

RLM

INSULATOR RECOMMENDATIONS



LOCKE INSULATOR CORPORATION, BALTIMORE, MARYLAND

NOTES ON RADIO INTERFERENCE

Introductory Remarks:

All forms of radio communications are based on the establishment and propagation of electro-magnetic waves in space. These waves when properly controlled or modulated may be used to transmit signals, intelligence or entertainment in a large variety of ways. The most familiar form is found in the present day commercial broadcasting of entertainment and news. In order to avail himself of these facilities the listener must provide himself with a suitable antenna for intercepting the electro-magnetic waves propagated by radio broadcasting stations. These waves cutting across the conducting antenna, induce feeble alternating voltages in it with reference to ground potential. These voltages, by means of a suitable receiver, may be amplified, rectified and converted into audible sound or other intelligible signals, according to the purpose intended.

Since the antenna to some degree responds to all electro-magnetic waves which cut across it, the receiver must have a means of selecting the one desired, and must be of sufficient sensitivity to respond adequately to the signal to be received. Because of the relatively small magnitude of the voltages induced in practical antennas, the receiver must be an extremely sensitive device capable of responding to almost infinitesimal voltage changes in the antenna. Accordingly it will respond to all electro-magnetic disturbances which cut across the antenna and which have frequency components corresponding to that to which the receiver is tuned. It is for this reason that the radio frequency spectrum (range of frequencies useful for radio communication) is divided into channels by governmental control and international agreement. These channels are allocated with suitable power levels to broadcasting and other forms of communication to prevent what would otherwise be a chaotic condition which would render radio communication impossible or at least unreliable.

It is unfortunate, but nevertheless true that a large variety of unwanted electro-magnetic disturbances either occur in nature or are incidentally produced by many devices which have come to be necessities in the modern mode of living. These may interfere or mar the reception of the desired signals. Natural disturbances (usually referred to as atmospheric static) of which lightning is the most common variety, are caused principally by electrical discharges in the atmosphere. Lightning strokes produce and propagate electro-magnetic disturbances having frequency components throughout most of the useful radio spectrum. With the established system of broadcasting there is little that is now known that can be done to eliminate this source of interference except to improve transmitting and receiving equipment and attempt to improve the strength of the desired signal in relation to the unwanted one. Other types or systems of broadcasting, such as frequency modulation, now mainly confined to ultra high frequencies, practically eliminate natural static and much that is man made. General acceptance and change-over, if ever, to frequency modulation is still several years away on account of the tremendous investment we have in amplitude modulation broadcasting stations and receivers.

METHODS OF MEASURING RADIO NOISE 1940

A Report of the Joint Coordination Committee on
Radio Reception of E.E.I., NEMA and R.M.A.

SUMMARY

This report contains the recommendations of the Joint Coordination Committee on Radio Reception of E.E.I., NEMA and R.M.A., as to the nature, essential characteristics and performance of a meter for the measurement of radio noise. It further gives detailed descriptions of recommended practices in the use of the meter for measuring directly radio noise from low and high voltage apparatus, for making radio noise measurements along overhead lines, for determining broadcast field strengths, and for collecting data for the establishment of radio noise standards.

E.E.I. Publication No. G9
NEMA Publication No. 107
R.M.A. Engineering Bulletin No. 32
Published February, 1940

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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
155 East 44th Street, New York, N. Y.

RADIO MANUFACTURERS ASSOCIATION
1317 F Street, N. W., Washington, D. C.

December 1951
Litho in USA



RIV

INVESTIGATION OF RADIO NOISE AS IT PERTAINS TO THE DESIGN OF
HIGH-VOLTAGE TRANSMISSION LINES

H. L. Rorden
Member AIEE

R. S. Gens
Associate Member AIEE

Both of:
Bonneville Power Administration
Portland, Ore.

Advance Copy
Not Released for Publication

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A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21-25, 1952. Manuscript submitted October 18, 1951; made available for printing December 11, 1951.

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60¢ To Nonmembers

January 1947



RADIO-NOISE INFLUENCE OF 230-KV LINES

H. L. Rorden

Member AIEE

Bonneville Power Administration,
U. S. Department of the Interior,
Portland, Oreg.

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RIV

INVESTIGATION OF RADIO NOISE
AS IT PERTAINS TO THE DESIGN
OF HIGH VOLTAGE TRANSMISSION LINES

H. L. Rorden

R. S. Gens

Bonneville Power Administration

October 1951

RIV

November 1950
Litho in USA



RADIO INFLUENCE TESTS IN FIELD AND LABORATORY —
500-KV TEST PROJECT OF THE AMERICAN GAS AND ELECTRIC COMPANY

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DEPARTMENT OF TRANSPORT

AIR SERVICES BRANCH
TELECOMMUNICATIONS DIVISION



ELECTRICAL INTERFERENCE TO TELEVISION

Subjective tests to determine the degree of
annoyance caused by interference from automobiles
and electrical appliances to television viewers.

OTTAWA, AUGUST 1st, 1952.

Baltimore, August 24, 1954.

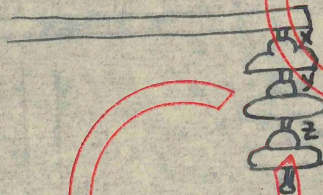
H. A. Frey: -

On August 17th I called on Mr. James A. McCutchen of the REA in Washington for the purpose of obtaining advice and information relative to radio and TV interference problems. Mr. McCutchen is recognized as an expert on this subject, and this call was aimed specifically toward setting up a possible program to make evaluation tests in the Locke laboratory.

In addition to a long discussion with Mr. McCutchen, in which he did most of the talking, we also adjourned to his new noise laboratory which is being fitted up near the REA offices and observed demonstrations and looked over samples of insulators that were known to be noisy in operation.

The following is a list of answers by Mr. McCutchen to questions asked:

- 1) Radio noise and TV noise are not compatible. It is possible that corroded hardware on a string of insulators, such as two No. 16583's in suspension, may give radio interference alone, or TV interference alone, or they may give interference to both radio and TV. A practical example is shown in the following sketch.



1. Corrosion at 1 and 2 may cause both Radio and T-V interference
2. Corrosion at 2 will cause T-V interference only

- 2) It takes from four to seven years to develop enough corrosion on galvanized hardware on a string of suspension insulators before noise will result. This is in a clean atmosphere in a rural locality.
- 3) Samples of No. 16583 suspensions which are known to be noisy appear to be hardly corroded at all except for tightly adhering black spots and blotches where hardware parts are in contact with one another. Examples of this are corrosion on the cotter bolt where it comes in contact with the clevis hole and on the eye bolt where it comes in contact with the cotter bolt. Also on the bearing surface of the clevis. McCutchen thinks high frequency charging currents cause some sort of electro plating on adjacent hardware parts to make the black corroded spots.

Corona - RIV
H. Fung

Transactions Paper

(Reviewed and Accepted for Publication)



THE CALCULATION OF THE RADIO INTERFERENCE LEVEL OF TRANSMISSION LINES CAUSED BY CORONA DISCHARGES

G. E. Adams

Associate Member AIEE

General Electric Company

Schenectady, N. Y.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 20, 1955; made available for printing December 20, 1955.

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Paper No.

56-222

Discussion in Duplicate Due February 15, 1956.

The Calculation of the Radio Interference Level of Transmission Lines Caused by Corona Discharges

G. E. ADAMS
ASSOCIATE MEMBER AIEE

Synopsis: The mechanism by which the principal wave, which travels along the line and interferes with radio reception, is generated is expressed in mathematical terms and related to the currents which flow during laboratory tests of samples of conductor. These tests are described in detail. The generating functions so determined are used to calculate the electric and magnetic intensities of the interference field near the line. The statistical properties, namely, the correlation function and the spectral density of the field intensities are employed to superimpose the effects of several line conductors. As an example, a comparison is given of the interference level of two lines equipped with the same conductor but one of horizontal and the other of vertical configuration.

AT THE present time, considerable interest in the radio interference level (RIL) of high-voltage transmission lines exists as evidenced by the numerous papers which have appeared recently on various phases of the subject such as test facilities and results, field experience, noise measurements, and announcements of future plans for study.

The purpose of this paper is to present a method of calculation of the RIL of an actual transmission line from the results of laboratory tests on conductor samples and knowledge of the geometry of the line. Such a method of calculation is useful for many purposes including:

1. Planning and interpreting the results of field tests.
2. Evaluating the effect of the various line design constants on RIL.

Paper 56-222, recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 20, 1955; made available for printing December 20, 1955.

G. E. ADAMS is with the General Electric Company, Schenectady, N. Y.

The analysis is an application of a more complete unpublished mathematical development by R. M. Lichtenstein, Rensselaer Polytechnical Institute Troy, N. Y. The author also wishes to acknowledge the many helpful suggestions and comments made by S. B. Crary and C. Concordia and the preparation of the calculating machine programs used in this study by Mrs. M. A. Fuller, all of the General Electric Company, Schenectady, N. Y.

3. Comparing different line configurations as to RIL.

4. Calculating the absolute RIL of a proposed line.

Many studies of radio interference have been made. However, these have consisted almost entirely of test programs, the results of which have usually been very difficult to interpret. Thus, an analysis such as is outlined here becomes a practical necessity.

The corona which is distributed along the line on the surface of the conductor has been considered to be the source of the radio interference. This conductor corona is influenced by many variables in addition to the line geometry such as conductor surface condition, precipitation, temperature, humidity, etc. Since the effect of these additional variables cannot be determined by analytical methods, the calculation procedure must be based upon the results of experiments or tests. These tests should be performed under laboratory conditions so that accurate control of the variables (particularly weather) can be obtained.

Nomenclature

E=electric intensity, volts per meter
H=magnetic intensity, ampere-turns per meter
J=current density, amperes per square meter
 $\nabla^2 = \partial^2/(\partial x^2) + \partial^2/(\partial y^2) + \partial^2/(\partial z^2)$ Laplacian operator
 $\phi^{(n)}$ =scalar potential function, volts
 x, y, z =rectangular co-ordinates, meters
 h =conductor height above ground, meters
 R =conductor radius, meters
 $\nabla = i \partial/\partial x + j \partial/\partial y + k \partial/\partial z$, nabla operator
 t =time in seconds
 $c = 3 \times 10^8$ meters per second = velocity of light in free space
 i, j, k =unit vectors in x, y , and z directions respectively
grad $\phi = i \partial\phi/\partial x + j \partial\phi/\partial y + k \partial\phi/\partial z$ =gradient, volts per meter
 $\mu_0 = 4\pi \times 10^{-7}$ =permeability of free space, henrys per meter
 $\epsilon_0 = 1/(36\pi) \times 10^{-9}$ =permittivity of free space, farads per meter
 M =number of sections into which line is divided
 l =length of one section of line in meters
 $R(\tau)$ =correlation function

SD =spectral density
 i_t =current which flows in external circuit when sample of conductor is placed in test cage, amperes
 U_0 =field factor
 k =test cage current spectral density factor
 ψ =scalar potential of charge cloud in test cage, volts
 ρ =charge density, coulombs per cubic meter
 b =test cage radius in meters
 $\langle \rangle$ =mean (with respect to time) value of

Corona Discharges

A strong electric field exists in the region adjacent to the transmission-line conductor during normal operation. This electric field varies periodically with time in the same manner as the applied voltage. Since the frequency of the applied voltage is relatively low, the distribution of the electric field can be calculated by the methods employed when studying electrostatic fields.

The characteristic of the electric field of primary interest is the spatial distribution of electric intensity near the conductor. The electric intensity is a vector quantity having both magnitude and direction. The magnitude will be called the "voltage gradient" and the direction is along a flux line drawn through the point in question.

If the voltage gradient is plotted as a function of distance along a particular flux line, it is found that the gradient attains its maximum value at the conductor surface. Moreover, the surface gradient depends upon the geometry of the conductor surface near the point in question and, in fact, is greatly intensified by the presence of sharp projections or irregularities on the surface.¹

If a free electron is present near the conductor, it will be accelerated by the electric field and move either toward or away from the conductor, depending upon the direction of the field near the conductor. If the gradient along the path taken by the electron is great enough, the electron will ionize an air molecule by collision, thereby creating both a positive ion and another free electron. A separation of charge results since the electron is accelerated in a direction opposite to that of the positive ion by the electric field. Both free electrons can be accelerated further and create additional electrons by collision. In this manner, an electron avalanche is formed.

This movement of charge, both positive and negative, constitutes an electric current. This electric current flows in the space near the conductor and can be characterized by the current density² $J(x, y, z, t)$. If the axis of the conductor is taken to be along the z axis of the co-ordinate system employed, the x and y

Transactions Paper

(Reviewed and Accepted for Publication)



AN ANALYSIS OF THE RADIO INTERFERENCE CHARACTERISTICS OF BUNDLED CONDUCTORS

G. E. Adams
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Schenectady, N. Y.

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56-994

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GENERAL ELECTRIC

Insulator Department

SUBJECT

Summary of Television
Interference Investigation
File #5702
File #2900

COPIES:

Paul Schratter
AL Starr - Kansas City
CB Vaughn
BE Kingsbury
J. Kaminski.

Baltimore, June 13, 1956.

J. W. Taulman (3)
Dallas.

In response to your request, I am writing a summary of our television interference investigation conducted in the High Voltage Laboratory.

During 1955 we received a few reports from the field that in isolated cases it was believed that suspension insulators were the source of television interference. The Engineering Section requested that our field representatives obtain a string of suspension insulators which had been established as the probable source of television interference.

In the meantime, the High Voltage Laboratory initiated a project to develop a technique for creating, recording, and measuring television interference. This course of action was necessary since television interference, unlike radio interference, is relatively new, no standards of measurement have been developed, no levels established nor have the techniques of recording television interference been standardized.

Our engineers recognized that it was theoretically possible for suspension insulators to generate television interference. It was thought that the principal source of such interference would be in the connecting elements between units, which, in the case of ball and socket type insulators, would be between the ball of one unit and the socket of the next lower unit. This condition could exist when a film of corrosion would form between mating surfaces serving as insulation between them. When this film was sufficiently stressed electrically, and when the constants of the associated circuits were of the proper magnitude, breakdown would occur and act as a small transmitter in the very high frequency band. It was not expected that this condition could exist when there was any appreciable load on the insulators which would provide a reasonable pressure contact.

The technique of developing television interference on suspension insulators basically was accomplished by inserting a thin sheet of paper between the ball and socket connections of two insulators. Stressing the insulators electrically sufficient to cause breakdown of the paper, showed a very definite interference pattern on the television screen. This pattern is essentially the same as electrical breakdowns similar in nature which have been recorded, and publicized in the past. These would include interference of the type produced by the spark plugs of an automobile.

On the picture screen, interference consists of numerous short-black lines chasing across the screen, of narrow band width which would slowly move vertically on the television screen. As the intensity of breakdown was increased by raising the voltage, the number of pulses in the stream increased. It was observed that the first interference recognized on the television screen consisted of a single narrow band of black pulses caused by the breakdown of the negative half cycle of 60 cycle voltage. As the voltage was

Transactions Paper

(Reviewed and Accepted for Publication)



INVESTIGATION OF RADIO NOISE FROM EXISTING LINES AND EQUIPMENT TO AID IN THE DESIGN OF FUTURE EXTRA-HIGH VOLTAGE LINES

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A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21-25, 1957. Manuscript submitted October 23, 1956; made available for printing December 11, 1956.

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INVESTIGATION OF RADIO NOISE FROM EXISTING LINES AND EQUIPMENT TO AID IN THE DESIGN OF FUTURE EXTRA-HIGH VOLTAGE LINES

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Paper No.

57-164

Discussion in Duplicate Due February 6, 1957.

Mr Kaminski
W. E. Pakala

Conference Paper



RADIO INFLUENCE EFFECTS OF SURFACE TREATMENTS ON SMALL CONDUCTORS

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Paper No. **CP**

57-802

R10

Transactions Paper

(Reviewed and Accepted for Publication)



THE RADIO INFLUENCE CHARACTERISTICS OF BUNDLE AND SINGLE CONDUCTORS (TIDD PROJECT)

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GENERAL ELECTRIC
INSULATOR DEPARTMENT

Baltimore - December 12, 1957

SUBJECT

COPIES: D.R. Samson
F.C. Vose

Mr. R. O. Lanoue
PITTSBURGH

Ralph, please accept my deepest apologies regarding the long delay in providing you with some dope on the television interference (TVI) problem. I can take credit for two months of the delay, anyway, as your letter became mislaid upon reaching my desk.

Ralph, what I plan to do is give you a brief run-down of what I know on the subject in general and relate some of the very meager test findings which we have, and also lend to you several booklets which, themselves, may throw more light on the subject.

Our initial contact with the problem was in 1955, regarding 69 KV circuits employing suspension units in the Florida Light and Power System. Their problem seemed to be quite severe, periodically. That is, after a damp, foggy day followed by a day or so of very hot, and relatively dry weather, TVI would become a problem in certain areas. Mr. H. A. Frey discussed the general problem with them and they agreed to send us a string of insulators believed to be the cause in order that we might perform laboratory investigations.

In the meantime, Mr. L. J. Stevens and myself went to see a quite qualified expert in the techniques of measuring and deciphering the TVI field (Mr. James McCutcheon, REA). He filled us in on some of his work and field analysis of the problem and gave us a start in the right direction, so that we might better cope with the above mentioned insulators upon their receipt.

It was at his suggestion that we obtained a standard television set of relatively low quality (one containing no filters other than those required in receiver's line cord and related circuits), so that any possible outside disturbances would be discernible on the screen of the set. This TV set is set up in the standard manner to watch any program - an antenna was mounted on the roof with leads brought into the set. In addition a testprobe antenna (several different sizes according to frequency range desired) was added to the receiving circuit and placed in parallel with the outside antenna. Thus we have a "measuring" system in which we can at least obtain qualitative data which is of some value for comparison purposes. Our set-up is as shown on the attached photograph. In the foreground is the TV receiver and in the background is the insulator string under test, and to its left is the test-probe antenna (which is merely a loop of wire). In order to obtain more realistic conditions of operation, an alternator was placed in the main antenna circuit, so that, in effect, we could cut down the incoming signal and simulate a quite distant TV station.

To digress a bit, let's examine some of the mechanisms which must be available to provide TVI. To date, I have seen no literature which indicates in any way that corona, as such, can cause TVI. Therefore, that leaves only the spark, which

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GENERAL ELECTRIC

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>L. Jandran</i> LF Jandran		SUBJECT CLASSIFICATION 1. Radio Influence 2. Corona		NO. 58PT158 DATE 7/14/58	
TITLE CORONA AND RADIO NOISE STUDIES OF BUNDLE CONDUCTORS WITH METALLIC POINT PROTRUSIONS					
ABSTRACT Four different diameter smooth aluminum conductors were tested in 1, 2, 3, and 4 bundle configurations to obtain radio noise, field strength, corona starting voltage and conductor surface gradient data.					
G.E. CLASS IV		REPRODUCIBLE COPY FILED TECHNICAL DOCUMENTS		NO. PAGES 43	
GOV. CLASS NONE					
CONCLUSION 1. The corona starting voltages for the four conductors tested increased with increasing conductor diameter, but the generated RIV became less with an increase in conductor diameter. 2.. Conductor-surface gradient (KVP/cm) at corona start is greater for the smaller diameter conductors and became less as the diameter of the conductor increased. 3. In changing from 1-4 bundle configuration, for a given conductor, the corona starting voltages are increased, the RN is decreased and the conductor-surface gradient (KVP/cm) stays fairly constant. 4. With an increase in conductor diameter the conduct-surface gradient (KVP/cm), at corona start, became less for all four conductor configuration tested.					

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For list of contents-drawings, photos, etc. and for distribution see reverse side.

INFORMATION PREPARED FOR Electrical Performed Systems Research

TESTS MADE BY L. Jandran, JE McDonough Tests Completed: 5/5/58

HV Development, Electrical Research

COUNTERSIGNED TW Liao SECTION Systems Research
Electrical Performance

BUILDING and ROOM No. 9-102 LOCATION Pittsfield, Mass.

-mjb

Transactions Paper

(Reviewed and Accepted for Publication)



DEVELOPMENT OF A SQUARE LAW RADIO NOISE METER - I

F. J. Trebby

Member AIEE

Kaiser Aluminum & Chemical Corp
Spokane, Wash.

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Transactions Paper

(Reviewed and Accepted for Publication)



A CORRELATION OF THE PRESENT WITH A PROPOSED STANDARD METHOD FOR RIV MEASUREMENTS ON HIGH VOLTAGE DEVICES

Charles J. Miller, Jr.
Fellow AIEE
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Barberton, Ohio

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>JL Wiesztort</i> JL Wiesztort		SUBJECT CLASSIFICATION 1. Insulators, Suspension 2. Radio Interference 3. Noise, Radio		NO. 59PT137
				DATE 7/9/59
TITLE RADIO NOISE TESTS ON STANDARD AND PLASTIC ROD SUSPENSION INSULATOR STRINGS				
ABSTRACT Reported are results of dry tests on 22 and 30 unit porcelain insulator strings and also on comparative lengths of new type plastic rod insulators. Incidental data on 34 and 45 standard unit strings are also included.				
G.E. CLASS IV M		REPRODUCIBLE COPY FILED TECHNICAL DOCUMENTS		NO. PAGES
GOV. CLASS None		Pittsfield, Works		10
CONCLUSION Listed below are radio noise results on the various configurations for 460 kv line-to-line (265 kv line-to-ground) and 650 kv line-to-line (375 kv line-to-ground)				
Type Units		Radio Noise (μ volts)		
		265 kv applied	375 kv applied	
22 - 15,000 lb.		200	580	
22 - 36,000 lb.		140	500	
30 - 15,000 lb.		150	340	
30 - 36,000 lb.		75	250	
4 - plastic rod		65	7500	
5 - plastic rod		65	80-3500	
6 - plastic rod		90	105	

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INFORMATION PREPARED FOR EHV / J. J. LaForest

TESTS MADE BY JL Wiesztort, J. Stevens Tests Completed: 4/24/59

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Corona

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
L.W. Graham	1. Line Traps	59PT141
<i>L.W. Graham</i>	2. Insulators, Switch and Bus	DATE
	3. Noise, Radio	8-26-59
TITLE RADIO NOISE AND VISUAL CORONA START TESTS ON A SIMULATED CARRIER FREQUENCY LINE TRAP AND SUPPORTING INSULATORS WITH CORONA SHIELD RINGS.		

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ENGINEERS FOR:

POWER AUTHORITY OF
THE STATE OF NEW YORK

October 13, 1959

100-9

SUBJECT: Conference Notes 100-9-C6
Niagara-Adirondack Tie Line

Mr. C. F. Davis
Power Authority of the State of New York
The Coliseum Tower
10 Columbus Circle
New York 19, New York

Dear Mr. Davis:

We are transmitting herewith for your information three (3) copies of Conference Notes 100-9-C6 on High Voltage Tests at General Electric Company Laboratory and three (3) copies of General Electric Company's report on these tests.

By copy of this letter we are sending a copy of the conference notes to all persons present at the meeting.

Very truly yours,

UHL, HALL & RICH

By

R. E. Moran

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Enclosures

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Transactions Paper

(Reviewed and Accepted for Publication)



THE EFFECT OF RAIN ON R.I.V. CHARACTERISTICS OF HIGH VOLTAGE SUSPENSION ASSEMBLIES

J. Kaminski
Member AIEE

B. E. Kingsbury
Associate Member AIEE

F. C. Vose
Member AIEE

All of:
General Electric Company
Baltimore, Md.

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., February 1-6, 1959. Manuscript submitted November 3, 1958; made available for printing December 3, 1958.

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Paper No.

59-94

Discussion in Duplicate Due February 20, 1959.

