maximum value at 2.5kv. and declines with increasing voltage. *B* and *C* show the measurement values of sample cable *A* after making it break down. Comparing it with the previous characteristics, we find out the result that the insulating resistance decelines more, while it is difficult to discriminate the deterioration and break-down when the both exist at the same time.

Fig. 9 illustrates the direct current resistance *v.s.* voltage characterstics of test pieces 20kv, *SL* cables *SL*-13, *SL*-0.2 (Furukawa make), and *SL*-22 (Sumitomo make). As above menticned, the change of characteristics of the test pieces due to the perforation appears, but conductive current at normal temperature is so little.

At high temperature, the conductive current increases and so the difference of characteristics due to perforation becomes appearing. We see the direct current resistance characteristics is powerful for detecting the weak points of inslators.

III Deterioration of Test-pieces by impressing over-Voltage

The test-pieces were the same size 2 (c), 3000 volts new cables, cut out 1.3 meters in length. They were treated in insulating cable oil. Used pieces are 3303-1,2, 3, 4 and 5.

(a) Short duaration break-down of sample cables by alternting voltage (3303-2). The test cables immersed in the cable oil at temperature 19°*C*. was impressed voltage gradually rising the voltage at the rate of 5.5 kv per minuite, and broke down at 32.5kv. The beak-down was confirmed with the voltmeter inserted in the primary circuit of a transformer and smoke emmitting from oil after several seconds.

The punctured point was the edge of the main lead electrode and had 800 Ω resistance by meggaring. The test cable was under the short duaration break down test again after several days. The punctured voltage was 23.0kv. tan δ. voltage characteristics before and after the break-down are shown in Table III.

Table 3 tanδ-voltage characteristics

impressed A.C. (kv)	tan δ	
	sound	after breakbown
3.0	0.5	0.6
4.5	0.5	0.6
6.0	0.5	0.6
oil temp	17°c	19°c

The difference between them are difficult to find out for the different oil temperature at measurement.

The difference may appear at higher temperature. Fig. 10 shows the diffrence between the insulating characteristics. It has decending curve at 2,5 kv.

But it has still 23.0kv dielectric strength after break-down and so it may by said to have high insulating resistance. The previous 2 (c) was the example of the break-down of a deteriorated cable and the diffrences before and after the break-down were confirmed by the fault ratio alone, while the differences before and after break-down in new cable to find out deciding from the differences of charactr-istics in Fig. 10 and the fault ratio (0.66: 1.08).

(b) Insulating resistance after impressing alternating voltage for long time (test cable 3303-4.5)

A purpose of this test was to find out the existence of the change of insulating resistances of new cables just before the break-down happend by impressed voltage, excepting for long hour break-down. The impress voltage values are shown below.

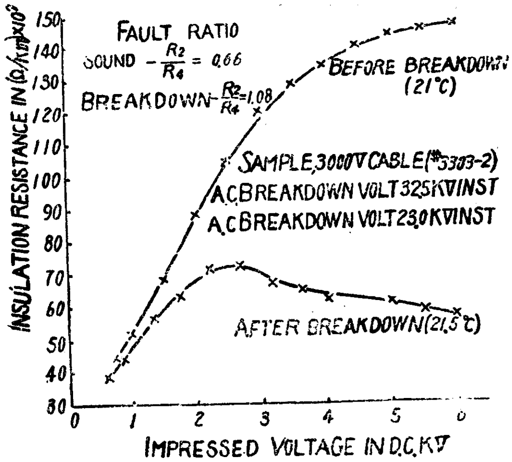


Fig. 10 Change of insulation risistance before and after the breakdown of 3000 v cable.

test cable 3303-5
(1) uninjured (in situation before test)
(2) measured after impressing 19.5kv (60 percent to 32kv) during 1 hour