GENERAL ELECTRIC COMPANY
Baltimore, Maryland

Technical Report No. LK-663-DR
May 9, 1960

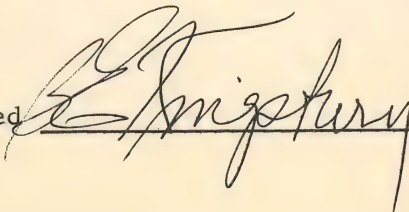
SUBJECT

VISUAL CORONA AND R.I.V. TESTS
ON BUNDLED CONDUCTOR ASSEMBLIES

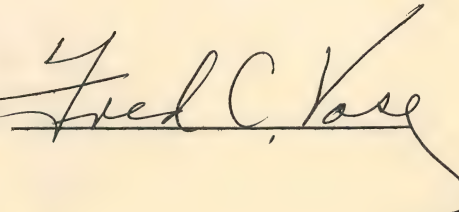
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E. Snigskurny

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Fred C. Vase

RIV

GENERAL ELECTRIC COMPANY

INSULATOR DEPARTMENT

Technical Report No. LK-665-DR

May 23, 1960

SUBJECT

Visual Corona and RIV Tests
On Bundled Conductor Assemblies

Joseph Kaminski, Jr.

This report contains:

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1 test result

Baltimore Maryland

Signed

Joseph Kaminski Jr

Approved

Fred C. Vore

R1V

OB Test Data

U.H.R.

N.Y. Power Auth.

345 KV line

GENERAL  ELECTRIC



RADIO AND CORONA TESTS
ON
HORIZONTAL 2-CONDUCTOR BUNDLES OF
795,000-CM ACSR "DRAKE" CONDUCTORS
AND ACCESSORIES
FOR
THE POWER AUTHORITY OF THE STATE OF NEW YORK

June 8, 1960
Barberton, Ohio

Charles J. Miller, Jr.
Research Engineer

Transactions Paper

(Reviewed and Accepted for Publication)



DECOUPLING OF TRANSMISSION LINES TO RADIO INFLUENCE VOLTAGES

S. B. Griscom
Fellow AIEE
Westinghouse Electric Corp.
East Pittsburgh, Pa.

D. F. Shankle
Member AIEE
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East Pittsburgh, Pa.

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Westinghouse Electric Corporation
East Pittsburgh, Pa.

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H. A. EREY

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Paper No.

60-1206

Discussion in Duplicate Due October 28, 1960.

For file Bek

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
L.F. Jandran	Switchgear Insulators, Switch & Bus	60PT156
		DATE
		Sept. 14, 1960
TITLE		
Impulse, Sixty-Cycle and Radio Noise Tests on a 650 KV Disconnect Switch		

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TRANSFORMER DIVISION

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A.I.E.E.

Penelec 460 KV Prototype Line

PREPARATORY RADIO INFLUENCE STUDY

R. J. Bacha - Pennsylvania Electric Company
Johnstown, Pennsylvania
Associate Member, AIEE

W. C. Guyker - West Penn Power Company
Greensburg, Pennsylvania
Associate Member, AIEE

E. S. Kocsan - Pennsylvania Electric Company
Johnstown, Pennsylvania
Associate Member, AIEE

October 1960

CONFERENCE PAPER
A.I.E.E.

Penelec 460 KV Prototype Line

PREPARATORY RADIO INFLUENCE STUDY

R. J. Bacha - Pennsylvania Electric Company
Johnstown, Pennsylvania
Associate Member, AIEE

W. C. Guyker - West Penn Power Company
Greensburg, Pennsylvania
Associate Member, AIEE

E. S. Kocsan - Pennsylvania Electric Company
Johnstown, Pennsylvania
Associate Member, AIEE

RIV

PREDICTION OF RADIO NOISE LEVELS BY DIGITAL TECHNIQUES

By

A. K. Abboushi
Associate Member, AIEE
Project EHV
General Electric Company
Pittsfield, Massachusetts

L. O. Barthold
Member, AIEE
Electric Utility Analytical Engineering
General Electric Company
Schenectady, New York

(To be presented at A.I.E.E. Second PICA Conference to be held in St. Louis, Missouri, November 9, 10, and 11, 1960).

District Conference Paper



ANALYSIS OF MEASURING CIRCUITS FOR RADIO INFLUENCE VOLTAGES

F. O. Simons, Jr.
Student Member AIEE

P. B. Jacob, Jr.
Member AIEE

Both of:
Mississippi State University
State College, Miss.

A paper recommended by the AIEE Transmission and Distribution Committee for presentation at the AIEE South East-South Central District Meeting, New Orleans, La., April 5-7, 1961. Manuscript submitted December 28, 1960; made available for printing February 8, 1961.

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61-490

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RIV

Transactions Paper

(Reviewed and Accepted for Publication)



DIGITAL CALCULATION OF RADIO NOISE LEVELS

A. K. Abboushi
Associate Member AIEE
General Electric Co.
Pittsfield, Mass.

L. O. Barthold
Member AIEE
General Electric Co.
Schenectady, N. Y.

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RADIO INFLUENCE TESTING ON 70 MILES OF 345 KV HORIZONTAL BUNDLE CONDUCTOR

R. E. Graham
Associate Member AIEE

C. R. Bond
Associate Member AIEE

Both of:
Ohio Edison Co.
Akron, Ohio

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Fall General Meeting, Detroit, Mich., October 15-20, 1961. Manuscript submitted June 15, 1961; made available for printing August 9, 1961.

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Paper No.

61-1027

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Conference Paper



SELECTION OF SINGLE AND BUNDLE CONDUCTORS AND ACCESSORIES FOR ACCEPTABLE RADIO NOISE PERFORMANCE

L. O. Barthold
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Schenectady, N. Y.

J. Kaminski
Member AIEE
General Electric Co.
Baltimore, Md.

H. E. House
Member AIEE
Aluminum Co. of America
Massena, N. Y.

J. J. LaForest
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Pittsfield, Mass.

Submitted in abstract or outline form only to the AIEE Transmission and Distribution Committee for presentation at the AIEE Fall General Meeting, Detroit, Mich., October 15-20, 1961. Manuscript submitted August 11, 1961; made available for printing August 17, 1961.

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Paper No. CP

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Discussion in Duplicate Due July 5, 1963.



A SUMMARY OF RADIO INTERFERENCE STUDIES APPLIED TO EHV LINES

J. Reichman
Member IEEE

J. R. Leslie
Senior Member IEEE

Both of:
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of Ontario
Toronto, Ont., Canada

A paper recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-27, 1963. Manuscript submitted March 18, 1963; made available for printing April 17, 1963.

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Paper No.

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Transactions Paper

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H. A. Erey*

RADIO NOISE FROM HIGH-VOLTAGE TRANSMISSION LINES

AIEE Radio Noise Subcommittee
of the
AIEE Transmission and Distribution Committee

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DEC 28 1961

H. A. EREY

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., January 28-February 2, 1962. Manuscript submitted October 18, 1961; made available for printing December 6, 1961.

Members of the AIEE Radio Noise Subcommittee: H. L. Rorden, Chairman; L. O. Barthold, P. L. Bellaschi, H. H. Brustle, F. C. Creed, F. R. Dallye, H. M. Ellis, C. D. Fiero, H. A. Gauper, E. H. Gehrig, R. E. Graham, F. L. Greene, N. S. Kent, J. J. LaForest, J. R. Leslie, T. W. Liao, R. J. Mather, C. J. Miller, A. C. Neaderland, W. E. Pakala, B. M. Pickens, M. G. Poland, L. M. Robertson, R. H. Schlomann, L. N. Stone, E. R. Taylor, F. L. Taylor, F. J. Trebby, P. D. Tuttle, F. C. Vose, F. A. Denbrock, H. M. Mather.

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62-106

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Transactions Paper

(Reviewed and Accepted for Publication)



AN INVESTIGATION OF RADIO INFLUENCE VOLTAGES ON TRANSMISSION AND DISTRIBUTION LINES ON THE SAME RIGHT-OF-WAY

F. L. Taylor
Member AIEE
The Detroit Edison Co.
Detroit, Mich.

J. F. Bouska
Associate Member AIEE
Commonwealth Edison Co.
Chicago, Ill.

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Fall General Meeting, Chicago, Ill., October 7-12, 1962. Manuscript submitted June 8, 1962; made available for printing August 7, 1962.

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Paper No.

62-1367

Discussion in Duplicate Due October 26, 1962.

Conference Paper



345 KV WOOD POLE TEST LINE -

RADIO INFLUENCE AND LEAKAGE CURRENT INVESTIGATIONS

T. W. Schroeder
Fellow IEEE
Illinois Power Company
Decatur, Ill.

G. L. England
Member IEEE
Illinois Power Company
Decatur, Ill.

J. E. O'Neil
Senior Member IEEE
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Paper No. **CP**

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Discussion in Duplicate Due July 5, 1963.



ANALYSIS OF RADIO NOISE FROM HIGH-VOLTAGE LINES

PART I. METER RESPONSE TO CORONA PULSES

O. Nigol

Member IEEE

The Hydro-Electric Power Commission of Ontario
Toronto, Ont., Canada

A paper recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-21, 1963. Manuscript submitted March 18, 1963; made available for printing April 23, 1963.

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Paper No

63-1022

Transactions Paper

(Reviewed and Accepted for Publication)

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ANALYSIS OF RADIO NOISE FROM HIGH VOLTAGE LINES

PART II. PROPAGATION THEORY

O. Nigol

Member IEEE

The Hydro-Electric Power Commission of Ontario
Toronto, Ont., Canada

A paper recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-21, 1963. Manuscript submitted March 18, 1963; made available for printing April 17, 1963.

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Paper No.

63-1023

Conference Paper



APPORTIONMENT OF OBSERVED BROADBAND NOISE AMONG POWER SYSTEMS

W. R. Foley
Member AIEE

R. E. Frese
Member AIEE

Both of:
U. S. Army Electronic Proving Ground
Fort Huachuca, Arizona

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H. A. FREY

A paper recommended by the AIEE Transmission and Distribution Committee for presentation at the AIEE Fall General Meeting, Chicago, Ill., October 7-12, 1962. Manuscript submitted June 15, 1962; made available for printing August 3, 1962.

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62-1350

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APPORTIONMENT OF OBSERVED BROADBAND NOISE AMONG POWER SYSTEMS

W. R. Foley
Member AIEE

R. E. Frese
Member AIEE

Both of:
U. S. Army Electronic Proving Ground
Fort Huachuca, Arizona

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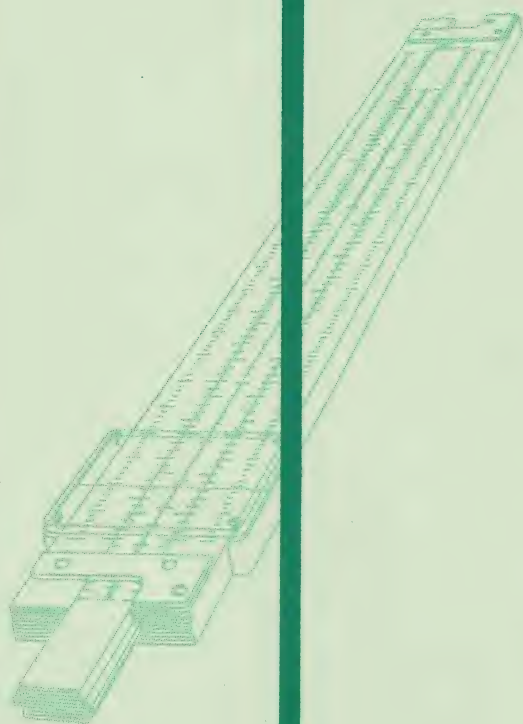
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Aluminum Line Hardware Resists Salt-Air Corrosion

M. K. DEAN, Electrical Engineer, Hawaiian Electric Co, Honolulu, H. I.

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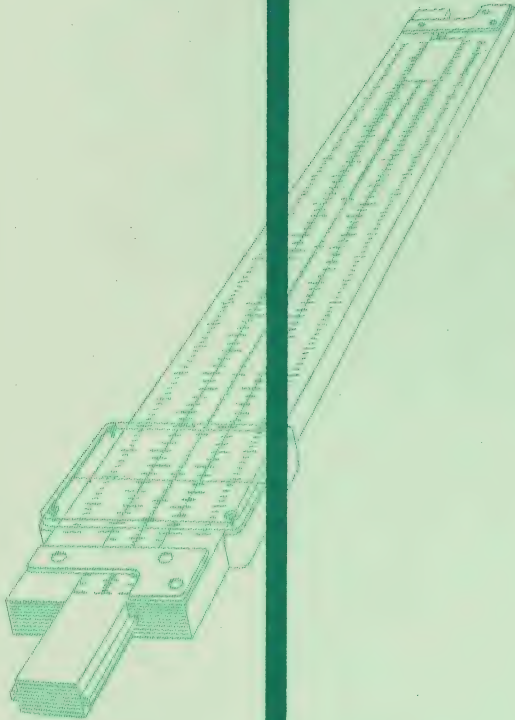


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Technical Paper No. 17

RESISTANCE OF WROUGHT
HIGH-STRENGTH ALUMINUM ALLOYS
TO STRESS CORROSION

BY D. O. SPROWLS

Research Engineer—Alcoa Research Laboratories

Chemical Metallurgy Division

AND

R. H. BROWN

Assistant Director of Research—Alcoa Research Laboratories



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PITTSBURGH, PENNSYLVANIA

1962

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NEW METHOD OF SPLICING ACSR & ALLOY CONDUCTORS

Adolph C. Neaderland
Supervisor - Project Engineering Section
U-I Division
Burndy Corporation

Paper To Be Presented At
The Pennsylvania Electric Association Meeting,
Pocono Manor, May 2, 1958

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR EJ Mets <i>EW</i> NW Roberts <i>NR</i>	SUBJECT CLASSIFICATION Fatigue of Metals	NO. 57TP469 DATE 7-10-57
TITLE Fatigue Characteristics of Aluminized and Galvanized Plain Forged Steel		

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GENERAL  ELECTRIC

TRANSFORMER AND ALLIED PRODUCTS DIVISION

**Aluminum, Aluminized Steel
And Galvanized Steel
In Severe Coastal Environments**

By
THOMAS A. LOWE
Research Engineer

Reprinted From CORROSION, Vol. 17, No. 4, PP. 177t-180t, (1961) April

KAISER ALUMINUM AND CHEMICAL CORPORATION
Department of Metallurgical Research

M. Kingsbury

**NEW ALUMINUM PERMANENT MOLD CASTING
ALLOYS C355 AND A356**

By

R. C. Lemon and H. Y. Hunsicker

This paper has been presented at the
60th Annual Meeting of the American
Foundrymen's Society, May 7, 1956,
in Atlantic City, New Jersey.

Distributed by
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d. R. Hanson

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

CONFERENCE PAPER #56-335

New York, New York
January 30, 1956

THE USE OF ALUMINUM ALLOY AND HIGH STRENGTH - LOW ALLOY STEEL
FOR POLE LINE HARDWARE

John L. Eberly
Hubbard and Company
Pittsburgh, Pennsylvania

THE USE OF ALUMINUM ALLOY AND HIGH STRENGTH LOW ALLOY STEEL FOR POLE LINE HARDWARE

John L. Eberly

INTRODUCTION

In recent years there have been vast improvements in the chemical treatments applied to wooden utility poles and cross arms and, as a result, there has been a substantial increase in the service life of these poles and arms. Consequently it has been necessary to supplement the ordinary galvanized steel pole line hardware with materials which are more resistant to corrosion. Depending upon the severity of the corrosion problem as well as the longevity required for the hardware, it has been found that this problem can be solved by using both aluminum alloy and high strength - low alloy steel as a material. Both of these materials are being used successfully and this paper will discuss both solutions to the problem in two separate parts.

PART I - ALUMINUM ALLOY POLE LINE HARDWARE

REASONS FOR SELECTION OF ALUMINUM ALLOYS

The need for aluminum alloy hardware has been prompted particularly in areas where there is a severe atmospheric corrosion situation which has caused galvanized hardware to fail prematurely. These areas can be placed in three categories; namely, heavy industrial, seacoast, and chemically contaminated. Aluminum alloys also will perform well in locations where erosion is the problem. This situation is normally encountered along seacoast areas where the wind blows sand and particles continuously to the point where any protective material is completely removed on the windward side. There are also many areas inland, especially in some of the plains states, where winds sweeping over unobstructed prairies cause this same situation. There are also locations where maintenance is extremely costly due to the inaccessibility of the hardware.

REASONS FOR ALUMINUM ALLOYS RESISTANCE TO ATMOSPHERIC CORROSION

The superior resistance of aluminum alloys to atmospheric corrosion is due primarily to an inherent characteristic of aluminum; namely, the fact that aluminum has a natural affinity for oxygen. When aluminum is exposed to the atmosphere, a coating of aluminum oxide begins to form on the surface and normally the coating will attain a depth of approximately 50 angstrom units or one fifth of a

Note: Figures in parentheses indicate number of reference which will be found at end of paper.

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
EJ Mets <i>E. J. Mets</i>	Aluminum & Its Alloys	55TP419
TITLE		DATE
Effect of Curing of Concrete on EC Al Strands in Concrete Reactors		3-24-55

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR EJ Mets <i>E. J. Mets</i>		SUBJECT CLASSIFICATION Aluminum & Its Alloys		NO. 55TP419	
				DATE 3-24-55	
TITLE Effect of Curing of Concrete on EC Al Strands in Concrete Reactors					
ABSTRACT Bare EC Al strands cast in concrete were exposed to accelerated curing cycles in an autoclave with similar set of aluminum strands not cast in concrete. Samples representing 1 to 10 cycles were examined for changes in mechanical properties and microstructure.					
G.E. CLASS 3		REPRODUCIBLE COPY FILED TECHNICAL DOCUMENTS		NO. PAGES	
GOV. CLASS None		PW Data Bureau		15	
CONCLUSION After 10 cycles, there was a loss of 35% in T.S. and 33% in Y.S. Approximately one-third of this loss is attributed to the effect of concrete and two-thirds due to the temperature of the autoclave. Percent elongation does not increase after the fourth or fifth cycle with the corresponding decrease in T.S. and Y.S. Loss in mechanical properties by affects of concrete occurs during the first curing cycle, and is due to reduction in area and pitting attack of the aluminum strands.					

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents-drawings, photos, etc. and for distribution see reverse side.

INFORMATION PREPARED FOR Concrete Reactor Engineering

TESTS MADE BY EJ Mets, JF Bacon, WP Tootill, Miss MA McGregor

COUNTERSIGNED W. Morrill *W. Morrill* SECTION Metallurgical Development
Materials & Processes Laboratory
 BUILDING and ROOM No. 7 - 260 LOCATION Transformer Division, Pittsfield
General Metallurgy Subsection

USE OF ALUMINUM ALLOYS IN ELECTRICAL TRANSMISSION STRUCTURES

By

Joseph E. Williams and George H. Phillips
Aluminum Company of America

A conference paper to be
presented at the Winter
General Meeting of the
American Institute of
Electrical Engineers, New
York, New York, January
18-22, 1954.

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Metallurgy Bulletin

Vol. 6, No. 1

Internal Information, for use of G-E Employees Only

January, 1953

CORROSION OF ALUMINUM

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	DEVELOPMENT OF HIGH STRESS-CORROSION RESISTANCE IN 7XXX SERIES ALUMINUM ALLOYS	P. L. Mehr E. H. Spuhler	ALCOA Pittsburgh, PA	7/15/63

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care of aluminum

**ARCHITECTURAL ALUMINUM
MANUFACTURERS ASSOCIATION**

1 East Wacker Drive
Chicago, Illinois 60601



THE ALUMINUM ASSOCIATION

750 Third Avenue
New York, N. Y. 10017

TECHNICAL INFORMATION SERIES

AUTHOR M. J. Bolton <i>M. J. Bolton</i>	SUBJECT CLASSIFICATION <u>Corrosion</u>	NO. 49TP160
TITLE "Atmospheric Corrosion Test Project Progress Report"		DATE June 12, 1950
ABSTRACT The results of two years exposure of metals and metal finishes are presented for test locations at Pitts-		

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GENERAL  ELECTRIC

TRANSFORMER & ALLIED PRODUCT DIVISIONS

GENERAL ELECTRIC

APPARATUS DEPT.

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR M. J. Bolton <i>M. J. Bolton</i>	SUBJECT CLASSIFICATION <u>Corrosion</u>	NO. 49TP160 DATE June 12, 1950
TITLE "Atmospheric Corrosion Test Project Progress Report"		
ABSTRACT The results of two years exposure of metals and metal finishes are presented for test locations at Pittsfield, Cape Cod, and Lynn, Mass. and Pittsburgh, Pa. Indications of the relative corrosion resistance of many materials and finishes are presented. The results on a new series of zinc base alloys are included. Completion of tests on Copper bearing steel have evaluated its corrosion properties as compared to low carbon steel.		
G.E. CLASS 3	REPRODUCIBLE COPY FILED TECHNICAL SERVICE DIV. PITTSFIELD	NO. PAGES 26
GOV. CLASS None	PW Data Bureau	
CONCLUSIONS 1. Unprotected copper bearing steel has a lower corrosion rate than a similar steel without the copper addition. 2. Chemical treatments on aluminum have shown that after two years exposure, the Alodine(hot dry) process is equivalent to chromic or sulfuric acid anodizing. 3. Speculum electroplates on copper or brass base have good corrosion resistant properties. On steel it does not show up so well. 4. The same thickness of tin on a steel base deposited either from a fluoborate bath or a stannate both shows a different corrosion rate. 5. The many proprietary processes for putting a chemical film on zinc electroplate(Cronak, Ebonal Z, Iridite, etc.) have proved of doubtful value. 6. Indium diffused into various metal electroplates on a steel base accelerates the corrosion rate rather than lowers it. 7. Zinc alloys (Zn-Cu-Be) have not exposed long enough to evaluate them properly.		

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents-drawings, photos, etc. and for distribution see reverse side.

INFORMATION PREPARED FOR General Engineering Information

TESTS MADE BY Michael J. Bolton, A. L. Jenny, D. Shutts, J. Nesbit, A. DiNicola

COUNTERSIGNED Weston Morrill *W.M.* DIV Metals Section - Laboratory

TRANSFORMER & ALLIED PRODUCT DIVISIONS

PITTSFIELD

A. I. E. E. 1956 WINTER MEETING
PAPER NO. 56-230

CORROSION AS IT AFFECTS INSULATOR AND CONDUCTOR HARDWARE

BY A. W. BARDEEN AND J. M. SHEADEL

DISCUSSION BY H. J. SANDWICK (THE BREWER-TITCHENER CORPORATION,
CORTLAND, NEW YORK)

The material in this paper is of interest particularly at this time, when the problem of corrosion of insulator components and conductor hardware has become the subject of increasing concern on the part of Utilities operating transmission lines in isolated sea coast or industrial areas.

We, at the Brewer-Titchener Corporation, as producers of forged steel and non-ferrous transmission materials discussed in this paper, are quite naturally concerned with this corrosion problem.

There is little to be added to the first part of the paper dealing with the causes, the variables, the classes, and the effects of corrosion.

SUSPENSION INSULATOR COMPONENT PARTS

A few utilities, a part of whose lines operate under severe corrosion conditions, express a preference for malleable iron versus forged steel suspension insulator caps. A major portion of suspension insulator manufacturers use forged steel caps because of their inherent greater strength and dimensional fidelity. From a corrosion standpoint, it would seem that too much emphasis is being placed on the cap material. Both the cap and stud are subject to corrosion. The critical cross section of the forged cap is approximately five times that of the steel ball pin. Actual

Corrosion

Conference Paper



FIELD EXPERIENCE WITH CORROSION OF DISTRIBUTION MATERIAL

A. S. Hadfield
Associate Member AIEE
Virginia Electric and Power Co.
Williamston, N. C.

Submitted in abstract or outline form only to the AIEE Committee on Transmission and Distribution for the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted November 28, 1955; made available for printing December 8, 1955.

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Paper No. **CP**

56-270

Corrosion
Return
B. E. Kingston

Conference Paper



FIRST REPORT ON CORROSION TESTS OF A NEW STEEL WIRE WITH THICK ALUMINUM COVERING

J. G. Cavanagh
Member AIEE
Copperweld Steel Company
Glassport, Pa.

*H. That you might be
interested in looking at
this. bek.*

A paper recommended by the AIEE Transmission and Distribution Committee for presentation at the AIEE Fall General Meeting, Pittsburgh, Pa., October 26-31, 1958. Manuscript submitted August 20, 1958; made available for printing September 2, 1958.

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Paper No. **CP**

58-1254

B. E. Kingsbury
Corrosion

GENERAL ELECTRIC COMPANY
INSULATOR DEPARTMENT

Technical Report No. LK-187-CR

March 21, 1961

SUBJECT:

ACCELERATED CORROSION TEST
FOR SUSPENSION INSULATOR BALL BOLTS

P. B. Horton

This report contains:

4 typewritten pages
4 pages of photographs

Baltimore, Maryland

Signed

P. B. Horton

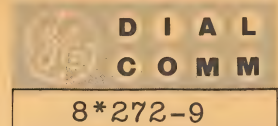
INDEX FOR: CORROSION

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Page #1

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49TP160	ATMOSPHERIC CORROSION TEST PROJECT PROGRESS REPORT	MJ Bolton	General Electric Pittsfield, MA	June 12, 1950
R56GL69	CORROSION SYMPOSIUM - 1955	RT Foley	General Electric Schenectady, NY	April 25, 1956
AIEE Paper #56-230	CORROSION AS IT AFFECTS INSULATOR AND CONDUCTOR HARD- WARE	AW Bardeen JM Sheadel		1956
AIEE CP 56-270	FIELD EXPERIENCE WITH CORROSION OF DISTRIBUTION MATERIAL	AS Hadfield	Va Elec & Power Co Williamston, NC	Dec 8, 1955
AIEE CP 58-1254	FIRST REPORT ON CORROSION TESTS OF A NEW STEEL WIRE WITH THICK ALUMINUM COVERING	JG Cavanagh	Copperweld Steel Glassport, PA	Sept 2, 1958
LK-187-CR	ACCELERATED CORROSION TEST FOR SUSPENSION INSULATOR BALL BOLTS	PB Horton	General Electric Insulator Dept.	March 21, 1961

GENERAL ELECTRIC

INSULATOR DEPARTMENT
2525 Insulator Drive
Baltimore, Md. 21230



COPIES: ES Wheeler
HA Frey
AJ Pezdek

February 22, 1967

SUBJECT: Catastrophic Damage Due
To Chipping

Messrs. R. Weller
J. Kaminski

I refer you to Test Report No. 23101 in which we reported the potential catastrophic damage that may result from chipping the inner petticoats of the NGK 20,000 lb. suspension insulator (NGK 557MG-20). Similar tests have also been performed to compare the NGK six inch insulator with our six inch insulator (LJ-16583 versus 16583).

These latter tests were performed in essentially the same manner as was done on the ten inch insulators. Briefly, the procedure was as follows:

- A. Impact, with steel nosed pendulum, the second petticoat (There are three petticoats, counting the outer rim.) The magnitude was started at 10 inch-lbs. and increased in 10 inch-lbs. increments until chipping occurred.
- B. Electrical test the units
- C. Thermal shock the units. Three cycles were employed, with bath temperatures being 32° F and 212° F
- D. Electrical test the units
- E. Perform M&E test on units

The results were as follows:

IMPACT TEST

<u>Catalog No.</u>	<u>Sample No.</u>	<u>Impact, in.-lbs.</u>	<u>Electrical Test</u>	<u>Remarks</u>
LJ-16583	1	20	Punctured	cracked shell
	2	30	FO	chipped petticoat
	3	20	FO	chipped petticoat
	4	20	FO	chipped petticoat
	5	20	FO	chipped petticoat
	11	20	FO	chipped petticoat

<u>Cat No.</u>	<u>Sh.</u>	<u>C.L.</u>	<u>Dia</u>	<u>Type</u>	<u>Competitors</u>
405360	40	$5\frac{3}{4}$	10	B & S	
505386	50	$6\frac{1}{8}$	$11\frac{5}{8}$	B & S	
18290	40	$6\frac{1}{4}$	$10\frac{3}{8}$	cl	
18380	50	7	$11\frac{5}{8}$	cl	

Dave Alexander, Victor Ins., Victor, N.Y.
called 2/7/67 with questions regarding
our conn. length & shell dia. on 40 & 50 k sup.

Gave him the above info., except that told
him $6\frac{1}{2}$ " spacing on 18290 which is in error
on the "Active Prod. Listing"

Bsk 2/5/67

Victor Ins. Victor, N.Y.
A/c 716 924-2127



INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

"Competitors"

No. 23101

Date 12/20/66

Page 1 of 4

Nature of Tests:

Impact, Thermal, Flashover, M&E, and Ultimate

Material

NGK-557MG-20
GE-20S840

Refer to

Test Req. No. 7297

Copies
to

The following testing was performed in order to determine a means of discrimination between suspension insulators of different manufacturers regarding the susceptibility to catastrophic cracking of the porcelain component.

Catastrophic cracking is defined as being damage to the insulator either to a critical degree or to a critical area as contrasted to the damage normally expected to be encountered by the type of test here after described.

Insulators from two manufacturers--General Electric Company and NGK--were subjected to tests.

I. These tests consisted of the following:

- A. Impact Insulators were mounted in the standard ASA impact machine. Instead of striking the edge of the shell, as is normal, the pendulum was adjusted so that the nose would impart an impact to the third petticoat from the edge of the shell (second petticoat from the pin hole). Each insulator was impacted with successively increasing magnitude in 10 inch-lbs. increments until chipping occurred.
- B. Electrical Test Then, all insulators were flashed over electrically
- C. Thermal Test Then, all insulators were subjected to one cycle of thermal shock (32° F to 210° F), ten minutes each half cycle.
- D. Electrical Test All insulators were flashed over electrically
- E. Impact Test All insulators were again impacted as in "A", above, except that the inner petticoat was impacted.
- F. Electrical Test Then all insulators were flashed over electrically
- G. Thermal Test All insulators were subjected to five (or less depending upon results) cycles of thermal shock (32° F to 210° F), ten minutes each half cycle.
- H. Electrical Test Then, all insulators were flashed over electrically
- I. M & E and Ultimate Test All insulators were then subjected to M & E test

Signed _____

Approved _____

Nature of Tests:

IMPACT TEST

Material

NGK 557 (6)
205840605 (6)

Refer to

Test Req. No. 7297

Copies to

FILE
BEK

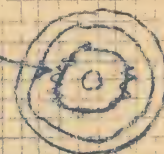
NGK 557 MG 20

ALL UNITS TESTED AT #3 PETTICOTT

SAMPLE VALUE REMARKS

1	20	BROKE AWAY 5 IN. OF "3 SKIN"
2	30	ALL
3	20	1/2
4	20	3"
5	30	1/2
6	20	4"

STEEL NOSE
WAS USED



205840605

1	30	1" CHIP
2	30	" "
3	30	" "
4	60	" "
5	30	" "
6	30	" "

ALL UNITS FLASHED OVER ON

THERMAL TEST

UNITS GIVEN ONE CYCLE OF FULL RANGE THERMAL SHOCK TEST. FOLLOWED BY A 602 FO. ALL OK



GE 20S840
TEST REQ #7297



NGK 557MG20
TEST REQ #7297

GENERAL ELECTRIC
INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

RECEIVED

DEC 14 1966

Competitors

No. 23088

Date 9-1-66

Page 1 of 5

Nature of Tests:

Design Tests

ENG.

Material

HBP-47
NGK HRBP-47
Sim. to Locke #2ND

Refer to

W. Lounsbury

Test Req. No.

7299

Copies
to

File

W. Lounsbury
B. Kingsbury

3 No. HBP-47
3 No. HRBP-47

R.T.V. Test

HRBP-47

- Rated 50kv. @ 5 kv.

Test Voltage		5 kv.	50 kv.	RAK 29.84
Spec. No. 1	Noise level	2 kv.	27 kv.	D.B. 88°F
" " 2	"	2 kv.	34 kv.	W.B. 71°F
" " 3	"	2 kv.	31 kv.	VAP 0.611

HBP-47

- Rated 2500 kv. @ 5 kv.

Test Voltage		5 kv.	2500 kv.
Spec. No. 4	Noise level	125 kv.	22.5 kv.
" " 5	"	100 kv.	23.5 kv.
" " 6	"	150 kv.	20.5 kv.

60w Dry F.O. test

Individual readings on 75 volt scale
Connected to 1000:1

HRBP-47

- Rated @ 50 kv.

Spec. No. 1	No. 2	No. 3	RAK 29.84
42 kv.	53 kv.	52 kv.	D.B. 88°F
51.5 "	52 "	52 "	W.B. 72°F
52 "	53 "	51 "	VAP 0.611
53 "			HUM. 0.997
52.5 "			RAK 0.995

Av. Uncorr. 51.4 kv.

52.6 kv.

51.6 kv.

Av. Corr. 51.6 kv.

52.8 kv.

51.8 kv.

HBP-47 Spec. No. 4

No. 5

No. 6

62

64

65

61

61

58

59

63

58

59

59

67

60

59

52

Av. Uncorr. 60.2

61.2

59 kv.

Av. Corr. 60.4

61.4

59.2 kv.

Signed C.R.P.-A.B.

GENERAL ELECTRIC

INSULATOR DEPARTMENT
2525 Insulator Drive
Baltimore, Md. 21230

RECEIVED

SEP 29 1966

ENG.

DIAL
COMM

8*272-9 234

COPIES:

GM Boyd
HA Frey
BE Kingsbury
ER Knooihuizen
RH Lester
WM Nave
AJ Pezdek
ES Wheeler

September 27, 1966

COMPETITIONS CLOSET:

A. B. Chance Epoxiglass Insulators

All District Managers
All Headquarters Marketing Personnel

Chuck McKinley learned that A. B. Chance, in recent weeks, has had a delegation at Louisiana Power and Light Co. to determine just what to do about replacing all the epoxiglass insulators that Louisiana Power and Light Co. has installed.

Also, Bob Bauer has learned of a series of failures of the "Epoxy-Glas" struts being used as 55-5 pin-type insulators on the Pacific Power & Light Co. system. In the latter case, struts were being used in an extremely contaminated coastal environment and damage is due to excessive leakage currents. This resulted in charring or burning of the strut, with some units burning the full length of the strut. Apparently, no radio interference problems have been encountered, but Pacific Power & Light is going to replace all units.

We have made tests on the style used by Louisiana Power and Light and a copy of these test results is attached. In the column showing "Equivalent 5-3/4 x 9" insulators", these are catalog values of strings of porcelain insulators which resulted in approximately the same flashover value as the epoxiglass-porcelain combination.

Under Test Group D, it is noted that severe tracking took place in 37 minutes under a special wet flashover test. These results appear to support the situation that is occurring in service.

Under Group F, the mechanical strength of the unit severely limits its application.

We have pointed out in previous communications that epoxiglass and other similar organic insulators are very susceptible to tracking and subsequent breakdown. Our GEPOL insulating material, on the other hand, a patented formula, has a high degree of freedom from tracking which gives us the confidence that chances for GEPOL's success are very high!

J. Kaminski, Jr.
J. Kaminski, Jr.

Product Planner & Application Engineer

pr

ATT.

File-Competitors

B. Kingsbury

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SEP 29 1966

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QUALITY CONTROL

TECHNICAL REPORT NO. VIII

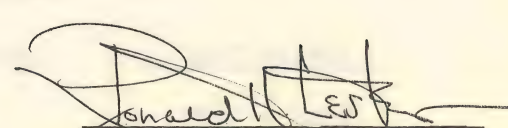
TEST RODS SUPPLIED BY N.G.K.

by

W. E. Taylor

September 26, 1966


Signed


Approved

GENERAL ELECTRIC

INSULATOR DEPARTMENT
2525 Insulator Drive
Baltimore, Md. 21230

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COPIES:

AJ Pezdek
J. Kaminski
FR McVicker
ES Wheeler



September 22, 1966

Subject: Arc-Over Tests on OB
and NGK Insulators

Mr. B. E. Kingsbury:

The laboratory recently had the opportunity of making tests on both OB insulators and NGK insulators which had been subjected to short circuit arc-over tests. The arc-over tests were made by the Baltimore Gas and Electric Co. at their Windy Edge test facility and was a continuation of the investigation for Stone and Webster for the Keystone Line. The objective of the tests was to obtain a comparison between the OB and NGK insulators so that a decision could be made on the usage of the insulators for the Keystone Transmission System.

The tests were made on a string of three units, which is similar to the procedure used at S.C.E. in their arc-over tests.

The insulators were brought into our laboratory for conducting the mechanical test after having been subjected to arc-overs of approximately 4,000 - 6,000 amp-sec. Mr. Bill Logan and Mr. Gordon Gaertner of the Baltimore Gas and Electric Company witnessed these tests and also took the insulators back for examination and review by other interested individuals.

The results obtained in the laboratory tests on the OB insulators are as follows. These units were rated at 25,000 lbs. M&E strength.

<u>Sample</u>	<u>M & E</u>	<u>Ultimate</u>	<u>Remarks</u>
1	32,100	32,100	Broke Socket
2	38,350	38,350	Normal Break
*3	Punctured	16,750	Normal Break
1A	34,300	34,300	Normal Break
2A	39,800	39,800	Broke Socket
*3A	30,400	30,400	Normal Break
1B	33,900	33,900	Normal Break
*2B	17,100	17,100	Normal Break
*3B	Punctured	17,600	Normal Break
1C	36,100	36,100	Broke Socket
2C	32,800	32,800	Broke Socket

Competitor's

Mr. Kensington

MEMORANDUM

August 31, 1966

Subject: NGK Quality Problem--Reports and
Information on Hand To Date

Messrs. WM Nave
GM Boyd
AJ Pezdek
ES Wheeler

1. The first indication of trouble with NGK insulators received by us came from Pacific Gas and Electric Company. It was reported that a 230 Kv circuit dropped under normal operating conditions--no wind, no rain, no abnormal loading. It was further reported that when additional NGK insulators on the same circuit were examined some (an unknown quantity) were found to be cracked. The NGK representative is reported to have told PG&E that the insulators had been roughly handled in construction and pointed out that a very light impact on the underside of the unit could cause breakage of the shells and subsequent reduction in M&E strength. When these reports were received, a simple test was made here (the so-called screw driver test) by simply dropping a screw driver so as to strike in the trough between any pair of the inner corrugations. It was found that a surprisingly light blow at this point would cause a part of the shell to break off. These tests were made on Japanese 18,000 lb. units and, in some cases, the units after being so broken were found to have mechanical strength tests of as low as between 5,000 and 6,000 lbs. Needless to say, not all units were so affected.
2. Pursuing further simple tests of this sort at Baltimore, it was found that by simply tapping the tips of the smooth inner corrugations with a screw driver or other metallic object, it was very easy to cause chips to spall off. Subsequently it was found that on insulators so chipped, there was a tendency for glaze to continue to flake off around the chip and after a single cycle thermal shock test some of the insulators cracked radially with the cracks progressing up into the head. This, of course, is a very dangerous situation since even if the mechanical strength is unaffected, a crack in the head of the insulator would represent an electrical failure and charging currents passing over this crack over a period of time in service could cause a blow-apart.
3. It was after the rather preliminary work indicated above had been done that Baltimore Gas and Electric Company (John Jones) called me to ask if we would be willing to make some tests for them on competitive insulators. In the course of the conversation it developed that they wished us to make tests on Japanese insulators and that they had heard from PG&E of the above difficulties. The tests were to be made under the direction of Stone and Webster, with representatives from BG&E, Pennsylvania Electric and NGK present. These tests were made, and Mr. Weller has reported on them in detail. However, a brief resume of the results is worth repeating here.

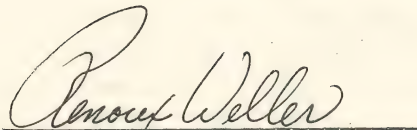
B. E. Kingsbury
Competitor

GENERAL ELECTRIC COMPANY
INSULATOR DEPARTMENT
Baltimore, Maryland

Technical Report No. LK-819
September 1, 1966

IMPACT TESTS ON NGK AND OB INSULATORS
MADE FOR STONE AND WEBSTER

This Report Contains
13 typewritten pages


Signed

GENERAL ELECTRIC

INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

competitor
No. 22929
Date AUG. 17, 1966
Page of

Nature of Tests:

WITHSTAND MTE

Material

NGK 30S
Locke 30S.

Refer to

Test Req. No.

Copies
to

FILE

H. FREY

R. WOLLER

B. K.

3 NGK 30,000 LB. UNITS WERE GIVEN A WITHSTAND
OF 126 KV UNDER OIL FOR ONE MINUTE FOLLOWED BY
A FLASHOVER AND MTE TEST.
ONE LOCKE 30S²⁵ WAS ALSO TESTED

SAMPLE	MTE	ULT	REMARKS
1	31500	31500	SHEARED SIDES OF BALLBOLT
2	32100	32100	" " " "
3	32500	32500	" " " "

LOCKE

1	36200	36200	PULLED THRU SOCKET
---	-------	-------	--------------------

Signed. RUS

Approved _____

GENERAL ELECTRIC

INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

No. 22929

Date AUG. 15, 1966

Page of

Nature of Tests: TIME LOAD AND MTE TEST AND		Material OB. 25,000 LBS NGK. 30000
THERMAL TEST		
Refer to	Test Rec. No.	

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to

FILE

INSPECTOR (A)

THESE UNITS HAVE NBP 10 CYCLES FULL (212°F - 32°F) RANGE

5 NGK.

(5 OB.) UNITS WERE PLACED IN THE TIME LOAD FRAME

FRIDAY 0830 '8-12-66 UNDER 18,000 LBS. LOAD.

UNITS WERE TAKEN DOWN 1300 '8-15-66 AND GIVEN A FLASH-
OVER TEST FOLLOWED BY AN MTE TEST.

SAMPLE	SEC FO.	MTE	ULT	REMARKS
OB				
X1	OK	42000	42000	SHEARED SIDES OF BALL
2	"	40000	40000	"
3	"	39500	39500	MEDIUM BREAK 1 1/32
4	"	46000	46000	CAP FAILED
5	"	41250	41250	CAP OFF
NGK 6	"	32150	32150	SHEARED SIDES OF BALL
7	"	31400	31400	"
8	"	32800	32800	CRACKED BACK OF SOCKET
9	"	32300	32300	SHEARED SIDES OF BALL
10	"	32700	32700	"

Signed RUS

Approved

GENERAL ELECTRIC

INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

competitor
No. 22912
Date 7/19/66
Page 1 of 1

Nature of Tests: M+E an UH. an Thermal test	Material: NGK 18000 LJ1840
Refer to	Test Req. No. 7284

Copies to

File

H. Frey

B. Kingsbury

approx. 1/2 of these did flashover when subj. to elec test prior to the thermal test.

Thermal Shock Test 6 units, two cycles.
All six units cracked on first cycle.
None of these units will hold voltage.

Sam. No.	Ultimate	Remarks
1.	8400	Chipped 2 inner petticoats before given Thermal test. Normal Break
2.	7900	Small chips on three inner petticoats before given Thermal test. Normal Break.
3.	8150	" " " " " "
4.	5700	Chipped all petticoats of unit before given thermal test. Normal Break
5.	9000	Chipped 3 outer petticoats before given thermal test. Normal Break
6.	7250	Very small chips in all petticoats before given Thermal test.

The next two units were not given Thermal test.
The two units cracked while being chipped,
They will not hold voltage.

1.	8800	Chip in First inner petticoat. Normal Break
2.	8250	" " " " " "

Thermal Shock Test 2 units, four cycles. No apparent damage.
These two units will hold Voltage.

1	25000	Very small chips on outer 3 petticoats before given thermal test. No cracks in shell. Broke the Shank
2.	24050	" " " " " "

Signed

[Signature]

Approved

K. Weller

Handwritten text in red ink, possibly a signature or date, with a blue line crossing through it.

- Richard Ginori

You will find Test Reports enclosed, as listed below, for your approval and forwarding to Manager - Line Insulator Engineering.

Vessel
EXPORT
Administration

H.M. Stickles
6/9/66

TEST REQUISITION
HIGH VOLTAGE LABORATORY
INSULATOR DEPARTMENTNature of Tests: *M & E*No. *2221*Date *4/25/66*

Auth.No.

Will Witness: Yes ☐ No ☒Requested By: *BEK*

For

Copies To: *RW HAF ATP BEK JK*

Material:

LS 1840

Assembly Date & Shift:

MATERIAL DESCRIPTION:

Standard ☐Developmental ☐Other ☐

- ① approx 132 ins. are @ HV Lab (in alley) from previous shipments
② 200 ins. (from most recent shipment) will be delivered to lab.

TESTS REQUIRED:

Standard Tests ☒Other Tests ☐*Please make M & E tests on:**IN ALLEY -**75 of item ①**COMING**75 of item ②*

SPECIAL INSTRUCTIONS:

Entered Laboratory File

By

Report Number

Dated

Signed *BEK*

~~JH Kehlbeck~~
~~B Kingsbury~~

Mr. R. H. Lester:

[illegible]

H.M.Stickles

GENERAL ELECTRIC

INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

No. 22878
Date 3/22/66
Page 1 of 3

Nature of Tests:

Material

Refer to

Design & Quality Conformance
R. WELLS

Test Req. No.

7202

NGK-DA-85082
LJ-29069
Post Ins.

Copies
to

File

R. Wells

RIV Tests Rated - 200KV @ 44KV

Sam # 1
KV - 44 100
UV - 3.5 200

Sam # 2
KV - 44 102
UV - 4 200

Sam # 3
KV - 44 99
UV - 3.5 200

Bar - 29.85
WB - 58
DB - 74
VP - .307

60 Dry 70 Tests

Rated - 235KV

Sam # 1
227
228
230
229
228

Sam # 2
226
228
228
227
228

Sam # 3
228
227
229
230
226

AV - 228.8KV
Corr. - 262KV

AV - 227.4KV
Corr. - 260KV

AV - 228KV
Corr. - 261KV

3/29/66

Bar. - 29.78
WB - 52
DB - 73
VP - .156
Hum - 1.144
Rad. - 1.000

60 Wet 70 Tests

Rated - 180KV

Sam # 1
188
187
188
186
190

Sam # 2
188
189
190
187
188

Sam # 3
192
186
186
189
188

AV - 187.8KV
Corr. - 187.8KV

AV - 188.4KV
Corr. - 188.4KV

AV - 188.7KV
Corr. - 188.7KV

Bar. - 29.78
DB - 73
Rad. - 1.000
Prec. - .18"/min
Res. H₂O - 6950w
Press. - 36psi

Signed WFS

Approved

GENERAL ELECTRIC

INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

No. 22876

Date 6-28-66

Page of

Nature of Tests:

Impact Test - AND Puncture IT

Material

16583-

UNDER OIL

Refer to

Test Req. No.

7271

GINORI

Copies
to

Sample No. #	Impact Value	Skirt-Thick	REMARKS
1	100 IN. LBS	16/32	1/2 OFF
2	90 " "	"	1/4 "
3	90 " "	17/32	2/3 "
4	90 " "	"	1/4 "
5	110 " "	"	2/3 "

Sample	Puncture Value	Location
1	134 K.V.	BASE OF CAP
2	90 K.V.	THUR THE HEAD
3	132 K.V.	BASE OF CAP
4	128 K.V.	THUR THE HEAD
5	120 K.V.	" " "
6	132 K.V.	BASE OF CAP
7	134 K.V.	" " "
8	130 K.V.	THUR THE HEAD
9	104 K.V.	" " "
10	132 K.V.	" " "

GENERAL ELECTRIC

INSULATOR DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

No.

22706

Date

2-15-66

Page

1 of 2

Nature of Tests:

Electrical, Mechanical and
Burning Tests

Refer to

F. Vose

Test Req. No.

7141

Material

A.B. Chance
Epoxy glass &
Porcelain

Copies
to

File
F. Vose
Kingsbury
Kaminski

One 24" epoxy glass insulator supporting 2
conventional 9" suspensions of A.B. Chance Co.

60W Dry F.C. test

Individual readings on 300 volt scale

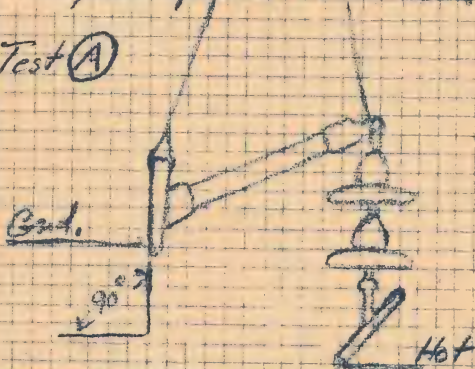
Connected to 150 volt scale, connected to 1000:1

Meter readings converted to KV, with use of calibration
curve of 3-350 KVA transformers in cascade.