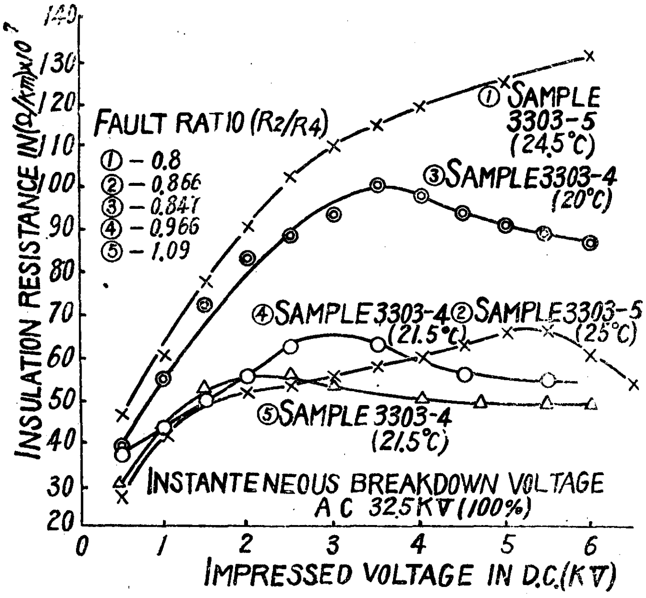
test cable 3303-4
(3) measured after impressing 21.1kv (65%) during 1 hour
(4) after test (3), measured after doing 22.7kv (70%) during 1 hour
(5) after test (4), measured after impressing the same voltage 22.7kv (70%) during 1 hour

The both test cables 3303-4 and 5 were all right in appearence after the test and in the tan δ after impressing *A.C.* over-voltage on the test cable during long time as shown in Table 4.

Table 4. tanδ-voltage characteristcis over-voltage, impression

impressed A.C. (kv)	tan δ				
	1	2	3	4	5
3.0	0.5	0.5	0.5	0.5	0 5
4.5	0.5	0.5	0.5	0.5	0.5
6.0	0.5	0.6	0.5	0.6	0.6
oil temp	22.5°C	25°C	20°C	21.5°C	21.5°C

Any change was scarecely found out, while as voltage 6.0kv, (4) and (5) change a little. Fig. 11 shows the change of the insulating resistance after impressing voltage.



Eig. 11. Change of insulation resistance of cable related to over voltage impression

The fault ratio of uninjured cable is 0.8 as showed in (1), while the characteristic curve has a maximum value at about 5.3kv after impreassing 60% voltage during one hour and the fault ratio increases to 0.866. Saying about the other test cable, characteristic curve (3) has a maximum value near 35kv after impressing 65 % voltage during one hour; the fault ratio becomes 0.847, and then after impressing 70% voltage during one hour again. the maximum value appears near 3kv as shown in the characteristic curve (4), while the fault ratio more increases to 0.966. After impressing the same voltage on the same test cable during one hour again, the maximum value appears near 2kv as shown in curve (5), while the fault ratio becomes 1.09. Nothing unusual was appreciated. It is remarkable phenomena that the fault ratio increases to near 1 by impreassing voltage and position of maximum value transposes to lower voltage. Curve (2) is under the curve (3) because the former was at later. In testing. we have a doubt that some small bubbles should be rising from near the grounded lead sheath of test cable 3303-4, and so we tried to inspect it by winding back the layers of paper at the both sides of the main lead electrode. As the result, it was confirmed that the part was burnt black (carbon tracking) and had gotton partial break bown.

As the result of this experiment, it is confirmed that the fault ratio may be an index of the degree of partial break down of cable inslation. Partial break down appeared in the way of increasing to fault ratio 1. Maximum value transposed to low voltage range and fault ratio increased in the way of impressing over-voltage.

IV. Insulating Resistance and Fault Ratio due to the Variation of Temperature

3000 V spare cables (3303-6), about 1.3 meter in length, which were the same cables with the previous ones, and 3000 V removed cables were used for the test pieces. All cables were tried to be tested in cable oil.

A Test on an uninjured test-piece

B Measurment on the same test-cable above mentioned impressed at 16.25kv, which means 50% voltage to short time break down voltage 32.5kv, during half hour

C Measurement on *B* impresed at 22.5kv, 70% to 32.5kv, during one hour again.

D Removed deteriorated cable.

(a) Variation of insulating resistance due to the polarity and the impressed voltage.

As shown in Fig. 12 the iesulating resistance varified from $10^{+6}\Omega$ to $10^{+8}\Omega$ at the temperature range from (22-23)°*C.* to 86.5°*C.* Therefore may be still difficult to be compared at 22°*C.* and 23°*C.* However there consideracle differences between the results of the measurements on test piece *A* due to the positive and negative polarity. *A* has low inclinaton of voltage rise and low insulating resistance compared with *A*, while test piece *B* has few differences to the polarity. At 86.5°*C.*, the effect of polarity above mentioned change over and inclination of voltage rise considerably declines.

Referring to alternating current, the phenemena shall be treated separately because there is difference between the conditions under the alternating and the direct current, namely the voltage which impresses each part of insulator is different. Fig. 13 shows that (*B*) has low resistance at the state of deterioration regardless of the polarity of the impressing voltage, and the fault ratio has different values with temperture, that is to say, becomes large with low temperture.

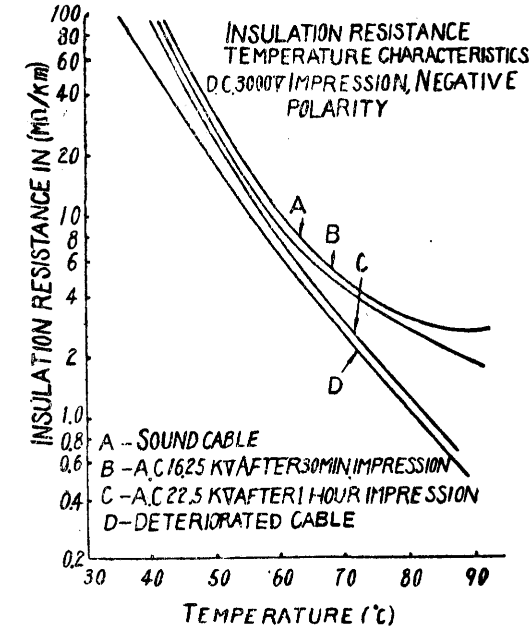


Fig. 12. Insulation resistance — temperature characteristics

(b) Fig. 14 shows the variatoin of insulating resistance by temperature. Insulating resistance declines exponentially with temperatur.

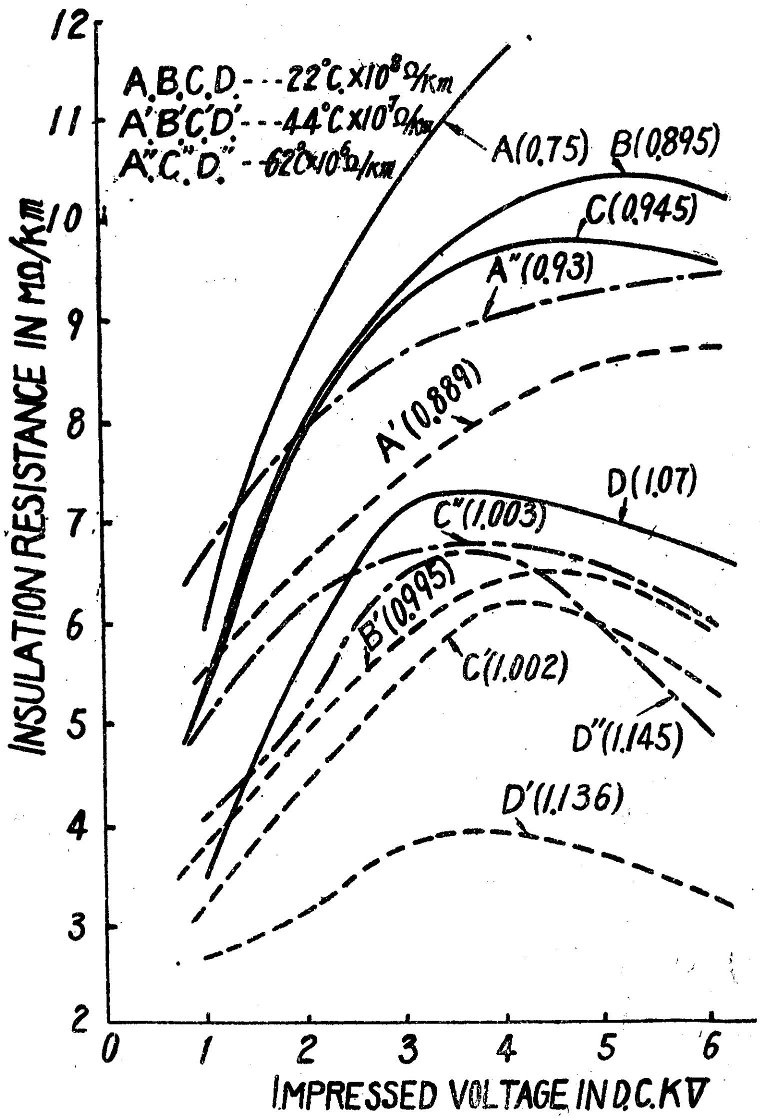


Fig. 13 Insulation resistance change referred to deterioration.