Test set up

Nylon rope to wire hook

Test (A)



L.S.V. KV.

70 224

71 227

71 227

71 227

70 224

Av. Uncorr. 225.8 KV.

Av. Corr. 246 KV.

BAR 30.37

D.B. 80°F

W.B. 60°F

VAR. 0.298

HUM. 1.097

RAD. 1.007

Test (B) Same as (A) except only one 9" suspension hanging
from support.

L.S.V. KV.

66 211

67 214

67 214

65 208

66 211

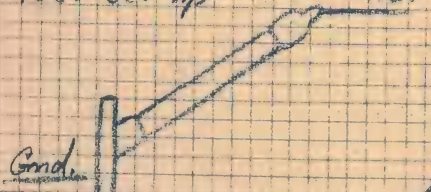
Av. Uncorr. 211.6 KV.

Av. Corr. 230.3 KV.

Test (C) Support insulator only

Test set up

Hot



L.S.V. KV.

57 182

57 182

55 176

55 176

55 176

Av. Uncorr. 178.4 KV.

Av. Corr. 194.4 KV.

TEST REQUISITION
HIGH VOLTAGE LABORATORY
INSULATOR DEPARTMENT

Nature of Tests:

MAF TESTS + OTHER
MISC

No.

7207

Date

MARCH 24, 1966

Auth.No.

Will Witness: Yes ☐ No ☒

Requested By:

RW

For

BEK

Copies To:

BEK, RW, HAF, R LESTER, B LANSBURY

Material:

32440

15,000 LB.

OB 47310

SUSPENSION

Assembly Date & Shift:

For Competitive data

MATERIAL DESCRIPTION:

Standard ☐

Developmental ☐

Other ☒

1. All units to have QC inspection before testing

TESTS REQUIRED:

Standard Tests ☐

Other Tests ☐

✓ 1. TEST 5 at 150°F (WATER)

✓ 2. TEST 5 at 0°F (AIR)

✓ 3. TEST 10 at room temp 70°F

✓ 4. TEST 5 at modified thermal load test

32 to 212°F at loading at 4500 lbs

(FOLLOWED BY

MAF TEST ✓

✓ 4a. Make deflection tests on caps of two units for comparison

✓ 5. All units to be given Quality Index Rating by QC before testing

6. Save remainder of units for other tests to be scheduled

7. Note various characteristics such as wax around cement, type of pin, coatings used, stamping on shells and other information

SPECIAL INSTRUCTIONS:

✓ 8. Save some components for shawing and metal analyses.

Entered Laboratory File

By RW

Report Number 22810

Dated 5-18-66

Signed

Weller

TEST REQUISITION
HIGH VOLTAGE LABORATORY
INSULATOR DEPARTMENTNature of Tests: *M & E*No. *7221*Date *4/25/66*

Auth.No.

Will Witness: Yes ☐ No ☒Requested By: *BEK*

For

Copies To: *RW HAF ATP BEK JK*

Assembly Date & Shift:

Material:

LS 1840

MATERIAL DESCRIPTION:

Standard ☐Developmental ☐Other ☐

- ① approx 132 ins. are @ HV Lab (in alley) from previous shipments
② 200 ins. (from most recent shipment) will be delivered to lab.

TESTS REQUIRED:

Standard Tests ☒Other Tests ☐*Please make M & E tests on:**IN ALLEY -**75 of item ①**CO. 10116**75 of item ②*

SPECIAL INSTRUCTIONS:

Entered Laboratory File

By

Report Number

Dated

Signed *BEK*

GENERAL ELECTRIC

INSULATOR DEPARTMENT

SUBJECT

- Engineering Comments
File #4412

COPIES:

Baltimore, September 25, 1961

Mailing List 9 Tab D

Subject: Tests on A. B. Chance (Porcelain Products) 15000 Lb.
Suspension Insulator #66255

We have recently completed a series of tests on the subject insulator and I thought you might like to see the results.

Physical Measurements

<u>Sample No.</u>	<u>Dry Arcing Distance</u>	<u>Leakage Distance</u>	<u>Connecting Length</u>	<u>Weight</u>
1	7 15/16	12	5 13/16	12 lb. 5 oz.
2	8	11 15/16	5 13/16	12 lb. 6 oz.
3	8 1/16	12 3/16	5 3/4	12 lb. 6 oz.

M & E and Ultimate Strength (Lbs.)

<u>Sample No.</u>	<u>M & E</u>	<u>Ultimate</u>
1	17150	20250
2	20100	24100
3	20150	25050
4	21150	22250
5	26400	26900
6	23150	23550
7	17100	21700
8	15800	20350
9	19800	21750
10	19800	24200
Average	20060	23010

INDEX FOR: DC - DIRECT CURRENT

Number	Title	Author	Company	Date
IR #429	DIRECT CURRENT TRANSMISSION	GJ Gross	Locke Ins. Corp. Baltimore, MD	May 23, 1947
53-998 IEEE	THE ELECTRICAL DESIGN OF FUTURE EHV SYSTEMS -- An Over-all View	LO Barthold EM Hunter	Elec. Utility Sys. General Electric	March 27, 1962
IEEE CP 63-1096	INSULATION REQUIREMENTS, CORONA LOSSES AND CORONA RADIO INTERFERENCE FOR HIGH VOLTAGE DIRECT CURRENT LINES	N Hylden-Cavallius S Annestrand V. Madzarevic H. Witt	ASEA, Hi Volt Lab Ludvika, Sweden	July 5, 1963
Excerpt	THE CONTI-SCAN HVDC PROJECT	G. von Geijer S. Smedsfelt L. Ahlgren	Pinneburg, WG Swedish State Power Board Stockholm, Sweden	May 9, 1963
T & D	INSULATION REQUIREMENTS, CORONA LOSSES, AND CORONA RADIO INTERFERENCE FOR HIGH VOLTAGE D-C LINES	Same as 63-998 IEEE		May 1964
	THE ROLE OF HVDC TODAY	PG Engstrom H Stackegard	ASEA, Ludvika, Sweden	Sept. 1964
Memorandum	HVDC TRANSMISSION STATUS REPORT: MARCH 15, 1965	EM Hunter	HVDC Trans Engng G.E. - Schenectady	March 15, 1965
Electrical World	DC INSULATOR SITUATIONS	HA Frey	Locke Dept. GE - Baltimore	July 12, 1965
Reprint	NEW ZEALAND INAUGURATES INTERISLAND HVDC			July 19, 1965
	EHV DC TRANSMISSION	EM Hunter GD Breuer CC Herskind	General Electric	Sept 1965
Excerpt International Science & Technology	LONG DISTANCE POWER TRANSMISSION	Uno Lamm		April 1966

INDEX FOR: DC - DIRECT CURRENT

Number	Title	Author	Company	Date
T&D 2786	UNDERGROUND DC LINK FOR LONDON			April 1966
F 76 228-7	STUDY ON THE INSULATION DESING OF OVERHEAD DC LINES	Y. Watanabe	Central Res. Inst. Elec. Power Ind. Tokyo, Japan	Sept. 2, 1975
RS-k10	BASIC PARAMETERS OF A-C and D-C CIRCUITS	Dr. Robt L. Peters	Consultant Design News	11/22 & 12/7/70

LOCHE INSULATOR CORPORATION
Baltimore Maryland

Technical Report No. 439
May 23, 1947.

Subject

DIRECT CURRENT TRANSMISSION

This report contains:

8 Typewritten Pages
4 Graphs
2 Drawings

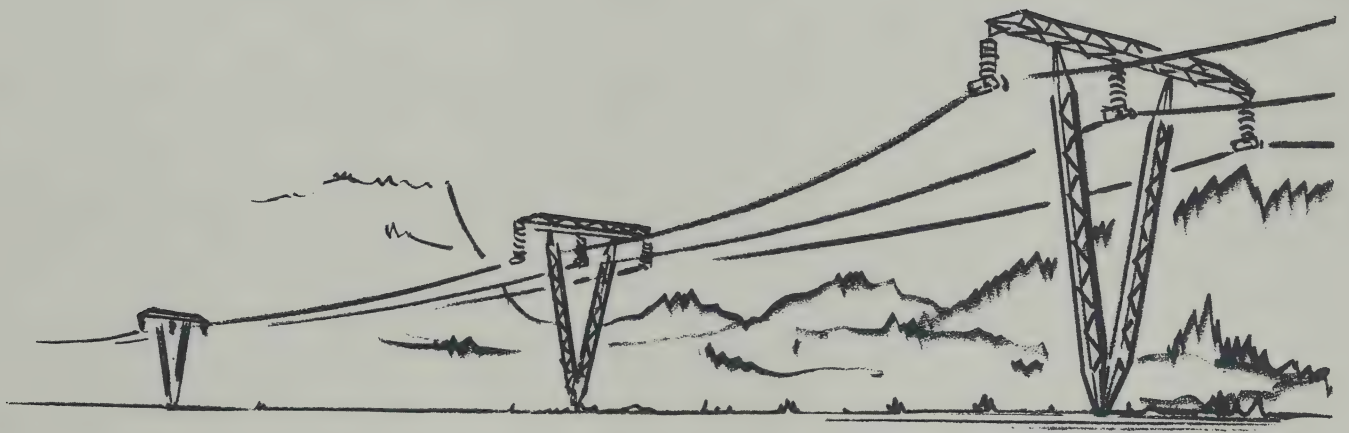
Signed

S. J. L. Hov

Approved

W. H. L. Hov

GENERAL  ELECTRIC



THE ELECTRICAL DESIGN OF FUTURE EHV SYSTEMS

L. O. BARTHOLD
E. M. HUNTER



ELECTRIC UTILITY ENGINEERING

Transactions Paper

(Reviewed and Accepted for Publication)

Discussion in Duplicate Due July 5, 1963.



INSULATION REQUIREMENTS, CORONA LOSSES AND CORONA RADIO INTERFERENCE FOR HIGH VOLTAGE DIRECT CURRENT LINES

N. Hyltén-Cavallius
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Ludvika, Sweden

A paper recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-21, 1963. Manuscript submitted March 21, 1963; made available for printing April 24, 1963.

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Litho in USA

Paper No.

63-998

Conference Paper



THE CONTI-SCAN HVDC PROJECT

G. von Geijer

S. Smedsfelt

L. Ahlgren

All of:

Swedish State Power Board
Stockholm, Sweden

Submitted in abstract or outline form only to the IEEE Substations Committee for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-21, 1963. Manuscript submitted April 23, 1963; made available for printing May 9, 1963.

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Paper No. **CP**

63-1096

Table VI. Repeatability of Readings

	Number of Samples	Difference Between Paired Readings, Db	
		Mean	Standard Deviation
Dampers	36	-1.2	4.9
Suspension Insulators with Clamps	30	-1.3	3.8
Compression Joints	6	+3.6	12.9
Dead-End Insulators with Clamps	4	-8.0	5.2
Loop Support Insulators with Clamps	6	-6.0	2.5

type requires a polarizing battery and a cathode follower. The model selected has a threshold sensitivity of 4.3 nanobars, a frequency upper limit of 20 kc, and is so insensitive to external fields that its performance is not impaired even directly under a 600-kv test line.

Tests after assembly showed that this microphone-reflector

combination gives adequate directionality, the 6-db beamwidth at 10 kc being 4.2 degrees. This directionality is sufficient to enable a skilled operator to locate a noise source 100 feet away with an accuracy of about 1 foot and to separate sources which are 3 feet apart. The sound absorption by the atmosphere is negligible at these frequencies in a 100-foot path.

The coronaphone amplifier, filter, and meter circuits, together with the necessary batteries, are housed in the box shown in Fig. 1. Transistors are used throughout the amplifier to reduce battery requirements, thereby increasing portability. Between the microphone and the first stage of the amplifier is a high-pass filter for the attenuation of the relatively large noise energies of low harmonics of 60-cycle and voice frequencies. The maximum voltage gain of the amplifier is 100,000. The effective frequency response is 10 db down at 1,500 and 20,000 cycles. The QP detector has time-constants of 1-millisecond charge time and 600-millisecond decay. An audible output is provided.

The arbitrary units quoted are based on 0 db = 2×10^{-4} microbars, when the band-pass filters and reflector have been removed from the system.

Insulation Requirements, Corona Losses, and Corona Radio Interference for High-Voltage D-C Lines

N. Hyllén-Cavallius, Member IEEE S. Annestrand H. Witt V. Madzarević

Insulation Requirements

GENERAL CONSIDERATIONS

Both a-c and d-c line insulation is stressed by lightning overvoltages, internal overvoltages, and normal operating voltage. The first two stresses impose requirements mainly on the insulator chain length, while the latter influences the choice of leakage distance, especially when pollution is considered.

For direct current, the fault clearing characteristics can be made much more effective than for alternating current by means of grid control. Further, the internal overvoltages in d-c systems are considerably lower than in a-c systems. The lower requirements on chain length thus imposed means that the insulators' capability to withstand normal operating voltage will be dimensioning in all zones of pollution. As a consequence, it may pay to use d-c insulators with especially long leakage paths even in relatively clean areas. This possible reduction of chain length is of great economic importance as, usually, the largest part of a high-voltage power line passes through clean areas.

The mechanism responsible for insulator pollution and subsequent flashovers, can be as follows. The air is contaminated with small dirt particles which become deposited on the insulator as a layer. The layer is dampened, especially during fog, and if it contains dissociable matter, it also becomes conducting. An arc may develop which dries the surface layer

and increases in length. If the leakage resistance of the entire chain is small enough, the arc will carry a large current and will grow quickly. Eventually it will flash over the entire chain if the arc grows at a quicker rate than the rate at which the chain is dried by the leakage current.

Thus, the severity of the insulator pollution depends both on the atmospheric pollution and on the amount of dissociable matter, for example, salt. (The dissociable matter may be increased by the presence of gaseous SO_2 .) But also the frequency and intensity of rain is of vital importance, as rain

Table I. Characteristic Data for Atmospheric Pollution, SO_2 Content, and Equivalent NaCl Deposit on Line Insulators in Various Districts

	Atmospheric Pollution, Mg/Cm ² */Month	SO_2 Content in Air, Parts	Equivalent NaCl Deposit on Line Insulators, Mg/Cm ²
Clean areas	0.01-0.2	10^{-8}	0.02-0.05
Industrial areas	0.2-0.8	10^{-7} - 10^{-6}	0.05-0.10
Heavily polluted areas	0.8-4	10^{-6} - 10^{-5}	0.10-0.40

* Milligrams per square centimeter.

Table II. Influence of Distance From Sea on Salt Deposit on Insulators

Distance to the Coast, m*	NaCl Deposit on Line Insulators, Mg/Cm ²
200	0.4
3,000	0.2
10,000	0.1
20,000	0.05

* Meters.

Paper 63-998, recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-21, 1963. Manuscript submitted March 21, 1963; made available for printing April 19, 1963.

N. HYLLÉN-CAVALLIUS, S. ANNESTRAND, and V. MADZAREVIĆ are with ASEA High-Voltage Laboratory, Ludvika, Sweden; H. WITT is of Pinneberg, West Germany.

The Role of HVDC Today

By **P. G. Engstrom**, Chief Engineer
and Manager and **H. Stackegard**,
Application and Project Engineer
DC Transmission Department
ASEA, Ludvika, Sweden

Editor's Note: Interest in the possibilities of high voltage dc transmission (HVDC) has been rapidly mounting in the United States and Canada. As we go to press, final Congressional approval has just been given on two 750-kv HVDC lines, connecting the Bonneville power system with Los Angeles and Hoover Dam.

Successful applications throughout the world indicate that this method of power transmission should be studied objectively, with careful analysis of the engineering

and economic factors involved in a particular case.

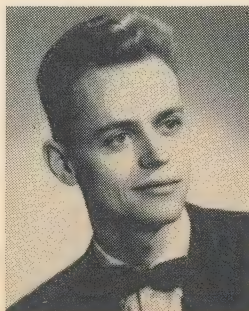
Heretofore, discussion of HVDC transmission in this country has been largely confined to comparisons of construction costs. Other factors of operating characteristics and equipment reliability must also be considered. These are discussed in this article. Additional special design considerations which are related specifically to HVDC equipment and its application will be treated in a subsequent T&D article.

The Authors . . .



Mr. P.G. Engstrom, Chief Engineer at the HVDC Department at ASEA, is a graduate of the Royal Institute of Technology, Stockholm, Sweden. He has been closely associated with the designing of control equipment used with the Gotland-mainland link as well as with the development of all equipment for d-c cable connections between French and English power grids. He is the Swedish representative to the IEC Subcommittee on Mercury-Arc Converters.

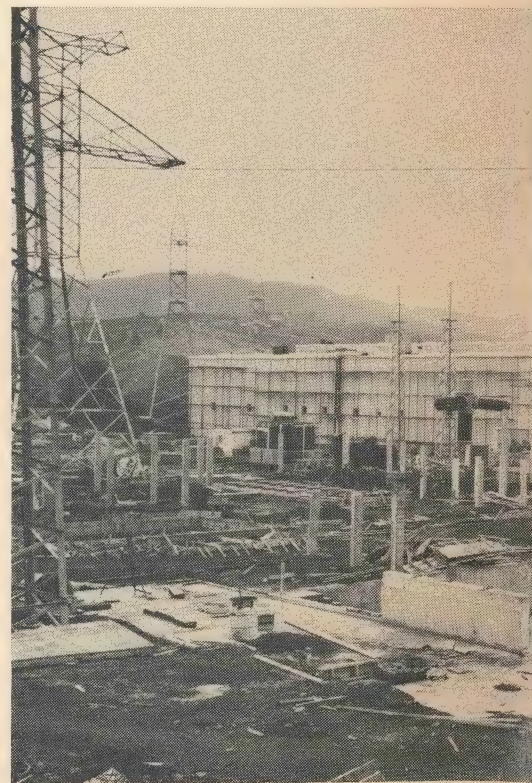
Mr. Hans Stackegard, also an electrical engineering graduate of the Royal Institute of Technology, is an application and project engineer at ASEA's HVDC Department. Prior to this he spent two years as a research engineer on saturable reactor development with the Hevi-Duty Electric Company, Milwaukee, Wisconsin.



SINCE THE FIRST long high voltage DC link connecting the island of Gotland and the Swedish mainland was commissioned ten years ago, six major HVDC projects have been undertaken in various parts of the world. Several other projects are contemplated, including two of very high capacity and length which involve power systems in North America.

The theoretical advantages of direct current for transmission have been recognized. These benefits stem primarily from the fact that the operation of the DC line is independent of line inductance and capacitance. Basic limitations on the general use of DC power systems are the impracticability of transforming direct voltage, the more efficient method of generating power at alternating current, and the difficulty of breaking direct current.

Modern use of HVDC for power transmission became practical with the development by ASEA of a high voltage mercury-



Above photo shows construction currently in progress on New Zealand's Haywards substation. The pit for the smoothing reactor can be seen in the foreground and the two valve damping resistors in the center of photo. Interior views of the sub-

HVDC TRANSMISSION

STATUS REPORT: MARCH 15, 1965

High-voltage d-c has economic application for the movement of large blocks of power from mine-mouth steam plants or remote hydro stations to load centers. It can usually be proved in where the overhead transmission distance is in excess of 400 to 600 miles or in metropolitan areas where overhead right-of-way is unattainable and cable must be used if the length exceeds 25 to 30 miles. Politics as well as engineering will play an important role in the decision for any specific undertaking. Experience has shown that it is most unwise to attempt to generalize on the break-even distance of a-c versus d-c transmission distance. Conclusions should be reached only after careful study of specific cases.

Five HVDC applications have been made by ASEA outside the Western Hemisphere (for listing, see Table I). Two are in commercial operation (Gotland and Cross Channel), and the other four are scheduled for commissioning in 1965. The New Zealand and Konti-Skan applications are particularly significant because of the dependence placed on the d-c link between the a-c networks. The operation of these systems will be followed with interest by all those having like applications.

In this part of the world, plans have finalized for an underseas link to Vancouver Island in British Columbia. ASEA is the prime contractor for the terminal equipment. Canadian General Electric will manufacture the converter transformers.

Also, congressional approval has been given to the overland d-c Pacific intertie. The Dalles-Los Angeles section is presently scheduled for operation for the fall of 1968. The second Dalles-Hoover Dam line is set for 1971. Orders for the terminal equipment and the transmission lines for this project will be placed in 1965.

As to the future pattern of growth, reference may be made to the National Power Survey Report issued on December 12, 1964, by the Federal Power Commission. Its projected 1980 transmission pattern includes the possibility of three major East-West EHV interties and another long-distance interconnection between the Northwest and Middle South, in lengths ranging up to nearly 2,000 miles and with power flows of as much as 4 million kilowatts.

The report visualizes that transmission will continue to be primarily over a-c networks but suggests that ± 500 -kv or ± 750 -kv d-c may be considered for these long-distance interconnections.

DC
AJ Pusdek
BE Kingsbury

July 12, 1965

Mr. J. Kaminski:

During a visit to Schenectady last week, Mr. Kingsbury and I spent a brief period with Gene Hunter discussing D. C. insulator situation.

You were particularly interested in contacts to make to secure the appearance performance business associated with this work. Mr. Hunter said that the General Electric representatives on the joint venture team are George Hauptman and Glen Brewer. Glen Brewer would be the man to contact concerning porcelains. G. E. already has the order on the substation equipment, so that the problem is that of determining exactly what porcelains will be required. I would, therefore, suggest that you call on or write Mr. Brewer on this matter.

Incidentally, if other information is required, Gene Matson, of Schenectady, has the complete system layouts.

The material must be on the site ready for construction by January, 1968. This includes a large number of wall bushings for 400 Kv plus and minus.

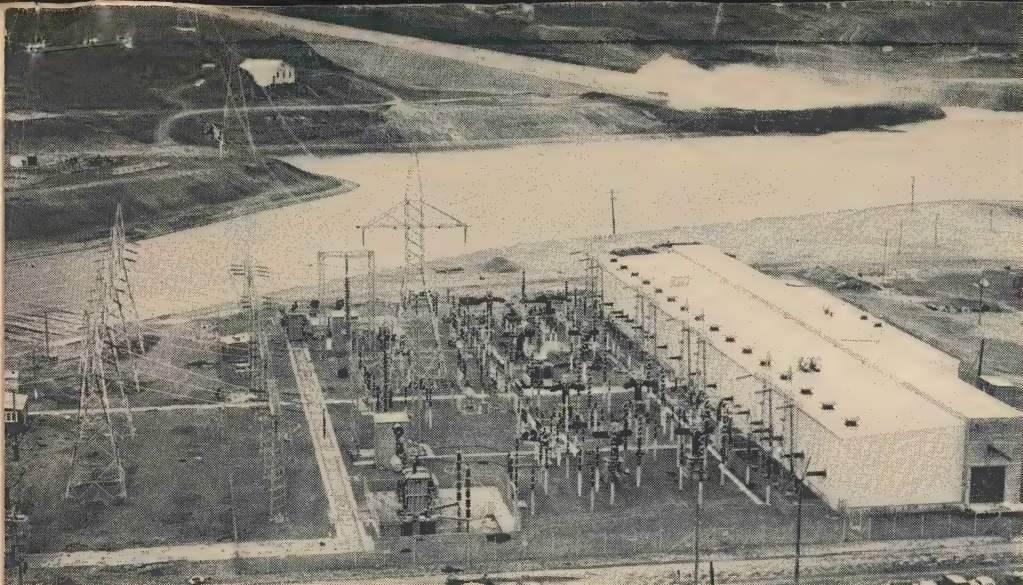
The switchyard and line insulators will be purchased by Bonneville Power (Clip Diamond is Bonneville purchasing agent). The first line will involve 830 miles and is scheduled for 1968 or sooner. The second line of about the same length is scheduled in 1970 or 1971.

Gene Hunter said that Gene Starr of Bonneville has been to Sediver, made and witnessed a number of tests on the glass insulators and is tremendously impressed by glass. This will be one obstacle that we will have to overcome. When our D. C. insulators are ready, perhaps we should get him here to counteract the Sediver influence.