However, same difference happens between uninjured cable and deteriorate one in high temperature range. The uninjured cable's insulating resistance becomes constant at near 85%, while B and C which are deteriorated by over voltage artificially, apt not to apart from the exponential curve in high temperature range too. D is a removed detriorated cable and is similar fo C in the charactristics.

Fig. 13 shows the insulating resistance voltage characteristics in which temperature is a parameter. The insulating resistance characteristic curves decline

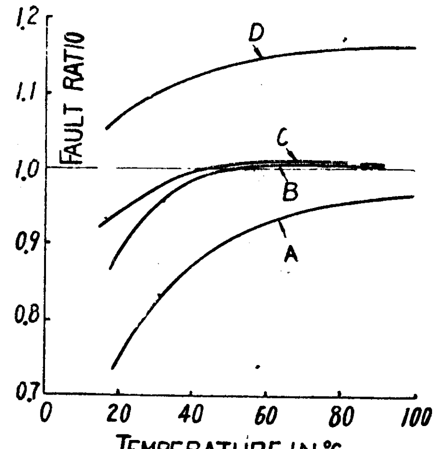


Fig. 14. Foult ratio depeuded to temperature

as $A \to B \to C \to D$, and the position of the maximum point moves to the direction of low voltage. fault ratio increases as $A(0.75)$, $B(0.795)$, $C(0.946)$, $D(1.07)$. A become A' and then becomes A'' with the temperature. It is the same with B and C. The fault ratios increase, because the inclination of the characteristics curves decline with the temperature, with the maximum point scarecely transposes.

(c) Variation of fault ratio due to temperature.

As above mentioned, the fault ratio changes by temperature. Fig. 14 shows the relations between the fault ratio and temperature.

We find out the fact from the figure that the more sound the cable is the more considerable the change of the fault ratio is. However the fault ratio of deteriorated cable is rather constant at over 45°C. when the fault ratio is under 1. It is an indispensable condition to point out the temperature in the measurement of fault ratio, especially at low temperature.

Moreover, deciding from this figure, the calibration of the fault ratio should be tried under the temperture 45°C. As the result of the experiment above mentioned, the fault ratio varies by temperature and so it is necessary to calibrate the temperutre. The range is under 45°C. The insulations resistances decline exponentially with the rising temperature, but at over 75°C, apt to be constant separating from the exponential curve with their soundness.

The insulating resistance values due to the polarity of impressing voltage turn over each other at low and high temperature.

V. Insulating Charactristics and the Dielectric Strength

It is considered that same causes of the deterioration of insulators are due to over voltage and the impressing time, and so we tried to search for the relations between the insulating characteristics and the dielectric strength in the way of making cables deteriorated. The test pieces were 3000V cables each 1.3 meter in length, which were divided from a same cable. They were treated to be deteriorated by over voltage as followed.

test-piece (1) 3304-1 no over-voltage impressed
(2) 3304-2 Impress $A.C$ 23 (65%) during half a hour (in oil)

(3) 3304-3 Impress *A.C* 23 (65%) during one hour(in oil)

(4) 3304-4 Impress .*C* 23 (65%) during two hour and half (in oil)

(5) 3304-5 Impress .*C* 21.5 (65 %) during two and half (in oil)

the short time break down voltage was 35kv, and so 23kv 21.5kv were each equal to 65% and 60% of the break down voltage. We tried to measure the tan δ and the insulating resistance charactristices and etc. after impressing over-voltage and then to seek for the value of the short time break down voltage Table *V* illustrate the insulating resistance, tan δ and the puncture voltage.

The differece of the value of tan δ by the deterioration of the test cable is not noticed at low temperature, while the value increases a little at high temperature with the proceeding deterioration.

Fig. 15 shows the insulating resistance characteristics of each test cable at 27°*C*. with the deterioration, it is noticed that both insulating resistance and the increment degree go down and more over the maximum insulating resistance points, test cable (2) is 5.5kv, (3), 4.75kv, and (4) 3.75kv, while the fault ratio is each 0.883, 0.922 and 1.095.

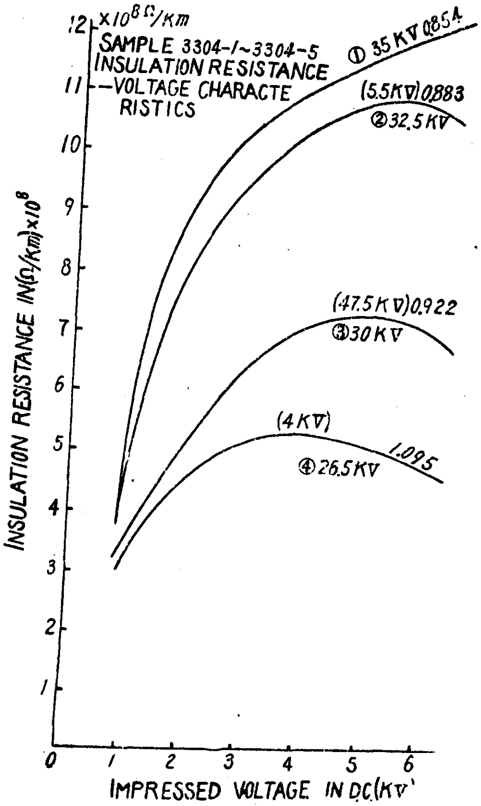


Fig. 15. Insulation resistance characteristics of samples at 27°C

Fig. 16 shows the relation between so called *A.C* dielectric strength and the insulating charactristic, in which the horizontal axis means short time break down voltage and the vertical axis means insulating charactristics. The product of the impressing voltage value and the time means the energie which deteriorates the insulator. This energy becomes increasing gradually at near 70% as shown in the figure. The noteworthy mutual relation looks not to be noticed till the 60% value. This figure illustrates that both insulating resistance curve and fault ratio curve have the same character, gradually increasing tendency, and are closely connected with each other. Besides, the position of the maximum point of insu-

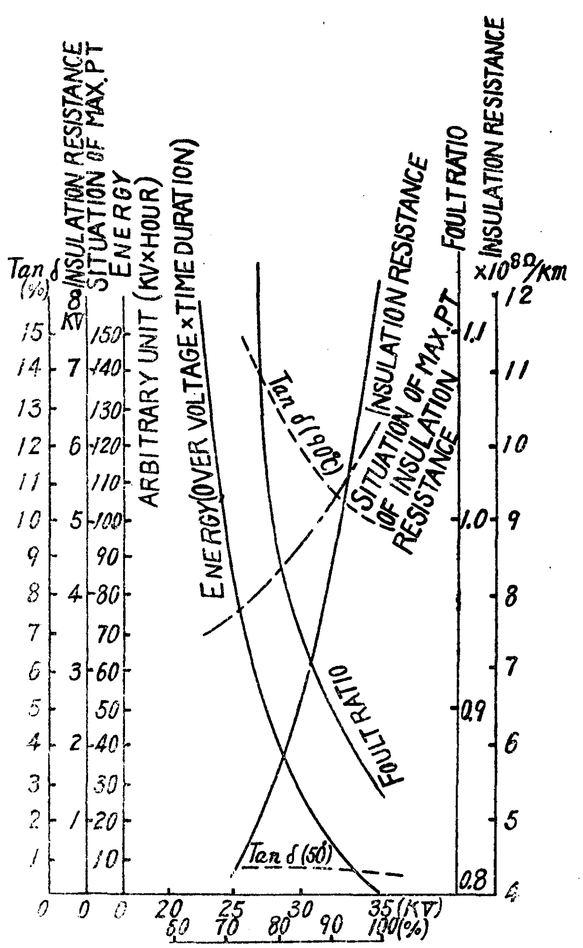


Fig. 16. Relation between dielectric strength and insulation characters

lating resistance declines a little inproportion to the dielectric strength. The value of tan δ changes little at low temperature range and rather relates with the dielectric strength at high temperature range (90°*C*.).