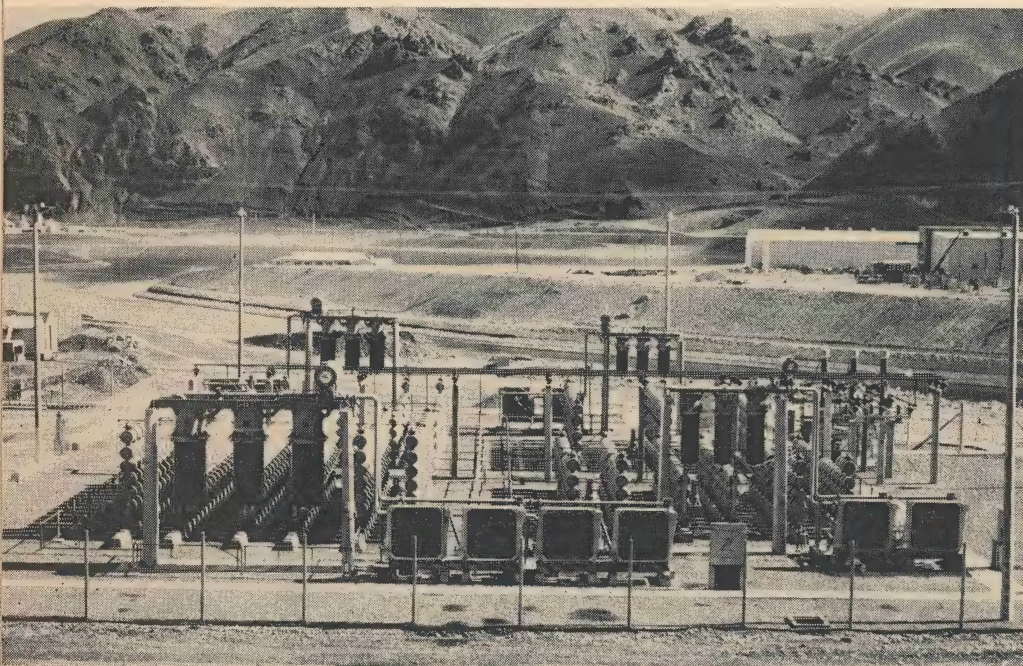
In response to specific questions concerning the most recent recommendations by ASEA on leakage distance, Mr. Hunter gave us the following information: ASEA recommended leakage distance for outdoor application at D. C.: 2.3 CM per Kv line to ground. ASEA recommended leakage distance for indoor application at D.C.: 1.4 CM per Kv line to ground.

These values are somewhat smaller than had been indicated from earlier information and Mr. Hunter indicated that this was not yet completely frozen but that complete information should be available within a few weeks.

New Zealand

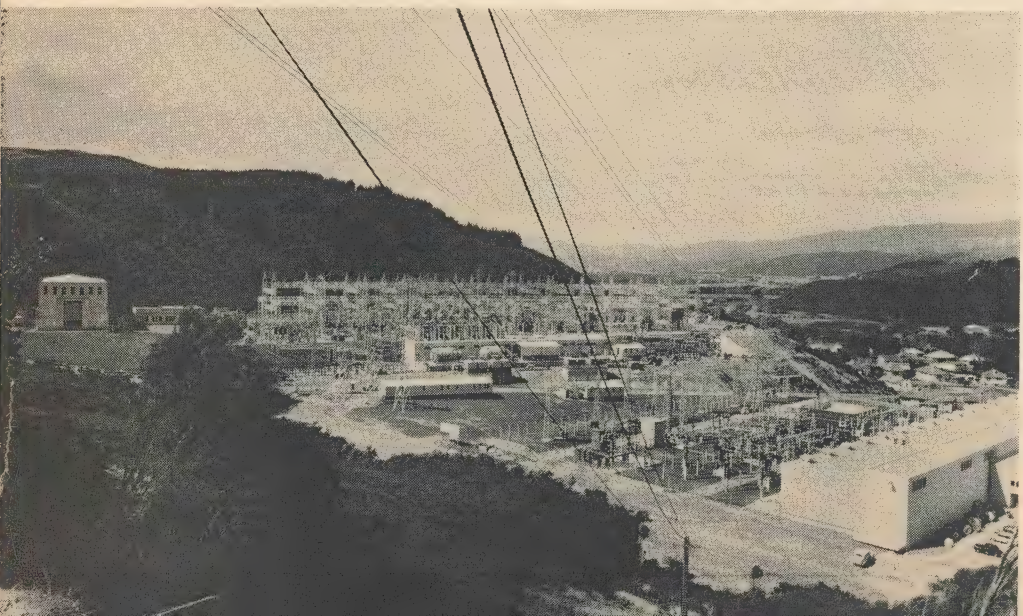


CONVERTER VALVE HOUSE, and dc switchyard at Benmore Hydro Station sends power transmitted at 500-kv dc to North Island 220-kv network



HARMONIC FILTER GROUP is shown at Benmore Ac-Dc Hydro Station which exploits South Island's hydro potential for transmission to North Island network

HAYWARDS SUBSTATION is the northern terminal of dc transmission and southernmost point on the North Island 220-kv ac system supplying city of Wellington



The 500-kv (± 250 kv to earth) dc transmission system recently put in operation at Benmore Station, South Island, places in New Zealand one of today's major advances in electric power technology. The line, now in commercial service and operating in conjunction with the submarine cables across Cook Strait (EW, March 29, 1965, p 24), has a capacity of 600 Mw.

The new line links Benmore Station with Haywards Substation. The latter is the southernmost point of North Island's 220-kv system. This project, like virtually all generation and transmission on both islands, was executed by the New Zealand Electricity Department, a government agency.

Inauguration of the line encountered some delay when a fault developed in one of the three 25-mile submarine cables spanning the water between the islands. But the fault was rectified, and the complicated project has been brought to fruition without further hitch.

Bold Step Endorsed

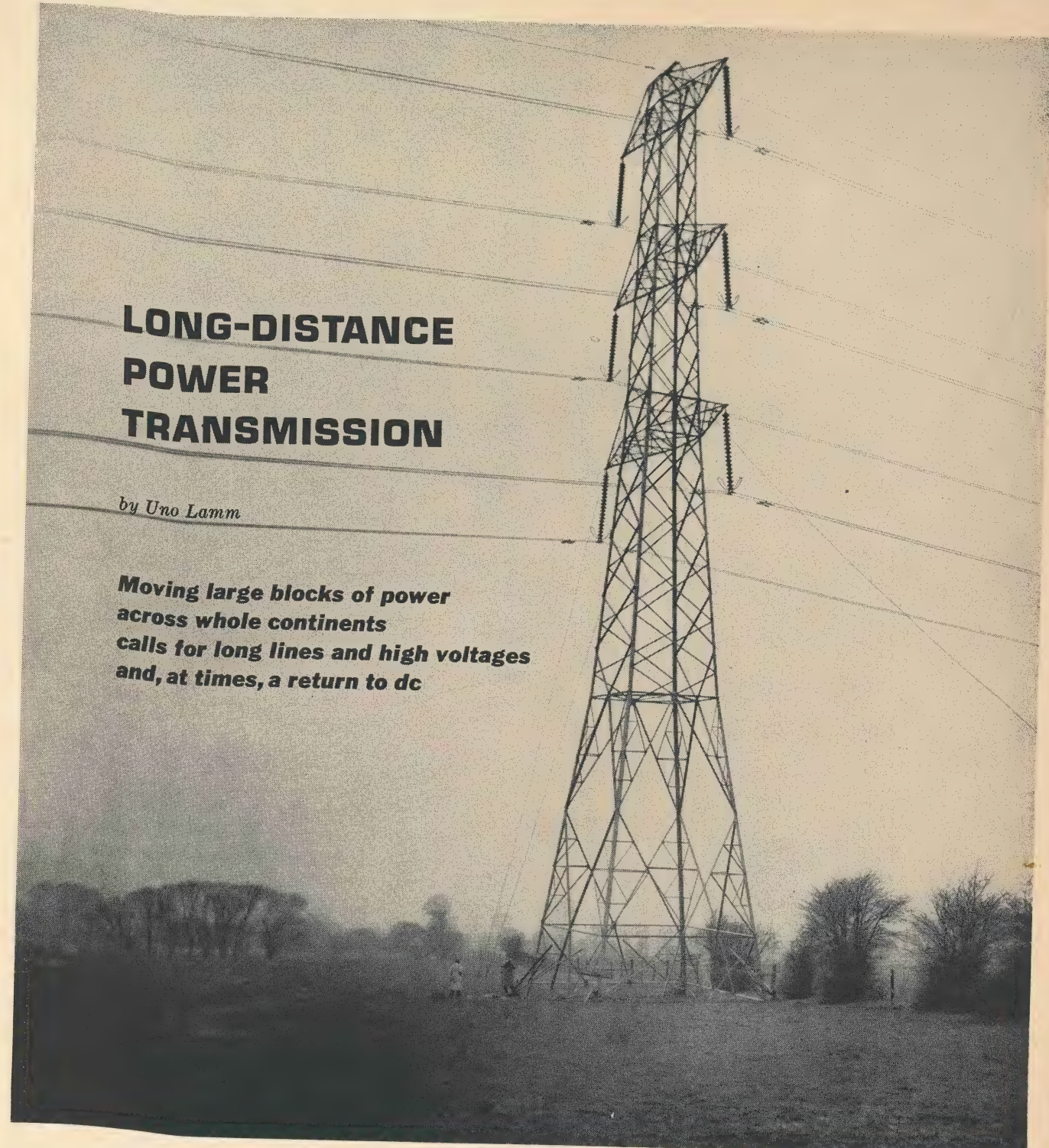
Some interference with telephone circuits and with the remote control equipment of two power supply authorities, also occurred during testing of the line. Extra temporary filtering equipment at Benmore reduced the noise to an acceptable level on South Island, but the converters at the Haywards Substation occasioned no major interference with telephone circuits on North Island.

North Island has 70% of New Zealand's population and 71% of the industry, and its last year's winter peak amounted to 1,314 Mw. Although South Island's comparable demand was only 560 Mw, it possesses far more abundant hydro-electrical sources, some so attractive technically and economically compared with North Island's remaining potential, that the country's power planner endorsed the bold step of

EHV DC TRANSMISSION

BY E. M. HUNTER, G. D. BREUER AND C. C. HERSKIND
THE GENERAL ELECTRIC COMPANY

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LONG-DISTANCE POWER TRANSMISSION

by Uno Lamm

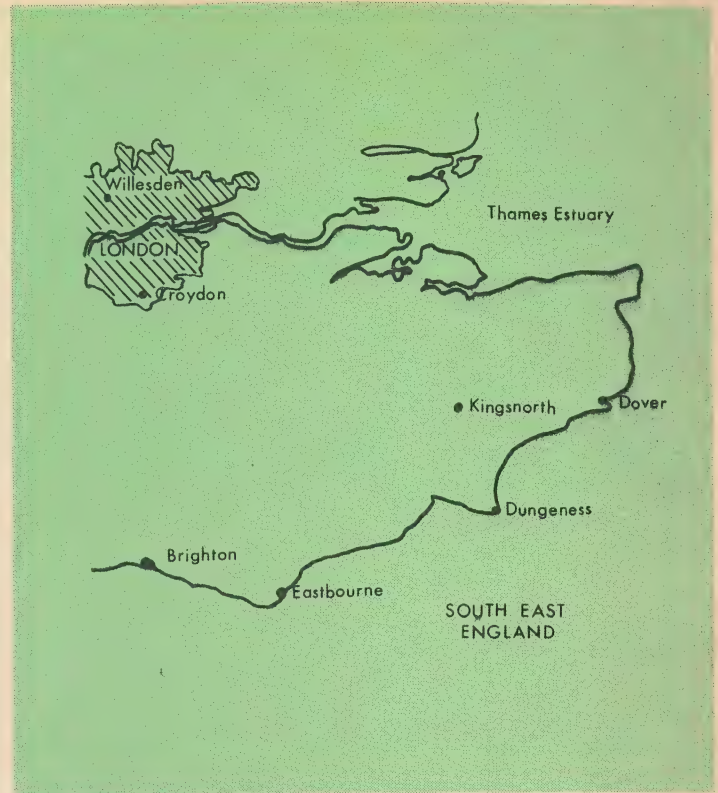
**Moving large blocks of power
across whole continents
calls for long lines and high voltages
and, at times, a return to dc**

IN BRIEF: There are many reasons for wanting to transport electric power over long distances: the desire to build power plants far from cities, the advantages of exchanging power between regions where demand occurs at different times of the day or seasons of the year, and the need to interconnect widely separated areas that have different sources of power. The key to carrying electricity over hundreds of miles, and doing it economically, is to use high voltages—a 700-kV line can carry about four

times as many watts as a 345-kV line. However, there's also the question of whether to use ac entirely or convert ac to dc for the actual transmission. Now that high-voltage convertors are practical, the latter method has been making a comeback in some of the new long-distance links. As the number of applications calling for the uninterrupted transmission of power over transcontinental distances continues to grow, you can expect that dc will play an increasingly important role.—M.F.W.

UNDERGROUND DC LINK FOR LONDON

City to have world's first
underground dc link
for metropolitan area



The world's first underground dc link for a metropolitan area, a 51-mile 266 kv transmission system is planned for London, England. A \$23 million order for electrical conversion equipment has been awarded to English Electric by Britain's Central Electricity Generating Board.

The line is scheduled to be in service by 1970. Power will be carried from a 2,000-Mw steam generating plant now under construction at Kingsnorth, in southeast England, to two points in London — first to Beddington, near Croydon 37 miles northwest of Kingsnorth, and then under the Thames to Willesden, a further 14 miles. Underground cable will be used for the entire 51-mile route. It will be the first dc power link to operate on the British mainland.

The Kingsnorth to London line will be used to move power in quantity underground into a heavily built-up area where overhead lines are out of the question. An important advantage is that dc transmission does not increase the receiving end fault level as power is added to the system. This arises from the precise and almost instantaneous control provided by the converters. The Kingsnorth-London dc link has been designed to operate as an integral part of a network and not, as in most schemes up to now, as a parallel adjunct to an existing alternating-current network.

The English Electric order covers the supply of electrical equipment for a 640-Mw converter station at Kingsnorth and similar equipment for two receiving stations. Half the power (320 Mw) will

be available at each receiving station and the flow of power into each will be separately controlled.

The design and engineering for this contract will be undertaken by English Electric's DC Transmission Division at Stafford, England, where the major part of the equipment will be built. The company is at present completing a 200-Mw dc link between Sardinia and the Italian mainland.

One positive and one negative cable at 266 kv dc to ground, together with a neutral cable, will carry the power over the 37 miles from Kingsnorth to Beddington. At Beddington, 320 Mw of power will be taken from one of these lines and the neutral. The other line and the neutral will continue 14 miles to Willesden to make another 320 Mw of power available there.

At the receiving stations the power will be fed directly into separate secondary transmission systems at 132 kv. When the receiving stations are isolated from the sending end, the dc link can be used as an interconnection for the transfer of power between south and northwest London.

The 56 4-anode mercury arc valves to be manufactured by English Electric are each rated at 133 kv, 1,200A dc in 3-phase bridge connection. At the converter stations, they will be arranged in groups of seven (six form a 3-phase bridge and one is a bypass valve); there will be four such groups at Kingsnorth (640 Mw) and two at each of the two 320 Mw receiving stations. Most of the equipment for the three converter stations will be installed indoors.

STUDY ON THE INSULATION DESIGN OF OVERHEAD DC LINES

Y. Watanabe

Central Research Institute of
Electric Power Industry
Tokyo, Japan

ABSTRACT

This paper presents the results of the study on the insulation design of overhead dc lines. Items are as follows. (1) General method of insulation design is discussed. (2) Withstand characteristics of air gaps and insulator strings for all types of voltage stresses are presented. (3) Features of the insulator string arrangements on the dc lines are discussed.

INTRODUCTION

The overhead transmission lines are subjected to stresses of various types such as the lightning overvoltages, the internal overvoltages and the operating voltage, and they are also exposed to the various meteorological conditions such as wind, rain, snow, icing and pollution. The insulations should be maintained as possible under these various situations. However, it has been generally recognized that it is uneconomical to design to withstand the most severe voltage stress under the most severe meteorological condition.

For the ac lines, the simple and convenient insulation design method, in which the combination probabilities of electrical and meteorological events are roughly considered, has been developed. As the basic concept of the insulation design of the dc lines is as same as that of the ac lines, the similar method is applied on the dc lines. Same concept has been already proposed in ref. 1.

The types of voltage stresses induced on the dc lines are different from those induced on the ac lines. Therefore, it is necessary to investigate the withstand characteristics of air gaps and insulator strings for the voltage stresses of the dc lines.

This paper presents the concept of the insulation design of the dc lines and the necessary withstand characteristics.

GENERAL CONCEPT OF INSULATION DESIGN

In the ac practice, the line insulations are generally decided by the requirements of the operating voltage and the internal overvoltages. Against the lightning, the countermeasure such as setting of ground wires or reducing tower foot resistance are considered to reduce the outage rate. Especially when the more reduction of the outage rate is necessary, the line insulations will be decided by the lightning requirement. According to this concept, lightning outages are induced frequently, while the other outages are restrained to the small frequency. The sensitivity of the insulation level to the lightning outage rate is far duller than those to other outage rates. In other words, while the lightning outage rate is not affected large-

ly by the insulation level, other outage rates are sensibly affected. Therefore, it is necessary for safety that other outage rates are controlled to smaller level than the lightning outage rate. The estimation of the lightning outages can be made by the method used for the ac lines. In this paper, the operating voltage and the internal overvoltages are generally discussed.

The internal overvoltages induced on the dc lines are classified to three types such as a switching impulse type, an ac type and a dc type. The characteristics of important overvoltages of each type

Table 1 Overvoltages on the dc lines

Cause	Builtup time (ms)	Crest voltage (p.u.)	Type
Induction to healthy poles when one pole grounding.	0.3~1	1.5~2.0	Switching impulse
Misfire of one or more value	Basic frequency	1.0~2.0	ac
Start with an open end.	2~20	1.5~2.3	dc

are shown in Table 1^{2,3}. The switching impulse type is a damped oscillation wave with the relatively steep front. The ac type is a basic frequency ac wave superposed on a dc wave. The dc type is a unilateral wave with a long front and a long tail.

The insulation design is made in accordance with several basic insulations, which are "String Length", "Horn space", "Strong Wind Space", "Middle Wind Space" and "Normal Space". Latter three spaces are tower spaces. These basic insulations are the minimum insulations maintained under certain conditions.

"String Length" is decided by the withstand characteristics of the strings contaminated with salt, snow, etc. for the dc operating voltage. The most severe overvoltage to the contaminated string is the dc type overvoltage, but its frequency is very small, so that the probability of the simultaneous occurrence with the severe contamination is negligible. The contamination withstands for other overvoltage are more than 2.6 times that for the dc voltage, while the overvoltage factors are 2.3 p.u. at most. Therefore, the internal overvoltages are not important to "String Length".

"Horn Space" is decided by the internal overvoltages. As the horn spaces are always constant, it is necessary to be correspond to the high withstand probability. However, only the dc type overvoltage is corresponded to the lower withstand probability than other overvoltages, because the dc type overvoltage is induced less frequently than other overvoltages. As discussed later, "Horn Space" is not important to the dc lines, because the required insulator string lengths is larger than the required air spaces. Therefore, the actual horn spaces will be decided almost freely.

F 76 228-7. A paper recommended by the IEEE Transmission and Distribution Committee of the IEEE Power Engineering Society for presentation at the IEEE PES Winter Meeting & Tesla Symposium, New York, N.Y., January 25-30, 1976. Manuscript submitted September 2, 1975; made available for printing December 9, 1975.

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RS K10

Basic Parameters Of A-C and D-C Circuits

DR. ROBERT L. PETERS,
Consultant, New York, N.Y.

This nomograph provides a simple method of establishing and relating the basic parameters of both a-c and d-c circuits. It provides nomographic relations of the fundamental parameters allowing rapid comparison of equivalent alternating and direct current circuits in terms of basic functions. For a-c, this graph relates power, apparent power, phase angle, current, voltage and impedance or reactance. For d-c circuits, it relates power, current, voltage and resistance.

With either a-c or d-c, the current can be considered as electronic drift or flow. The force that produces this flow, the electromotive force, is measured as the potential between two points. This potential, or voltage, which tends to produce current or electron movement, can be expressed in electrostatic units but is more commonly expressed in voltage. A volt is the potential that produces a current of 1 amp through a resistance of 1 ohm.

Resistance is the capacity of resisting electron flow. It is the effective force of retardation of current, measured in ohms. An ohm is the resistance that causes a potential drop of 1v in a current of 1 amp. Resistance is the reciprocal of conductance.

Impedance, the vectorial addition of resistance and reactance, is the tendency to impede the flow of an alternating current. Reactance, either inductive or capacitive, is the resistance to react to a sinusoidal current. It is the imaginary part of electrical impedance. The reactance varies with the frequency of the current. Its reciprocal is admittance.

Power, the time rate of transforming energy, (commonly measured in watts, kilowatts or horsepower) is directly proportional to both the voltage and current. A watt is the power expended in 1 joule in 1 second or 10,000,000 ergs in 1 second. An erg is the work accomplished by a force of 1 dyne exerted through 1 cm.

Active power is the time average of instantaneous a-c power:

$$P = EI \cos\phi \quad (1)$$

Apparent power is the a-c product of voltage times current:

$$P' = EI \quad (2)$$

The power factor is the ratio of active

power to apparent power:

$$P_f = P/P' = \cos\phi \quad (3)$$

Power loss may be determined by the reactive power, measured in vars (volt-ampere reactive) and is the product of the reactive current times the effective voltage. This may be equated:

$$P_q = EI_q = EI \sin\phi \quad (4)$$

The reactive current, I_q , sometimes referred to as wattless current or quadrature current, contributes to power losses without contributing usable power. This current can be equated:

$$I_q = I \sin\phi \quad (5)$$

To minimize I^2R losses, the phase angle can be reduced to its lowest value consistent with other circuit requirements. A phase angle of zero produces no reactive current.

The active current may be considered as the current divided by the cosine of the phase angle while the effective resistance may be equated as the actual resistance divided by the efficiency.

TO USE THE NOMOGRAPH:

D-C CIRCUITS:

To Determine the Power:

1) Extracting the decimals, select two of the following:

- The resistance on the left line
- The current on the right line
- The voltage on the line at center

2) Align these values to intersect the power on the line second from right. Restore the decimal notation as indicated.

To Determine the Resistance:

1) Extracting the decimals, select two of the following:

- The current on the right line
- The power on the next line
- The voltage on the line at center

2) Align these values to intersect the resistance on the left line. Restore the decimals as indicated.

To Determine the Voltage:

1) Extracting the decimals, select two of the following:

- The current on the right line
- The power on the next line
- The resistance on the left line

2) Align these values to intersect the voltage at center. Restore the decimals as indicated.

To Determine the Current:

1) Extracting the decimals, select two of the following:

- The resistance on the left line
- The power on the line second from right
- The voltage on the centerline

2) Align these values to intersect the current at right. Restore the decimals as indicated.

Example:

What is the power when the current is 2 amps and the resistance is 5 ohms?

Conference Paper



ELECTROSTATICALLY INDUCED VOLTAGES AND CURRENTS ON CONDUCTING OBJECTS UNDER EHV TRANSMISSION LINES

J. D. Tranen

G. L. Wilson
Member IEEE

Both of:
Massachusetts Institute of Technology
Department of Electrical Engineering
Cambridge, Mass.

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CONSTRUCTION ASPECTS OF THE PINARD-HANMER 500 KV TRANSMISSION LINE

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Senior Member IEEE

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A paper recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Department for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-21, 1963. Manuscript submitted March 18, 1963; made available for printing April 24, 1963.

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ENGINEERING DESIGN FEATURES OF THE PINARD-HANMER 500 KV TRANSMISSION LINE

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Conference Paper



OVERVOLTAGES ON ONTARIO HYDRO'S 500 KV SYSTEM AND THEIR EFFECT ON SYSTEM DESIGN

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APPLICATION OF NEW CONCEPTS TO 500-KV SYSTEM INSULATION COORDINATION

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Paper No.

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District Conference Paper



A REVIEW OF ELECTRICAL DESIGN FACTORS FOR EHV TRANSMISSION

H. R. Stewart
Fellow IEEE
New England Electric System
Boston, Mass.

Submitted in abstract or outline form only to the IEEE Transmission and Distribution Committee for presentation at the IEEE Northeastern District Meeting, Portsmouth, N. H., May 20-22, 1963. Manuscript submitted February 20, 1963; made available for printing March 15, 1963.

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ed. J. Kaminski!
Ref. 1000

District Conference Paper



OPTIMIZED EHV TRANSMISSION LINE CONSTRUCTION

F. A. DENBROCK
MEMBER IEEE

Commonwealth Associates Inc.
Jackson, Michigan

A PAPER FOR PRESENTATION AT THE
IEEE GREAT LAKES DISTRICT MEETING
DAVENPORT, IOWA
May 1, 2 and 3, 1963

Conference Paper



ARC CHARACTERISTICS OF INSULATOR STRINGS FOR EHV TRANSMISSION LINES

Y. Ozaki

Central Research Institute of Electric Power Industry
Tokyo, Japan

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CP 61-634	POLE TOP DESIGN FOR 23 KV DISTRIBUTION	SR Gilligan, Jr	Hartford Elec Lt Wethersfield, CT	March 20, 1960

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IMPROVEMENT OF ELECTRIC SERVICE PERFORMANCE PART II. SELECTIVE MODERNIZATION OF DISTRIBUTION	JE Weed RK Moore NN Smeloff	PA Power & Lt. Allentown, PA AIEE Member	April 12, 1961
IMPROVEMENT OF ELECTRIC SERVICE PERFORMANCE PART III. GREATER PROTECTION AND AUTOMATION OF DISTRIBUTION	JE Treweek RK Moore NN Smeloff	PA Power & Lt Allentown, PA AIEE Member	April 12, 1961
VOLTAGE NOMENCLATURE-SECONDARY AND UTILIZATION SYSTEMS ENGINEERING AND APPLICATION PRINCIPLES FOR ESTIMATING DISTRIBUTION TRANSFORMER LAODS BY THE LOAD FACTOR METHOD	AS Anderson CF Mitchell	Ebasco Services, Inc RTE Corporation Waukesha, Wisc.	April 14, 1961 Feb. 16. 1962
ECONOMICS OF CONVERTING A DISTRIBUTION SYSTEM FROM 5 KV DELTA TO 13.2 KV WYE	RM Decker WA Wickes	Cleveland Elec I11 Cleveland, OH	March 14, 1962
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SIMPLIFIED CALCULATION OF ZERO-SEQUENCE IMPEDANCE OF DISTRIBUTION LINES	LW Long	Duke Power Co. Charlotte, NC	Feb. 21. 1963

May 1951
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ECONOMIC PRIMARY CIRCUIT DESIGN BENEFICIALLY STUDIED BY UNIT SYSTEM

D. K. Blake
Member AIEE
General Electric Company
Schenectady, N. Y.

Advance Copy
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DISTRIBUTION-SUBSTATION AND PRIMARY-FEEDER PLANNING

W. J. Denton
Associate Member AIEE
Westinghouse Electric Corp.
Des Moines, Iowa

D. N. Reys
Associate Member AIEE
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Dexter Spleen

Transactions Paper

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OPERATING EXPERIENCE WITH 14.4/24.9 KV AS A RURAL DISTRIBUTION VOLTAGE

W. M. Edmunds
Member AIEE

L. B. Crann
Associate Member AIEE

Both of:
Rural Electrification Administration
Washington, D. C.

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OVERHEAD DISTRIBUTION AT 4.16 KV AND 12.47 KV IN URBAN AREAS

J. R. Oberholtzer
Member AIEE

F. E. Sanford
Fellow AIEE

Both of:
Commonwealth Associates, Inc.
Jackson, Mich.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 20, 1955; made available for printing December 12, 1955.

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OVERHEAD DISTRIBUTION AT 4.16 KV AND 12.47 KV IN URBAN AREAS

J. R. Oberholtzer
Member AIEE

F. E. Sanford
Fellow AIEE

Both of:
Commonwealth Associates, Inc.
Jackson, Mich.

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*Distribution
Systems*



IMPROVE EXISTING 4 KV EXPAND AT 12 KV

G. A. Davis
Member AIEE
Planning Engineer
Southern California Edison Co.
Los Angeles, Calif.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 21, 1955; made available for printing December 6, 1955.

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IS CONVERSION TO HIGHER DISTRIBUTION VOLTAGE JUSTIFIED?

H. G. Dallas
Associate Member AIEE

J. W. Gallagher
Associate Member AIEE

Both of:
Philadelphia Electric Co.
Philadelphia, Pa.

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USE OF DISTRIBUTION VOLTAGES ABOVE 4 KV

E. V. Sayles
Fellow AIEE
Consumers Power Company
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A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 26, 1955; made available for printing December 12, 1955.

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USE OF DISTRIBUTION VOLTAGES ABOVE 4 KV

E. V. Sayles
Fellow AIEE
Consumers Power Company
Jackson, Mich.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 26, 1955; made available for printing December 12, 1955.

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RESIDENTIAL DISTRIBUTION -- AN ANALYSIS OF SYSTEMS TO SERVE EXPANDING LOADS

S. B. Griscom
Fellow AIEE

R. F. Lawrence
Member AIEE

Both of:
Westinghouse Electric Corp.
East Pittsburgh, Pa.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 24, 1955; made available for printing December 12, 1955.

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THE PRIMARY SERVICE UNIT SYSTEM FOR RESIDENTIAL DISTRIBUTION

A. M. Lockie
Member AIEE
Westinghouse Electric Corp.
Sharon, Pa.

H. B. Thacker
Member AIEE
Westinghouse Electric Corp.
East Pittsburgh, Pa.

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W. R. Bullard

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H. A. FREY

GENERAL PURPOSE OVERHEAD DISTRIBUTION ABOVE 5,000 VOLTS IN URBAN AREAS

W. R. Bullard
Fellow AIEE
Ebasco Services, Inc.
New York, N. Y.

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THE ECONIMICS OF SUBTRANSMISSION PLANNING

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DISTRIBUTION TRANSFORMER LOAD MANAGEMENT

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Member AIEE
Westinghouse Electric Corp.
East Pittsburgh, Pa.

A. M. Lockie
Member AIEE
Westinghouse Electric Corp.
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H. A. FREY

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DISTRIBUTION SYSTEM PRIMARY-FEEDER VOLTAGE CONTROL

PART IV. A SUPPLEMENTARY COMPUTER PROGRAM FOR MAIN-CIRCUIT ANALYSIS

D. N. Reys
Member AIEE

R. F. Cook
Associate Member AIEE

Both of:
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PRACTICAL APPLICATIONS OF DIGITAL COMPUTERS TO DISTRIBUTION SYSTEMS

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Edward L. Busby
Associate Member AIEE

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Dallas, Texas

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DETERMINATION OF ECONOMICAL DISTRIBUTION SUBSTATION SIZE

J. A. Smith
Member AIEE
General Electric Company
Schenectady, N. Y.

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ECONOMICS OF PRIMARY DISTRIBUTION VOLTAGES OF 4.16 THROUGH 34.5 KV

J. A. Smith
Member AIEE
General Electric Company
Schenectady, N. Y.

A paper recommended by the AIEE Transmission and Distribution Committee for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 19-24, 1960. Manuscript submitted March 14, 1960; made available for printing April 27, 1960..

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THE INFLUENCE OF TRANSMISSION ON DISTRIBUTION SYSTEM COST

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Member AIEE

J. E. McNabb
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Both of:
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East Pittsburgh, Pa.

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DISTRIBUTION SYSTEM PLANNING THROUGH OPTIMIZED DESIGN PART III. CHOICE OF VOLTAGE-REGULATION POINT IN THE SYSTEM

R. F. Lawrence
Member AIEE

D. N. Reps
Member AIEE

A. D. Patton
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All of:
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CORRELATION OF RADIAL DISTRIBUTION FEEDER REGULATION VARIABLES AND DETERMINATION OF REGULATOR VOLTAGE CONTROL LIMITS

C. J. Couy
Member AIEE
Duquesne Light Co.
McKeesport, Pa.

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SINGLE-PHASE, SINGLE-WIRE TRANSMISSION FOR RURAL ELECTRIFICATION

R. W. Atkinson
Fellow AIEE

R. K. Garg
Associate Member AIEE

Both of:
Bihar Institute of Technology
P. O. Sindri Institute
Dhanbad (Bihar), India

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DISTRIBUTION SYSTEM PLANNING FOR GROWTH

PART I. SECONDARY SYSTEM PROGRAM DEVELOPMENT

M. W. Gangel
Associate Member AIEE

R. C. Ender
Member AIEE

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General Electric Co.
Schenectady, N. Y.

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H. A. FREY

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ANALYSIS OF FEEDER SERVICE CONTINUITY

J. E. McNabb
Associate Member AIEE
Westinghouse Electric Corp.
East Pittsburgh, Pa.

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H. A. FREY

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Transactions Paper

(Reviewed and Accepted for Publication)

A
E E
I

USE OF 34.5 KV SUPPLY TO REDUCE 4.16 AND 12.47 KV

DISTRIBUTION SYSTEM INVESTMENT

Robert H. Sarikas
Associate Member AIEE
Illinois Power Co.
Decatur, Ill.

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G. M. JOYD

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G. M. BOYD

POLE TOP DESIGN FOR 23 KV DISTRIBUTION

S. R. Gilligan, Jr.
Member AIEE
The Hartford Electric Light Co.
Wethersfield, Conn.

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H. A. EREY.

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Conference Paper



IMPROVEMENT OF ELECTRIC SERVICE PERFORMANCE

PART II. SELECTIVE MODERNIZATION OF DISTRIBUTION

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Allentown, Pa.

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VOLTAGE NOMENCLATURE-SECONDARY AND UTILIZATION SYSTEMS

A. S. Anderson
Fellow AIEE
Ebasco Services, Inc.
New York, N.Y.

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ENGINEERING AND APPLICATION PRINCIPLES FOR ESTIMATING
DISTRIBUTION TRANSFORMER LOADS BY THE LOAD FACTOR METHOD

C. F. Mitchell
Member AIEE
RTE Corporation
Waukesha, Wis.

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H. A. FREY.

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ECONOMICS OF CONVERTING A DISTRIBUTION SYSTEM

FROM 5 KV DELTA TO 13.2 KV WYE

R. M. Decker
Associate Member AIEE

W. A. Wickes
Associate Member AIEE

Both of:
The Cleveland Electric Illuminating Co.
Cleveland, Ohio

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VOLTAGE REGULATION OF A NEW POWER SYSTEM INTERCONNECTION

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R. B. Killen
Member AIEE

Both of:
The Dayton Power and Light Co.
Dayton, Ohio

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PLANNING FUTURE DEVELOPMENT OF DISTRIBUTION SUBSTATIONS IN THE TWIN CITIES AREA

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Northern States Power Co.
Minneapolis, Minn.

G. W. Alexander
Member AIEE
General Electric Co.
Minneapolis, Minn.

J. A. Smith
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Conference Paper



SIMPLIFIED CALCULATION OF ZERO-SEQUENCE IMPEDANCE OF DISTRIBUTION LINES

L. W. Long
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Duke Power Company
Charlotte, N. C.

A paper recommended by the IEEE Transmission and Distribution Committee for presentation at the IEEE Region 3 Meeting, Richmond, Va., April 24-26, 1963. Manuscript submitted February 13, 1963; made available for printing February 21, 1963.

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Transactions Paper

(Reviewed and Accepted for Publication)



SHIELDING 13.8 KV DISTRIBUTION CIRCUITS

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M. G. West
Nonmember AIEE

Both of:
New Orleans Public Service Inc.
New Orleans, La.

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RADIO INFLUENCE FROM HIGH-VOLTAGE CORONA

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DESERT MEASUREMENTS OF CORONA LOSS ON CONDUCTORS FOR OPERATION ABOVE 230 KV

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CORONA INVESTIGATION ON EXTRA-HIGH-VOLTAGE LINES --
500-KV TEST PROJECT OF THE AMERICAN GAS AND ELECTRIC COMPANY

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ANALYSIS OF TOTAL AND INCREMENTAL LOSSES IN TRANSMISSION SYSTEMS

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LINE INSULATOR LOSS UNDER NORMAL CONDITIONS —

500-KV TEST PROJECT OF THE AMERICAN GAS AND ELECTRIC COMPANY

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THE MECHANISM OF CORONA ON A-C TRANSMISSION LINES

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IMPULSE CORONA -- DETECTION, MEASUREMENT OF INTENSITY AND DAMAGE PRODUCED

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CORONA STUDIES -- IN RELATION TO INSULATION

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EFFECTS OF CORONA ON TRAVELING WAVES

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FIELD STUDIES OF NOISE AT TELEVISION FREQUENCIES FROM POWER CIRCUITS

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VARIATIONS IN RADIO AND TELEVISION INTERFERENCE FROM TRANSMISSION LINES

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CONSIDERATIONS IN SPECIFYING CORONA TESTS

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THE FRENCH 380 KV SYSTEM

MEASUREMENT OF CORONA LOSSES ON TRANSMISSION LINES UNDER NORMAL OPERATING CONDITIONS

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CORONA LOSS MEASUREMENTS ON BUNDLE CONDUCTORS -

500-KV TEST PROJECT OF AG&E

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DEVELOPMENT OF CORONA SHIELDS FOR SUSPENSION ASSEMBLIES OF BUNDLED CONDUCTOR TRANSMISSION LINES

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Discussion in Duplicate Due February 19, 1958.

Transactions Paper

(Reviewed and Accepted for Publication)



DEVELOPMENT OF CORONA SHIELDS FOR SUSPENSION ASSEMBLIES OF BUNDLED CONDUCTOR TRANSMISSION LINES

J. Kaminski, Jr.
Member AIEE
General Electric Co.
Baltimore, Md.

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., February 2-7, 1958. Manuscript submitted October 14, 1957; made available for printing November 7, 1957.

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Transactions Paper *Coron*

(Reviewed and Accepted for Publication)



RADIO NOISE PROPAGATION AND ATTENUATION TESTS ON BONNEVILLE POWER ADMINISTRATION McNARY-ROSS 345 KV LINE

G. E. Adams
Associate Member AIEE
General Electric Company
Schenectady, N. Y.

T. W. Liao
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Spokane, Wash.

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Whitell
"Kingsbury"

Transactions Paper

(Reviewed and Accepted for Publication)

Carson



DEVELOPMENT OF A SQUARE LAW RADIO NOISE METER - I

F. J. Trebby
Member AIEE

Kaiser Aluminum & Chemical Corp
Spokane, Wash.

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JAN 5 1959

H. A. FREY

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Corona



A CORRELATION OF THE PRESENT WITH A PROPOSED STANDARD METHOD FOR RIV MEASUREMENTS ON HIGH VOLTAGE DEVICES

Charles J. Miller, Jr.
Fellow AIEE
The Ohio Brass Company
Barberton, Ohio

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W. A. FREY

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Corona



THE EFFECT OF RAIN ON R.I.V. CHARACTERISTICS OF HIGH VOLTAGE SUSPENSION ASSEMBLIES

J. Kaminski
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Baltimore, Md.

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., February 1-6, 1959. Manuscript submitted November 3, 1958; made available for printing December 3, 1958.

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(Reviewed and Accepted for Publication)

Carona



THE EFFECT OF RAIN ON R.I.V. CHARACTERISTICS OF HIGH VOLTAGE SUSPENSION ASSEMBLIES

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Baltimore, Md.

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Member AIEE

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Baltimore, Md.

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Paper No.

59-94

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~~M. Stone~~
" ~~Kaminski~~
" ~~Weller~~
" ~~Kingsbury~~
~~Plonitum~~
HAF

Transactions Paper

Corona

(Reviewed and Accepted for Publication)



WAVE PROPAGATION ALONG UNBALANCED HIGH VOLTAGE TRANSMISSION LINES

G. E. Adams
Associate Member AIEE
General Electric Company
Schenectady, N. Y.

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(Reviewed and Accepted for Publication)



RELATIONSHIP BETWEEN CORONA AND RADIO NOISE ON TRANSMISSION LINES

PART II. CONDUCTOR AND INSULATOR CORONA

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Member AIEE

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Both of:
General Electric Company
Pittsfield, Mass.

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H. A. FREY

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Corona
Transactions Paper

(Reviewed and Accepted for Publication)

H. A. FREY



DEVELOPMENT OF A SQUARE LAW RADIO NOISE METER - II

F. J. Trebby

Member AIEE

Kaiser Aluminum & Chemical Corp.
Spokane, Wash.

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Transactions Paper

(Reviewed and Accepted for Publication)

Mr. Von
Carson



THE ELECTRIC STRESS GRADING OF INSULATOR STRINGS AND THEIR RADIO INFLUENCE VOLTAGES

A. S. Denholm
Associate Member AIEE
National Research Council
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A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31-February 5, 1960. Manuscript submitted October 23, 1959; made available for printing December 2, 1959.

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THE CALCULATION OF ATTENUATION CONSTANTS FOR RADIO NOISE ANALYSIS OF OVERHEAD LINES

G. E. Adams
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Member AIEE
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Schenectady, N. Y.

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 19-24, 1960. Manuscript submitted March 14, 1960; made available for printing April 27, 1960.

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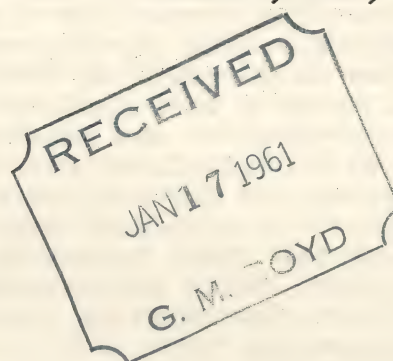
Transactions Paper

(Reviewed and Accepted for Publication)

A
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I

INSTRUMENTATION FOR POWER LOSS AND METEOROLOGICAL MEASUREMENTS AT THE ONTARIO HYDRO COLDWATER PROJECT

J. M. Vanderleck
Member AIEE
The Hydro-Electric Power Commission of Ontario
Toronto, Ont., Canada



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H. A. FREY

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THE SPECTRUM OF CORONA NOISE NEAR A POWER TRANSMISSION LINE

Carl W. Helstrom
Nonmember AIEE
Westinghouse Electric Corp.
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Corona - RW

Transactions Paper

(Reviewed and Accepted for Publication)



✓

RADIO INFLUENCE TESTING ON 70 MILES OF 345 KV HORIZONTAL BUNDLE CONDUCTOR

R. E. Graham
Associate Member AIEE

C. R. Bond
Associate Member AIEE

Both of:
Ohio Edison Co.
Akron, Ohio

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SEP 12 1961
H. A. EREY

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Conference Paper



SELECTION OF SINGLE AND BUNDLE CONDUCTORS AND ACCESSORIES FOR ACCEPTABLE RADIO NOISE PERFORMANCE

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Pittsfield, Mass.

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Corona

Transactions Paper

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LEADVILLE HIGH ALTITUDE EHV TEST PROJECT SINGLE CONDUCTOR TESTS

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Denver, Colo.

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A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Summer General Meeting, Denver, Colo., June 17-22, 1962. Manuscript submitted March 21, 1962; made available for printing May 1, 1962.

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A
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I

LEADVILLE HIGH ALTITUDE EHV TEST PROJECT SINGLE CONDUCTOR TESTS

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AN INVESTIGATION OF RADIO INFLUENCE VOLTAGES ON TRANSMISSION AND DISTRIBUTION LINES ON THE SAME RIGHT-OF-WAY

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Member AIEE
The Detroit Edison Co.
Detroit, Mich.

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Chicago, Ill.

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H. A. FREY

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Paper No.

62-1367

Discussion in Duplicate Due October 26, 1962.

~~Mr. Stone~~
~~Mr. Kanarish~~
~~Mr. Kergelung~~

Corona

Conference Paper



METHOD OF EVALUATING CORONA NOISE GENERATION FROM MEASUREMENTS ON SHORT TEST LINES

M. C. Perz
Associate Member AIEE
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Toronto, Ont., Canada

A paper recommended by the AIEE Transmission and Distribution Committee for presentation at the AIEE Fall General Meeting, Chicago, Ill., October 7-12, 1962. Manuscript submitted June 13, 1962; made available for printing August 15, 1962.

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I·E·E·E

RADIO INTERFERENCE FROM HIGH VOLTAGE LINES

PART II. DISTRIBUTION AND CORRELATION

R. J. Mather
Senior Member IEEE
Federal Power Commission
Washington, D. C.

B. M. Bailey
Member IEEE
U. S. Dept. of the Interior
Bonneville Power Administration
Portland, Oregon

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the Winter General Meeting, New York, N. Y., January 27-February 1, 1963. Manuscript submitted April 17, 1962; made available for printing November 20, 1962.

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WEATHER, CORONA AND THE DECAY OF TRAPPED ENERGY ON TRANSMISSION LINES

J. E. Beehler
Senior Member IEEE
American Electric Power Service Corp.
New York, N. Y.

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ALTERNATING CURRENT CORONA IN FOUL WEATHER

PART I. ABOVE FREEZING POINT

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Senior Member IEEE

B. J. Jakubczyk

Both of:
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Faculté des Sciences
Quebec, Canada

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Paper No.

64-51

Conference Paper



CORONA CHARACTERISTICS OF HELICALLY FORMED ALUMINUM ALLOY ARMOR RODS

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Submitted in abstract or outline form only to the
IEEE Transmission and Distribution Committee for
presentation at the IEEE Winter Power Meeting,
New York, N. Y., February 2-7, 1964.

Conference Paper



CORONA CHARACTERISTICS OF HELICALLY FORMED ALUMINUM ALLOY ARMOR RODS

P. B. Jacob, Jr.
Senior Member IEEE
Dept. of Electrical Engineering
Mississippi State University
State College, Mississippi

R. L. Reese
Member IEEE
The Fanner Mfg. Co.
Cleveland, Ohio

Submitted in abstract or outline form only to the
IEEE Transmission and Distribution Committee for
presentation at the IEEE Winter Power Meeting,
New York, N. Y., February 2-7, 1964.

JOE KAMINSKI

Conference Paper



CORONA AND TRACKING ON AERIAL SPACER CABLE
IN TWO OUTDOOR ACCELERATED TEST STATIONS
AN INTERIM PROJECT REPORT

J. C. Thompson
Member IEEE
Houston Lighting and Power Co.
Houston, Texas

G. H. Redden
Member IEEE
Olin Mathieson Chemical Corp.
Chattanooga, Tenn.

A paper recommended by the IEEE Insulated Conductors Committee of the IEEE Power Group for presentation at the IEEE Winter Power Meeting, New York, N. Y., January 31-February 5, 1965. Manuscript submitted November 2, 1964; made available for printing December 29, 1964.

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CORONA LOSS CHARACTERISTICS OF EHV TRANSMISSION LINES

BASED ON PROJECT EHV RESEARCH

J. G. Anderson

M. Baretzky, Jr.

D. D. MacCarthy

All of:
General Electric Company
Pittsfield, Mass.

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ALTERNATING CURRENT CORONA IN FOUL WEATHER.

PART II - BELOW FREEZING POINT

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Montreal, Que., Can.

L. Cahill
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Montreal, Que., Can.

B. J. Jakubczyk
Universite Laval
Quebec, Canada.

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LONG AND SHORT LINE RADIO INFLUENCE CHARACTERISTICS

B. M. Bailey
Member IEEE
Bonneville Power Administration
Portland, Oregon.

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SOME OBSERVATIONS OF FOUL WEATHER EHV TELEVISION INTERFERENCE

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Member IEEE

Both of:
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A paper recommended by the IEEE Transmission and Distribution Committee of the IEEE Power Group for presentation at the IEEE Winter Power Meeting, New York, N. Y., January 25-30, 1970. Manuscript submitted September 11, 1969; made available for printing December 2, 1969.

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Paper No.

70 TP 104 - PWR

Transactions Paper

(Reviewed and Accepted for Publication)

DISCUSSION IN QUADRUPLICATE DUE February 13, 1970.



PREDETERMINATION OF CORONA LOSSES UNDER RAIN INFLUENCE OF RAININTENSITY AND UTILIZATION OF AN UNIVERSAL CHART

J. J. Cladé
Member IEEE

C. H. Gary

Both of:
Electricite de France
Paris, France.