The insulating resistance at 6 kv *DC.* are closely connected with it too.

VI. Insulating Resistance about Cable Artificially Submerged by Water

In order to search for the insulating resistance of the water-impregnated cables the following four sample 3000V Cable were made to be inundated by the means as shown in Fig. 17.

A: a test cable, about 1.3 meter in length, which the lead sheath has a leak with a lead pipe, gum pipe or glass pipe; measured in an insulating cable oil without water.

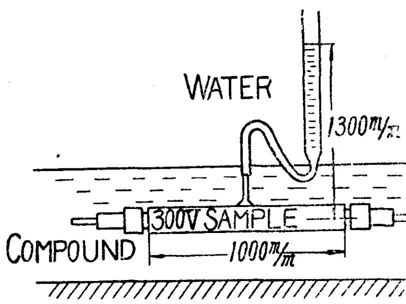


Fig. 17. Water impregnation test

B: driped in the oil 24°C. Adding to the condition of *A*, made to by impregnated during one hour under the pressure of a water column 1300 m/m in height shown in Fig: 17. The volume of the submerged water was about 2 cc.

C: inundated during one hour more in the condition of B. the volume of the impregnated water was about 15 cc.

D: diped in water during one hour after two hours in oil at temperature 90°C. and then measured after removing the submerged water by hunging itself in air

Table 5. Characteristics of 3000V cable depending to over voltage deterioration

Samples	Sample	Sample	Sample	Sample	Sample
Over voltage impression AC(kv)		23	23	23	11.5
Instanteneous breakdown voltage in %		65	65	65	60
Time duraton of over voltage		30	1	2.30	
oil temp °c	27	27	27	26.5	
DC voltage measured (kv)	insulation resistance × 10^3 Ω/km				
1	5.56	4.9	3.62	3.33	
2	9.72	8.34	5.38	4.76	
3	19.4	9.6	6.58	5.31	
4	11.1	10.42	7.24	5.37	
5	11.56	10.9v	7.43	5.21	
6	12.18	10.87	7.15	4.85	
Foult ratio R_3/R_6	0.854	0.883	0.922	1.092	
AC instanteneous breakdown voltage in kv	35	32.5	30	25.5	
AC instanteneous breakdown voltage in %	100	93	85.7	75.7	
situation of max. pt. of insulation resistance DCkv		5.5	4.75	4	

tan δ (%) / voltage (kv) / oil temp.	tan δ (%)				
	6.0	6.0	6.0	6.0	6.0
30	0.4	9.4	0.4	0.4	
40	0.4	0.4	0.4	0.4	
50	9.6	0.7	0.7	0.8	
60	1.4	1.6	1.7	1.9	
70	2.9	3.1	3.6	3.9	
80	5.2	5.5	6.8	7.8	
90	9.8	10.2	11.5	13.8	
100	18.0	18.6	21.0	22.6	

during 48 hours. As the result of it. the *A,C* break down voltage was 2.5kv.

Saying about the state of inundation, water mainly concentrated between the lead sheath and the insulator, and the rest drained from the ends of the test cable.

Accordingly, the result of this experiment looks to be more affected by the ex-

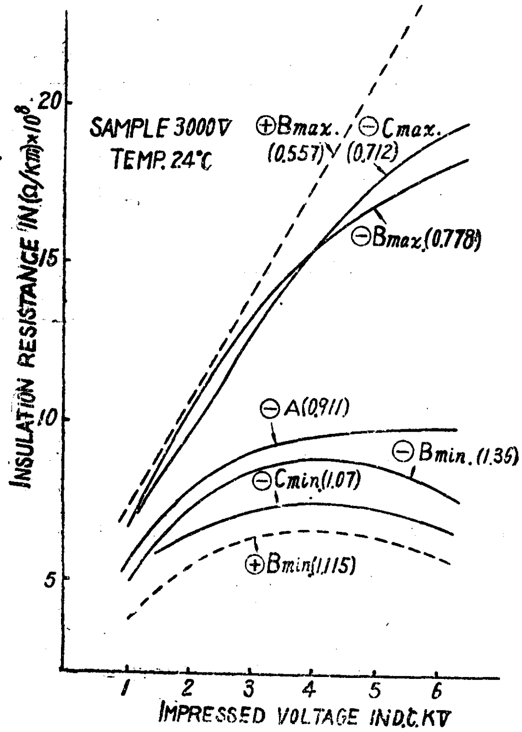


Fig. 18. Insuation resistance of cable in the case where cable is absorbed the moisture artificially

istence of the water between lead sheath and insulator than by the inundation to the insulating paper.

The lead sheath of a test cable *A* was worked up to be submerged, and so the fault ratio was rather larger for the leak than in the previous (see Table 6 and Fig.18.).

A test cable *B* caused the unstable deflections of a meter for the inundation *A* pointer of a galvanometer shaked in about 10 minutes interval. The deflection range for shaking increased with the impressing voltage. According, the insulating resistance and the fault ratio had different value at lower limit. The fault ratio increased at upper limit decresed at lower limit.

The increasing rate of the fault ratio was small as the main insulator might be new one, as compared with that due to general deterioration. It has only a special feature for the measurement to be unstable. Saying about the measurment to be unstable the unsteady deflection was generally larger at positive porality, and the value of the lower limit insulating resistance was small, while the value of the upper lim t insulating resistance was larg at the positive voltage than a negative.

Table 6. Tan δ - voltage characteristics

Voltage impression AC (kv)	tan δ (%) A	B	C
1,5	0.4	0.4	0.5
3.0	0.4	0.4	0.6
4.5	0.4	0.5	0.7
6.0	0.5	0.7	1.3
oil temp	24°c	24°c	24°c

Test cable *C* was inundated one.

The deflections was large and the insulating resistance was decreasing a little. The fault ratio increased compared with the former *B*.

Test cable *D* was impregnated by water. It broke down at *A.C* 25kv

According to Table *VI*, the value of tan δ of *B* rather increased at 6kv more than that of A and C was more increasing in the value of tan δ than A nd B, but there was not so remarkable difference in the insulating resistance charactristic. When a cable is submerged as above mentioned, the deflection of a meter becomes unsteady, and thus, it will be reasonable to try to get a fault ratio from the lower limit value of the insulaing resistance measured by the degree of deflection of the meter.

VII. Level Deciding for Deterioration

3000 V cable, were mostly used as the test samples in this research, except few cases where 20kv sampling cables were used and cables served for power supply was hold at the field. The main subject of the experiment in this research was was to obtain the deterioration only by means over voltage too.

A expriment on thermal deterioration has not been tried artificially though we have had only a experience of a test on a deteriorated cable at the field, and so it may be difficult to set up the level of deteriorations of various kinds of 20kv cables, however we want estimate the ranking of deterioration of the cable by some stndard.

The following are considerd as such incidental levels which the suitability may be reestimated after a long interval.

(A)

1. Fault ratio 0.85 (temperture 20-40°C.)
2. Position of maximum point H
3. Insulating resistance ohm Farad/

(B) 20°C. $D.C$ 40-50 measured after 10 min.)

1. Fault ratio $\doteqdot$ 1.00 (temperature 20-40°C.)
2. Position of maximum point M
3. Insulating resistance ohm Farad/

(C) (20°C. $D.C$ 40-50, measured after 10 min.)

1. Fault ratio $>$ 1.25 (temperature 20-40°C.)
2. Position of maximum point L
3. Insulationg resistance ohm Farad/

20°C, $D.C$ 40-40, measurd after 10 min,

reference. M means a case when a value of a maximum point of insulating resistance is situated between D,C 20kv and 40. H meanas the same in the outer upper voltage range and L means the same in the lower.

VIII. Conclusion

The insulation resistance characteristics at $D.C.$ high voltage is superior to tan δ charactristics because it has the ab lity of detecting insnlation fault especialy, as in this research, about the deterioration of insulator due to over voltage or inundation.

Our research is now under the contemplations to establish some practical test methöd to apply it at field on the cable after a long time running. we wants to have men conservating the electrical equipments to keep the deterioration level of insulation of and to examine whether these methodes were suitable or not for the statistics of the accidents due to deterioration of insulator.

Moreover we make a plan to continue the experiments of thermal deterioration during more long time duration.

This research depended upon the support of the insulation insulation committe of the Electric Co-research Society and the expenses for scientific research of the Educatioual Department (27th term).