A paper recommended by the IEEE Transmission and Distribution Committee of the IEEE Power Group for presentation at the IEEE Winter Power Meeting, New York, N.Y., January 25-30, 1970. Manuscript submitted September 15, 1969; made available for printing November 21, 1969.

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Paper No.

70 TP 106 - FWR

INDEX FOR: COATINGS (See Contamination)

Number	Title	Author	Company	Date
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9TP208-3	CONDUCTING GLAZE ON PORCELAIN INSULATORS	LW Spooner	General Electric Pittsfield, MA	8/8/49
13-24	IMMERSION TEST FOR UNIFORMITY AND THICKNESS OF ALUMINUM ON ALUMINIZED STEEL	HJ Wittrock	Kaier Alum. Co. Spokane, WA	4/17/53
4TP432	METAL COATINGS - ALUMINIZING OF STEEL	JF Bacon EJ Mets	General Electric Pittsfield, MA	6/17/54
11188	DETECTION OF THIN INSULATING FILMS ON METALS	DG Flom RH Savage	General Electric Schenectady, NY	10/54
4TP481	PREPARATION & CORROSION RESISTANCE OF ALUMINIZED POWER-LINE HARDWARE	EJ Metz	General Electric Pittsfield, MA	12/9/54
56GL204	COATING BY THE FLUIDIZED BED TECHNIQUE	J. Gaynor	General Electric Schenectady, NY	6/29/56
6TP483	Gauging thin non-magnetic coatings on oriented SX-10 strip	GH Smith	General Electric Pittsfield, MA	12/24/56
IEE	SURVEY OF INSULATOR TREATMENT WITH SILICONES AND OTHER COMPOUNDS	H. N. Ekval		1/22/57
K-153-CR (2)	COATING TO DEVELOP A HYDROPHOBIC SURFACE	RH Lester	General Electric Baltimore, MD	6/24/57
IEE 58-211 CP	INTERNAL OXIDATION MECHANISM FOR NON-TRACKING ORGANIC INSULATIONS	RS Norman AA Kessel	General Electric West Lynn, MA	10/14/57
IEE 58-933	A SYSTEM FOR GAGING PLATING THICKNESS	RG Myers DL Waidelich	Argonne Nat Lab Univ of MO	7/9/58
1A-176 (3)	SPRAY APPLICATION OF SILICONE GREASE TO COMBAT INSULATOR SURFACE CONTAMINATION	RH Lester	General Electric Baltimore, MD	5/59

INDEX FOR: COATINGS

Number	Title	Author	Company	Date
TIA-166	COMBAT INSULATOR CONTAMINATION WITH INSULJEL APPLICATION OF SILICONE GREASE TO COMBAT INSULATOR SURFACE CONTAMINATION UCAR R-101 SILICONE METAL PROTECTANT	RH Lester	General Electric Baltimore, MD Benel Electric Baltimore, MD Union Carbide	2/59 10/30/61 7/62

GENERAL ELECTRIC
Research Laboratory

CONDUCTING COATINGS FOR VERY HIGH VOLTAGE GRADIENTS

by

Katharine B. Blodgett, Research Laboratory, and
Lynn H. Stauffer, General Engineering and Consulting Laboratory

Report No. RL 111

October, 1948

SCHENECTADY, NEW YORK

Cooling

Locke Aug 1949

TECHNICAL INFORMATION SERIES

REPORT NO. 49TP208-3

TITLE
CONDUCTING GLAZE ON PORCELAIN
INSULATORS

AUTHOR L.W. SPOONER
AUGUST 8, 1949

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FN-612 (12-48)

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR L. W. Spooner	SUBJECT CLASSIFICATION -----	NO. 49TP208-3 DATE Aug. 8, 1949
TITLE Conducting Glaze on Porcelain Insulators		
ABSTRACT The properties of a ceramic conducting glaze on a British made porcelain insulator were studied. The dependence of resistance upon temperature, voltage and time at elevated wattages was measured. Probable composition and condition of firing are reported.		
G.E. CLASS III GOV. CLASS None	REPRODUCIBLE COPY FILLED TECHNICAL SERVICE DIV. PITTSFIELD PW Data Bureau	NO. PAGES 6
CONCLUSION This ceramic glaze has a resistivity of 0.6 meg per square at 30°C and a large negative temperature coefficient. The resistivity is independent of voltage gradient within the limits of our tests. When immersed in oil, a wattage intensity of 5.8 watts per square inch was dissipated without significant change for more than 50 days. Fe_3O_4 appears to be the conducting element and the glaze was probably fired in air.		

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INFORMATION PREPARED FOR Engineering Information

TESTS MADE BY L. W. Spooner and R. E. Leab

COUNTERSIGNED S. E. Q. Ashley L. W. Spooner Pittsfield Works Laboratory

TRANSFORMER & ALLIED PRODUCT DIVISIONS

PITTSFIELD

Coatings

PROGRESS REPORT

No. 53-24

IMMERSION TEST FOR UNIFORMITY AND THICKNESS
OF ALUMINUM ON ALUMINIZED STEEL

H^c J. WITTROCK

April 17, 1953

UNRESTRICTED

PR NO. 53-24

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KAISER ALUMINUM & CHEMICAL CORPORATION

Division of Metallurgical Research

P. O. Box 1451
Spokane 10, Washington

PROGRESS REPORT

Project No. 817-2

Date: April 17, 1953

SUBJECT: IMMERSION TEST FOR UNIFORMITY AND THICKNESS OF ALUMINUM
ON ALUMINIZED STEEL

SUMMARY

An immersion test, similar to the Preece test for galvanized steel, was developed for determining the uniformity and thickness of the aluminum coating on aluminized steel. A variety of etching solutions were explored. The preferred solution contains copper and fluoride ions, and hydrofluoric or sulfuric acids. When the latter acid is used, the fluoride may be added as a solid ammonium salt. This reduces the hazard to personnel.

The test consists of repeatedly immersing the aluminized steel specimen in a suitable etching solution and noting when the intermetallic compound and the bare iron become exposed. The aluminum appears bright and granular, while the intermetallic layer is dark grey and matte. Wherever it has become exposed, the iron is coated with an adherent layer of copper. A clear distinction is thus afforded between the aluminum, the aluminum-iron intermetallic compound, and the iron. Weight loss measurements indicate a removal of the aluminum coating at the rate of 0.00023 inch per immersion.

The test requires only about ten minutes to perform. It can undoubtedly be used in its present form, but further work is needed for a complete understanding of the operating variables.

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
JF Bacon	Metal Coatings	54TP432
EJ Mets <i>EJMS</i>		DATE 6-17-54
TITLE Aluminizing of Steel		

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
JF Bacon EJ Mets <i>EJ Mets</i>	Metal Coatings	54TP432
TITLE		DATE
Aluminizing of Steel		6-17-54
ABSTRACT 1012 steel has been hot-dip aluminized, with and without flux pre-treatments. The effects of immersion time, bath temperature and bath composition, on coating thickness, structure, appearance, mechanical properties and corrosion resistance, have been examined.		
G.E. CLASS	REPRODUCIBLE COPY FILED	NO. PAGES
3	TECHNICAL DOCUMENTS	
GOV. CLASS	PW Data Bureau	24
None		
CONCLUSION		
Better aluminum coatings were obtained on mild steel without any flux preparation. Aqueous flux solutions had no significant advantage, while molten fluxes appear desirable for larger ferrous parts to obtain uniform coating thickness. The presence of 3% Fe in a commercially pure aluminum bath increased coating thickness up to 25% with no significant effect on ductility or corrosion resistance. Accelerated corrosion tests show the superiority of aluminized steel in industrial-type atmosphere.		

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INFORMATION PREPARED FOR Lightning Arrester, Cutout, Capacitor and
Distribution Transformer Engineering

TESTS MADE BY E. J. Mets and J. F. Bacon

COUNTERSIGNED R. T. Foley *RT Foley*

SECTION Metallurgical Development
Materials & Processes Laboratory
Transformer Division, Pittsfield

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GENERAL ELECTRIC
Research Laboratory

Coating

DETECTION OF THIN INSULATING FILMS ON METALS

by

D. G. Flom and R. H. Savage

Report No. RL-1188 - *Submitted for publication in November 1954* October 1954

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SCHENECTADY, NEW YORK

~~Mr. [unclear]~~
Pls note + pass to
product Engineering
10/27

H. A. Frey
Lacke Dept.
Baltimore

TECHNICAL INFORMATION SERIES

Title Page		
AUTHOR	SUBJECT CLASSIFICATION	NO.
EJ Mets EJ Mats	Metal Coatings	54TP481
		DATE
		12-9-54
TITLE		
Preparation & Corrosion Resistance of Aluminized Power-Line Hardware		

~~Handwritten notes and signatures on the left side of the page, including "Mr. [unclear]" and "Mrs. [unclear]".~~

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR EJ Mets <i>EJ Mets</i>	SUBJECT CLASSIFICATION Metal Coatings	NO. 54TP481 DATE 12-9-54
TITLE Preparation & Corrosion Resistance of Aluminized Power-Line Hardware		
ABSTRACT Power-line hardware parts have been hot-dip aluminized and evaluated in accelerated corrosion exposures of salt fog and sulfur atmosphere by comparison with standard galvanized parts.		
G.E. CLASS 3 GOV. CLASS None	REPRODUCIBLE COPY FILED TECHNICAL DOCUMENTS PW Data Bureau	NO. PAGES 11
CONCLUSION Caps and ball bolts have been successfully hot-dip aluminized without the use of flux. Accelerated corrosion tests in salt fog show aluminized coatings of 1.5-2 mils to be 2-3 times more resistant to attack than galvanized coatings of 3-4 mils. In sulfur atmosphere, this advantage is at least five times over galvanized coatings.		

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TESTS MADE BY J. F. Bacon - E. J. Mets

COUNTERSIGNED W. Morrill *Morrill*

BUILDING and ROOM No. 7 - 260 LOCATION General Metallurgy Subsection

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GENERAL ENGINEERING LABORATORY

Coatings

COATING BY THE FLUIDIZED BED TECHNIQUE

By

J. Gaynor

Report No. R56GL204

June 29, 1956

(211)

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General Engineering Laboratory

SCHENECTADY, NEW YORK

TECHNICAL INFORMATION SERIES

AUTHOR	SUBJECT CLASSIFICATION	NO.
J. Gaynor	Coatings	R56GL204
		DATE
		6/29/56
TITLE		
COATING BY THE FLUIDIZED BED TECHNIQUE		
ABSTRACT		
A review of the patent literature on coatings via powdered solids is presented. In addition, the results of an experimental program, not yet complete, to apply polymer, glass, ceramic, and metal coatings to a variety of substrates, via a fluidized bed		
G.E. CLASS	REPRODUCIBLE COPY FILED AT LIBRARY OF GENERAL ENGINEERING LABORATORY SCHENECTADY, NEW YORK	NO. PAGES
2		
GOV. CLASS.		12
CONCLUSIONS		
technique, where the article to be coated is not heated prior to exposure to the fluidized bed, are presented. The state of the art including the work in General Electric is discussed and a plan for action suggested.		

INFORMATION PREPARED FOR GENERAL ENGINEERING LABORATORY

TESTS MADE BY J. Gaynor, Wm. J. Vallier

AUTHOR Dr. Joseph Gaynor

COUNTERSIGNED M.L. Feldman *M.L. Feldman* H.R. Schmidt

COMPONENT CHEMICAL ENGINEERING

Coatings

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR GH Smith	SUBJECT CLASSIFICATION Steel-Silicon Gauging Thin Films	NO. 56TP483 DATE 12-24-56
TITLE Gauging Thin Non-Magnetic Coatings on Oriented SX-10 Strip		

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR GH Smith	SUBJECT CLASSIFICATION Steel-Silicon Gauging Thin Films	NO. 56TP483 DATE 12-24-56
TITLE Gauging Thin Non-Magnetic Coatings on Oriented SX-10 Strip		
ABSTRACT An evaluation of the Pocket Handi-Gauge, Aminco Brenner Magne-Gauge, Elcometer, and G-E Thickness Gauge Type B for measuring the thickness of thin insulating coatings on oriented electrical steel strip has been made.		
G.E. CLASS 3 GOV. CLASS None	REPRODUCIBLE COPY FILED TECHNICAL DOCUMENTS PW Data Bureau	NO. PAGES 47
CONCLUSION 1. With proper use, the Pocket Handi-Gauge, Aminco Brenner Magne-Gauge, Elcometer, and G-E Thickness Gauge Type B can be used to measure the thickness in the range 0.1 to 0.6 mil of non-magnetic films on oriented electrical steel strip. 2. Sample to sample variations, size of sample, backing material under sample, and direction of testing (with- or cross-grain) were found to influence the calibration of the instruments. 3. The accuracy (3 Sigma) for readings taken with the gauges was: ± 0.18 mil for the Pocket Handi-Gauge, ± 0.15 mil for the Magne-Gauge, ± 0.03 mil for the Elcometer and G-E Type B. (Project No. 1-3-4)		

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TESTS MADE BY HI Marcil, Mrs. BM Perkins, Mrs. MO Dojka, GH Smith

COUNTERSIGNED W. L. Chu SECTION Metallurgical Development

BUILDING and ROOM No. 7-223 LOCATION Materials & Processes Laboratory Transformer Division, Pittsfield

~~Insulators~~
Coatings

SURVEY OF INSULATOR TREATMENT
WITH
SILICONES AND OTHER COMPOUNDS

AIEE Lightning and Insulator Subcommittee

Report by
H. N. Ekvall

January 22, 1957

Mr. B. Kingbury

GENERAL ELECTRIC COMPANY
INSULATOR DEPARTMENT

Technical Report No. IK-153-CR

June 24, 1957

SUBJECT

COATING TO DEVELOP A HYDROPHOBIC SURFACE

Ronald H. Lester

This report contains:

4 typewritten pages
4 tables
1 nomograph
2 photographs

Baltimore, Maryland

Signed

R. H. Lester

Approved

D. C. Trues

B. Kingsbury

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GENERAL ELECTRIC COMPANY
INSULATOR DEPARTMENT

Technical Report No. LK-153-CR
Supplement #1

October 9, 1957

Coating To Develop a Hydrophobic Surface

Ronald H. Lester

This report contains

3 typewritten pages
2 tables
6 charts

Baltimore, Maryland

Signed

Ronald H. Lester

Approved

W. C. Thies

JAN 29 1958

Coatings

Conference Paper



INTERNAL OXIDATION MECHANISM FOR NON-TRACKING ORGANIC INSULATIONS

R. S. Norman
Associate Member AIEE

A. A. Kessel
Nonmember AIEE

Both of:
General Electric Company
West Lynn, Mass.

A paper recommended by the AIEE Dielectrics Committee for the AIEE Winter General Meeting, New York, N. Y., February 2-7, 1958. Manuscript submitted October 14, 1957; made available for printing December 6, 1957.

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Paper No. **CP**

58-211

Transactions Paper

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Coatings

A SYSTEM FOR GAGING PLATING THICKNESS

R. G. Myers
Associate Member AIEE
Argonne National Laboratory
Lemont, Ill.

D. L. Waidelich
Fellow AIEE
University of Missouri
Columbia, Mo.

A paper recommended by the AIEE Special Instruments and Auxiliary Apparatus Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Summer General Meeting and Air Transportation Conference, Buffalo, N. Y., June 22-27, 1958. Manuscript submitted January 17, 1958; made available for printing April 25, 1958.

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Paper No.

58-933

Discussion in Duplicate Due July 9, 1958.

SPRAY APPLICATION OF SILICONE GREASE TO COMBAT INSULATOR SURFACE CONTAMINATION

By R. H. Lester
Ceramic Research Engineer
Insulator Department
General Electric Company

Industrial and natural contaminations have created operating problems on electric utility systems for many years. Attempts to nullify the effects of these contaminants on electrical insulators have included special insulator designs, umbrella shields of varying shapes, high pressure washing equipment, and the application of special waxes, oils, and greases. Each method has its specific benefits and shortcomings.

Over-insulation, the use of insulators larger than normally required, has solved many problems. Special fog type insulators, built with lengthened leakage distances, have been used with reasonable success in a number of areas. This added leakage distance may not be sufficient when considering the tremendous decrease in surface resistance caused by the electrolytic form of the moistened contaminants.

Periodic washings with high pressure water jets has been necessary in some areas. In some local applications, it has been a practice to take a station out of service for a period of time, remove the insulators, clean them by hand with special preparations, and replace them. Boiling in caustics has sometimes been necessary to remove certain bonding contaminants.

An early approach to the solution of the contamination problem was the trial of surface treatments with oils, waxes and greases, but the organic nature of these materials often resulted in their rapid deterioration under corona conditions. In October 1950, a silicone fluid, (see page 6, Ref. 1), was introduced and showed considerable improvement over the organic material. Other noteworthy investigations have since been made in the use of silicone greases and waxes, (see page 6, Refs. 2, 3, 4 and 5.) In 1958 a forward step in the solution of contamination problems was made by the introduction of a new silicone. This new silicone is suitable for use in the conventional grease form but has the outstanding advantage in that it may be placed in solution for spray application.

Field and laboratory tests show that the liquid silicone can be applied to moderately contaminated insulators without the necessity of first cleaning the insulator to remove the contaminant and successful reapplication of the liquid silicone has been achieved with cost savings benefits by simply spraying over dirt saturated grease. The purpose of this article is to explain the coating theory of the new silicone and to briefly describe the laboratory testing required to demonstrate its effectiveness.

THEORY OF SILICONE FUNCTIONING

The theory of the use of the early silicone waxes was to provide a hard, smooth surface, and to hinder the dissolved contaminating salts from spreading by capillary action. The wax tends to "bunch" the moisture droplets, retarding the formation of a continuous electrolytic film, hence the low resistance paths are broken up, reducing the flow of leakage current and the formation of excessively distorted voltage gradients.

The intent of the new silicone is three-fold. The first is to accomplish the same droplet "bunching" obtained by the waxes, the second is to provide a thick durable layer of silicone capable of prolong weather exposure, and the third is to provide a material that engulfs the individual contaminating particles as they are deposited on the silicone surface. The result of the third factor is that the engulfed particle is prevented from becoming an electrolyte through the exclusion of its contact with moisture.

To better understand the hydrophobic, or water shedding, properties of the silicone greases consider the solid-liquid-gas system shown in Figure 1. (Also see page 6, Refs. 6 and 7.) This figure depicts the equilibrium that exists between a water droplet, air, and a silicone grease surface. The phases present contact each other along a line such that the points X are intercepts. There are three interfacial energies involved in the system, each of which tends to minimize the area of its own interface. They are represented in the figure by the vectors γ_{SG} , γ_{SL} and γ_{LG} . Vector γ_{LG} tangential to the liquid surface at X forms with the solid-liquid interface an angle θ , which

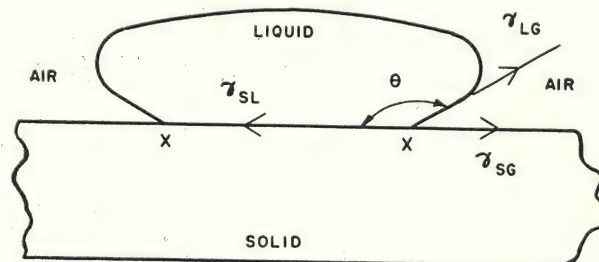


Figure 1
Schematic of Contact Angle Showing
Interfacial Forces Acting on a Liquid Drop
on a Solid Plate in Air

SPRAY APPLICATION OF SILICONE GREASE TO COMBAT INSULATOR SURFACE CONTAMINATION

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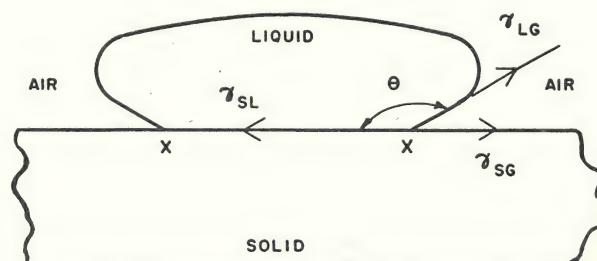


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The intent of the new silicone is three-fold. The first is to accomplish the same droplet "bunching" obtained by the waxes, the second is to provide a thick durable layer of silicone capable of prolong weather exposure, and the third is to provide a material that engulfs the individual contaminating particles as they are deposited on the silicone surface. The result of the third factor is that the engulfed particle is prevented from becoming an electrolyte through the exclusion of its contact with moisture.

To better understand the hydrophobic, or water shedding, properties of the silicone greases consider the solid-liquid-gas system shown in Figure 1. (Also see page 6, Refs. 6 and 7.) This figure depicts the equilibrium that exists between a water droplet, air, and a silicone grease surface. The phases present contact each other along a line such that the points X are intercepts. There are three interfacial energies involved in the system, each of which tends to minimize the area of its own interface. They are represented in the figure by the vectors γ_{SG} , γ_{SL} and γ_{LG} . Vector γ_{LG} tangential to the liquid surface at X forms with the solid-liquid interface an angle θ , which

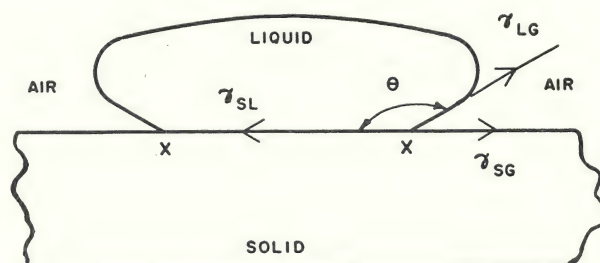


Figure 1
Schematic of Contact Angle Showing
Interfacial Forces Acting on a Liquid Drop
on a Solid Plate in Air

Coatings

Prave Kingsbury

Color	DC-5 Colorless	Insulgreen Colorless
Pentathum ASTM D217-98		
Unworked	200-240	180-240
Worked (max)	300	310
Bleed % 24hr at 400°F	10	10
Evaporation % 24hr at 400°F	3	2 1/2
Dielectric Strength V/mil at 15mils	500	750
Dielectric Constant at 23°C ASTM D150-47T		
AT 100 cycles	2.85	—
AT 105 cycles	2.85	—
AFTER 96hrs at 96% RH at 25°C		
AT 100 cycles	3.00	—
AT 105 cycles	3.00	3.10
Power Factor at 23°C ASTM D150-47T		
AT 100 cycles	.0001	—
AT 105 cycles	.0009	—
AFTER 96hrs at 96% RH at 25°C		
AT 100 cycles	.001	—
AT 105 cycles	.003	.0025
ARC Resistance standard ASTM D995-98 T	80	125
* ARC Resistance MIL I-8660	58.4 block	170 white
* Dielectric Strength .050" gap	589 pack	633 pack

* RUN AT GEL

See Insulgreen Bureau

P. H. Lofgren
Jan 1961

Engineering Comments
File #4412

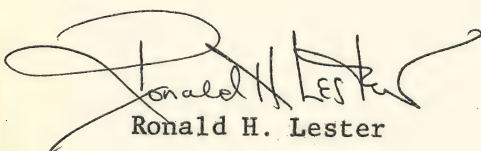
Baltimore, October 30, 1961

Mailing List 9 Tab D

Subject: INSULJEL-INSULGREASE PRESENTATION AT DETROIT EDISON

Attached you will find a copy of a presentation given to Detroit Edison and information on the small pressure sprayer we found useful for spraying INSULJEL. Many of the utilities will have these sprayers in their shops, but if this is not the case, the investment is only slight and will soon save the dollars spent on aerosol cans. Packing replacements are required from time to time, but this is a simple purchase and the packing cost but four cents.

Presentations such as attached can be made most effective when we hear from each of you in the field. Each innovation or new use of INSULJEL and INSULGREASE is a potential piece of sales promotion. My thanks to Paul Jorgenson and Heintz Burnham who have been feeding back this field information enabling us to talk about our good points and improve upon our weak ones.


Ronald H. Lester

ep

Attachments



SILICONES DIVISION

UNION CARBIDE CORPORATION

270 PARK AVENUE, NEW YORK 17, N. Y.

Coatings

Mr. B.E. Kingsbury, Supv.
High Voltage Lab.
General Electric Company
So. Charles & Cromwell Sts
Baltimore 30, Md.

Dear Sir:

Thank you for inquiring about our new UCAR Silicone Metal Protectants. We appreciate your interest.

I believe you will find that the enclosed Product Information and Price Bulletins will answer most of the questions you may have. However, we would like to call to your attention the fact that, due to their limited shelf life at room temperature, these materials are not suitable for aerosol packaging. Also, they cannot be used on silver or pewter hollowware, although a product for this application is available under separate license.

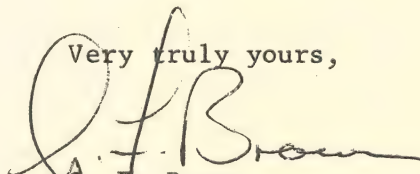
To facilitate your preliminary evaluation of UCAR Metal Protectants, we have established a Sample Treating Service which you will find fully described in the enclosed Customer Service Bulletin.

For your convenience in ordering samples for in-plant evaluation, we have enclosed a Sample Order Form and reply envelope which may be used to order the minimum sized one pint samples at \$15.00 per pint.

If you have any further questions, why not use the back of this letter and the reply envelope, or if you wish, you can contact any Silicones Division Sales Office for further information.

Thank you again for your interest. We hope that you will evaluate UCAR Metal Protectants at your earliest convenience, and see for yourself how these new materials can help you solve your corrosion problems.

Very truly yours,


G. F. Brown
Advertising Manager

GFB/gm

Attachments

BALL BOLTS

Coatings

I. 2 COATS IN STD. MANNER

#1		C		C	
	82	116	120	92	
	89	116	119	92	
	86	119	117	108	
	84	119	118	87	
	85	120	117	84	
	85	118	118	96	
	3.13	4.83	4.83	94	
		2.88	2.88	3.55	

#2		+C		C		C		C	
	89	117	107	65	119	82	115		
	94	117	108	65	118	87	115		
	97	117	108	72	118	84	116		
	86	117	108	63	119	84	115		
	85	117	108	64	119	84	115		
	90	5.17	4.45	66	5.35	84	5.00		
	3.40	3.15	2.57	2.38	3.28	3.07	3.00		

Avg. 3.03

II. 1 COAT OUT OF BARREL

#4		C		C		C		C	
	101	73	73	96	99	66			
	102	62	68	102	98	78			
	103	63	68	102	102	67			
	103	72	72	103	104	70			
	103	66	68	101	101	67			
	4.10	87	90	106	3.98	68			
	2.30	2.42	2.50	4.03	2.20	2.45			
				2.23					

#5		C		C		C		C	
	88	31	94	63	99	66			
	90	36	95	63	98	78			
	88	31	94	63	102	67			
	90	31	94	63	104	70			
	89	31	94	63	101	67			
	3.30	1.62	3.57	64	3.98	68			
	1.65		1.87	2.32					

Avg. 2.16

Number	Title	Author	Company	Date
Paper	RELATIONSHIP BETWEEN CORONA & RADIO NOISE ON TRANSMISSION LINES Part II: CONDUCTOR & INSULATOR CORONA	TW Liso JJ LaForest	General Electric Schenectady, NY	
Paper	ON PROCEDURES FOR RELIABILITY EVALUATION ON TRANSMISSION SYSTEMS	RJ Ringlee SD Goode	Public Service Co. of Colorado	
Booklet	PUBLIC SERVICE COMPANY OF COLORADO -- WELCOMES YOU TO THE HIGH-VOLTAGE HIGH-ALTITUDE RESEARCH PROJECT AT LEADVILLE, COLORADO			
Paper	LINE HARDWARE DISCUSSION - R.I.V.		Insulator Dept. General Electric	
Paper (2)	CORONA AND RIV INVESTIGATION ON INSULATORS AND RELATED CONDUCTOR SUPPORT ACCESSORIES	J. Kaminski, Jr.	Insulator Dept. General Electric	
Paper	DEVELOPMENT OF CORONA SHIELDS FOR SUSPENSION ASSEMBLIES OF BUNDLED CONDUCTOR TRANSMISSION LINES	J. Kaminski, Jr.	Insulator Dept. General Electric	
Paper - AIEE	CONTROL OF CORONA AND RADIO INFLUENCE VOLTAGE ON DISCONNECTING SWITCHES FOR 330 KV	JB Ownes	AIEE Member Westinghouse Corp.	
DF51GL103	RADIO NOISE REDUCTION WORK ON D-C MACHINES	PC Gardiner	General Electric Schenectady, NY	June 12, 1951
Booklet	TELEVISION INTERFERENCE IN RURAL AREAS		US Dept of Agriculture Rural Electrification Adm	Dec 1951
DF55GL80	BIBLIOGRAPHY ON CORONA	JW Ryan	General Electric	Feb. 10, 1955
R55GL294	PULSE DEISTRIBUTION ANALYZER FOR CORONA ANALYSIS	WT Starr LW Johnston	General Electric Schenectady, NY	Oct. 10, 1955
DF56GL47	SUPPLEMENT TO BIBLIOGRAPHY ON CORONA	JE Doolittle	General Electric Schenectady, NY	Feb. 1, 1956
59GL11	CORONA	BV Bhimani	General Electric Schenectady, NY	Jan. 13, 1959
R56GL180	RECENT RADIO INTERFERENCE INVESTIGATIONS - HIGH VOLTAGE TRANSMISSION LINES TEST METHODS FOR CORONA, ARCING AND TRACKING INTERACTIONS WITH INSULATING MATERIALS	GE Adams WT Starr JJ Hinchen HS Endicott MW Albright	General Electric Schenectady, NY	1956 Sept 26, 1956

Number	Title	Author	Company	Date
Insulation Magazine excerpt aper 57-711	PART I: CORONA AND ITS EFFECT ON INSULATION -- A Resume	TW Liao	General Electric Pittsfield, MA	March 1957
PT137	INTERNAL CORONA SPACES IN CABLES Manometric Detection of Internal Corona and Auto-graphic Mapping of Corona Spaces	DW Kitchen OS Pratt	AIEE Member Nonmember AIEE	April 26, 1957
JF58AD-11	RADIO NOISE TESTS ON STANDARD AND PLASTIC ROD SUSPENSION INSULATOR STRINGS	VR Mulhall	General Electric Pittsfield, MA	July 9, 1959
ol. 11, No. 1 Research News"	ACTIVITIES IN CORONA STUDIES, MEASUREMENT AND DEVELOPMENT SINCE JANUARY 1957	JH Maghorne DE Jones JR Leslie	Canadian GE Ltd.	June 12, 1958
	POWER TRANSMISSION AT EXTRA HIGH VOLTAGE (EHV) - Pg 1 RADIO-INTERFERENCE PROBLEMS AT EXTRA HIGH VOLTAGE -pg18	O. Nigol A. Elek C. Nigol	Hydro Elec Power Co	Jan-March 1959
K-659-DR	THE CORONA LOSS PROBLEM THE INSULATOR LOSS PROBLEM Etc.	J. Kaminski, Jr.	General Electric Insulator Dept.	Sept. 29, 1959
andwritten Notes	CORONA AND RIV TESTS ON BUNDLED CONDUCTOR ASSEMBLIES			Jan 13, 1960
K-665-DR	CORONA	J. Kaminski, Jr.	General Electric Insulator Dept.	May 23, 1960
PT150	VISUAL CORONA AND RIV TESTS ON BUNDLED CONDUCTOR ASSEMBLIES	L. Graham	General Electric Pittsfield, MA	July 28, 1960
K-671-DR	EFFECT OF GREASE AND ARTIFICIAL AGING ON THE CORONA START AND RADIO NOISE FROM CUREW TRANSMISSION LINE CONDUCTORS	J. Kaminski, Jr.	General Electric Insulator Dept.	August 8, 1960
PT155	VISUAL CORONA AND RIV TESTS ON 460 KV SINGLE AND BUNDLED CONDUCTOR ASSEMBLIES	LF Jandran	General Electric Pittsfield, MA	Sept 19, 1960
	RADIO NOISE & LEAKAGE CURRENT INVESTIGATION OF WOODEN & CONCRETE TRANSMISSION LINE TOWER MEMBERS & THEIR ASSOCIATED HARDWARE			

INDEX FOR: CORONA -- RIV

Pg #3

Number	Title	Author	Company	Date
K-671-DR	VISUAL CORONA & RIV TESTS ON 460 KV SINGLE & BUNDLED CONDUCTOR ASSEMBLIES	J. Kaminski, Jr.	General Electric Insulator Dept.	August 8, 1960
P #60-1273 (2)	EFFECT OF BUNDLED CONDUCTOR FIELD INFLUENCE ON EHV TRANSMISSION LINE DESIGN	RW Harmon	Ohio Brass Co. Barberton, OH	Oct 12, 1960
app Info.	LAPP CORONA SHILED INFORMATION TEST OF MARCH 1 & Feb. 28, 1961		Lapp HV Lab.	Feb. 27, 1961
K-683-DR	CORONA & RIV TESTS ON BUNDLED KAISER ACSR CONDUCTORS	BE Kingsbury	General Electric Insulator Dept.	June 14, 1961
K-684-DR (2)	CORONA & RIV TESTS ON BUNDLED CONDUCTOR ASSEMBLIES	BE Kingsbury	General Electric Insulator Dept.	June 14, 1961
1-GC-188	RESEARCH & DEVELOPMENT ON CORONA-RESISTANT MATERIALS Quarterly Progress Report #4 to: Wright Air Development Division	JC Devins HL Greenhaus DR Johnston DL Harms FY DuPont AL Lynn A. Pletenik HG Pfeiffer	General Electric	July 1961
K-689-DR (2)	CORONA & RIV TESTS ON BUNDLED REYNOLDS ACSR CONDUCTORS	BE Kingsbury	General Electric Insulator Dept.	Sept. 11, 1961
62FL10	THE DEVELOPMENT OF A METHOD TO DETECT GROUND INSULATOR DEFECTS	HH Richardson	General Electric Ft. Wayne, Indiana	April 12, 1962
K-707-DR (2)	VISUAL CORONA & RIV TESTS ON SUSPENSION INSULATOR ASSEMBLIES FOR PACIFIC GAS & ELECTRIC -- 500 KV System	BE Kingsbury	General Electric Insulator Dept.	May 11, 1962
K-708-DR	VISUAL CORONA & RIV TESTS ON SUSPENSION INSULATOR ASSEMBLIES FOR HOUSTON LIGHTING & POWER CO. - 345 KV	BE Kingsbury	General Electric	1962
K-712-DR	VISUAL CORONA & RIV TESTS ON SUSPENSION INSULATOR ASSEMBLIES FOR PACIFIC GAS & ELECTRIC - 500 KV System	BE Kingsbury	General Electric Insulator Dept	Dec. 11, 1962
F-62-AD-43	UNIFORM & DISCRETE DISTRIBUTION OF CORONA DISCHARGES ON A LINE	JJ LaForest	General Electric Pittsfield, MA	Dec. 17, 1962
3-GC-0234 C	RESEARCH & DEVELOPMENT ON CORONA-RESISTANT MATERIALS Quarterly Progress Report #1 to Wright Air Development	JC Devins HL Greenhaus DR Johnston A Pletenik HG Pfeiffer	General Electric Schenectady, NY	April 9 1963

Number	Title	Author	Company	Date
GC-0254-C	RESEARCH & DEVELOPMENT ON CORONA-RESISTANT MATERIALS Quarterly Report No. 3 to Wright Air Development Center	FF Carnini JC Devins HL Greenhaus DR Johnston A. Pletenik HG Pfeiffer BE Kingsbury	General Electric Schenectady, NY	October 1963
722-Dr	RIV & VISUAL CORONA TESTS ON P.G. & E. 500 KV ASSEMBLIES MADE IN PITTSFIELD HIGH VOLTAGE LABORATORY	N. Hylden-Cavallius S. Anestrand JL Maksiejewski J. Ellder N. Knudsen	General Electric Insulator Depart. ASEA Ludvika, (Sweden) Warsaw, Poland Gothenburg, Sweden Chalmers Univ of Tech Sweden	May 27, 1963 1964
07 (2)	CORONA LOSSES, RADIO INTERFERENCE & INSULATOR REQUIREMENTS FOR H.V.D.C. LINES. STUDIES REGARDING INSULATOR INTERFERENCE FOR FREQUENCIES BETWEEN 30 & 1500 MHZ	RM Morris B. Rakoshdas	IEEE Member IEEE Member	Dec 3, 1962
11 (2)	CORONA LOSS & RADIO INTERFERENCE MEASUREMENTS AT HIGH VOLTAGE A.C. ON TEST LINES IN SWEDEN AN INVESTIGATION OF CORONA LOSS & RADIO INTERFERENCE FROM TRANSMISSION LINE CONDUCTORS AT HIGH DIRECT VOLTAGES	RL McCoy J. Kaminski, Jr. M. Betha, Jr.	General Electric Insulator Dept GE-Insulator Dept Betha - Ala.	April 3, 1964 January 1967
per #63-84	RADIO INTERFERENCE FROM EHV TRANSMISSION LINES AND SUBSTATIONS EHV INSULATOR ASSEMBLIES CAN BE CORONAPROOF	JJ LaForest WT Starr M. Olyphant, Jr	General Electric Schenectady, NY General Electric Schenectady, NY Dielectric Mat & Sys St. Paul, MN	March 3, 1967 March 1967 June 28, 1967
S-67EU-03	CHOICE OF 1000-KV CONDUCTOR CONFIGURATIONS AND UHV CAGE DESIGN CORONA TESTS ON VARIOUS COMPONENTS	G. Grueneich LE Zaffanello	Houston Ltg & Pwr Houston, TX General Electric Pittsfield, MA	April 1968 March 26, 1970
-C-082	INTERNAL CORONA TESTING OF CASTING RESINS RADIO INFLUENCE OF A 345-KV TRANSMISSION LINE			
cept per 31 PP 66-500	CAGE TESTING INVESTIGATION OF AUDIBLE NOISE OF EHV & UHV TRANSMISSION LINE CONDUCTORS			
cept from & D				
per				

GENERAL  ELECTRIC

SUBJECT

Corona

COPIES: H. A. Frey, Baltimore
J. Kawinski, Baltimore
C. H. Titus, 10-7
R. L. Williams, 21-1

Mr. King

LABORATORIES DEPARTMENT - PHILADELPHIA
April 16, 1959

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APR 20 1959

ENG. DEPT.

F. Vose

Mr. F. Vose
General Electric Company
BALTIMORE WORKS

The enclosed discussion by Dr. A. S. Denholm of the National Research Council of Canada might be of interest to you, particularly in the section pertaining to insulator noise.

T. W. Liao

T. W. Liao
PLANNING ENGINEER
SWITCHGEAR DEVELOPMENT LAB.

TWL:pcs

Attachment

ON PROCEDURES FOR RELIABILITY EVALUATIONS OF TRANSMISSION SYSTEMS

R.J. Ringlee S.D. Goode
General Electric Company
Schenectady, New York

ABSTRACT

A step-by-step procedure for reliability evaluations of transmission systems is described in this paper. Simple algebraic results for prediction of frequency and duration of transmission contingencies are obtained with the use of renewal process theory.

INTRODUCTION

A continuing interest in quantitative reliability evaluations of transmission systems has prompted the preparation of this paper. With the substantial progress that has been made in the perfection of methods for simulating network power flows by fast methods on digital computing machines, the time for the general realization of quantitative transmission system reliability evaluations may be near. One limiting area appears to be the practical, rapid evaluation of stability limits. Techniques for predicting the frequency with which certain transmission contingencies will occur have been known for some time. The combination of rapid simulation methods with event prediction techniques may offer a practical method for carrying out transmission system reliability evaluations. To the already substantial body of technique published on the subject of transmission system reliability, this paper offers a generalization of the concepts of the component run-fail-repair "life cycle" and describes a step-by-step procedure for performing reliability evaluations. Component reliability/availability models have been investigated using renewal processes. The techniques described have proved quite feasible for hand as well as machine computations.

RESUME OF RECENT EFFORTS

Suggestions of numerical reliability criteria for transmission and distribution systems extend back at least three decades to Dean¹ who reported on interruption frequency and duration measures as an aid in decisions to modify circuit protection arrangements. Frequency and probability measures were suggested for generation and transmission systems nearly four decades ago by Lyman² and Smith.³

Cohn⁴ suggested a criterion for generation and transmission reliability based upon the risk of overlapping transmission and generation outages. Todd⁵ developed a probabilistic approach for transmission and distribution circuits. Treating circuit and component outages as independent events, he developed expressions for the probability of outage of one or more series-connected components and the probability of overlapping outage of parallel paths. Todd's criteria

was based upon each outage lasting 24 hours, or conversely, counting "one day" interruption for an outage event. Two outages overlapped if they occurred within the same 24-hour span. It is interesting to note that the component failure rate expressed in failures per day will be very closely estimated by Todd's component probability-of-outage. Parallel paths were assumed to be fully redundant such that the criterion of success could be measured by the existence of a path from the source to the load.

Modeling of repairable systems was greatly enhanced by the use of the Markov Chain with continuous time parameter. Barlow and Hunter⁶ gave a brief analysis of such an approach, and DeSieno and Stine⁷ presented a state-description approach which employed Boolean Algebra and Markov Chains for the analysis of system reliability problems. The Boolean Algebra approach has been applied by Esser, Wasilew, and Egly.⁸ Effects of less than full redundancy in parallel circuits, effects of environmental states and of scheduled outages were investigated by Gaver, et al⁹ and Montmeat et al.¹⁰ Formulas were developed for the prediction of the frequency and duration of outages in series and parallel paths. This work was extended by Mallard and Thomas¹¹ to multiple path transmission circuits. Expressions were developed for the probability of path overload given that specified paths were out of service. Path overload contingency curves were developed for cases of single and multiple path forced outages. Patton, in a discussion of the paper, questioned the method employed to estimate the risk of cascading outages, of overload outages precipitated by other overload outages. The essential point in question was the degree of correlation between loads at various points in the system and upon various components. It was Patton's observation that there was a definite correlation between loads which must be accounted for in probabilistic models of overload occurrence.

Methods of analysis and criteria discussed so far were directed to the prediction of interruptions at specific points in a network. While the methods are readily adaptable to predictions of broader scope, the preparation of numbers of individual "reliability diagrams" or diagrams of paths between sources and load points appears to be needlessly repetitive. An alternative approach, long used in reliability predictions, literally a state-enumeration technique, offers an alternative for developing predictions of system effect rather than load-point effect.

PUBLIC SERVICE COMPANY
OF COLORADO

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HIGH-VOLTAGE HIGH-ALTITUDE
RESEARCH PROJECT

AT

LEADVILLE, COLORADO

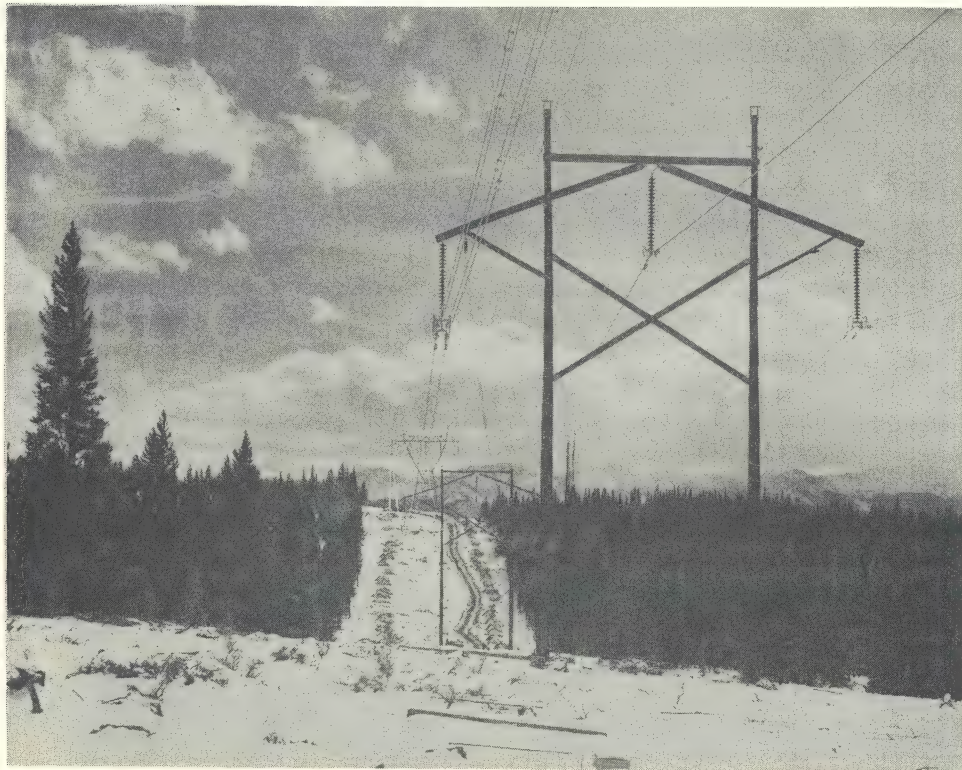


PHOTO BY BILL DANFORD

CORONA AND RIV INVESTIGATION ON INSULATORS
AND RELATED CONDUCTOR SUPPORT ACCESSORIES

J. Kaminski, Jr.

The purpose of this paper is to publish results of RIV investigations on insulators and related hardware carried out at the High Voltage Laboratory in Baltimore.

The general area covered by this report is:

RIV and Corona Performance of Long Insulator Strings

Comparison of RIV and Corona Performance Between Rod Type and Suspension Insulators

Comparison of Single and Bundled Conductor Shielded and Unshielded Arrangements for 460 kv Operation.

Comparison of Shielded V String Assemblies for 345 kv and 460 kv Operation

PERFORMANCE OF LONG INSULATOR STRINGS

Investigations were carried out on long strings of insulators using conventional 5-3/4 x 10 inch standard suspension insulators in single and quadruple strings of 34 units per string. Independent measurements of the test equipment were made including readings with the 600 mmf capacitor located in several different locations in the laboratory, to obtain the minimum of RIV background noise in order to obtain the lowest possible effect on subsequent tests. A 4-1/2 inch O.D. aluminum conductor was attached to the capacitor and supported from overhead by a glass rope. A control ring was used to suppress the possible corona effects of the supporting hardware. An attempt was made to place the ring in such a position that its influence on the lower units would be minimized. Background noise measurements were made with the test arrangement as just described.

The RIV general characteristics of long insulator strings is shown on Figure 1 as gradual ascending RIV levels with major distortions to the pattern occurring at corona onset points. Observations show that the highest stressed area occurred on the bottom insulators at the base of the cap. The presence of glow type corona was readily detectable at the values shown on the curve. The variation in corona readings, as well as RIV values between single and quadruple strings, can be attributed to a difference in grading effect provided by the control ring used to shield cable support hardware.

In order to minimize the effect of the insulator string as a source of RIV, further investigations were made with quadruple strings of insulators to determine the appropriate shielding required for improvement of corona onset voltages. Subsequent tests made with variations in shielding positions resulted in corona starting voltage of 396 kv for a quadruple string as compared to 214 kv without insulator shields.

COMPARISON BETWEEN SPECIAL ROD TYPE INSULATORS
AND STANDARD SUSPENSION INSULATORS

Special rod type insulators each having a dry arcing distance of 20 inches and a leakage distance of 37 inches were used in the following test. Each rod type insulator was substantially equivalent to a string of three standard suspension insulators having a 5-3/4 inch spacing.

Corona

DEVELOPMENT OF CORONA SHIELDS
FOR
SUSPENSION ASSEMBLIES OF BUNDLED CONDUCTOR TRANSMISSION LINES

Joseph Kaminski, Jr.

The task of keeping pace with consumer electrical power requirements has required the development of power stations with single unit capacities in excess of 250,000 kw. These huge concentrations of generating capacity must be located in areas where the economic feasibility will justify their investment. Often times each plant location will not be properly disposed with respect to load centers, therefore, the transmission of large blocks of power economically, and the need of firming up transmission systems has led to the employment of extremely high voltage transmission lines.

Accompanying the increased voltage is the further necessity of determining proper size conductor for use with these higher voltages.

There are many problems to be considered and evaluated in the determination of the conductor to be selected. The problem includes both mechanical and electrical characteristics of the conductors. Proper sags and tensions, terrain and topographic features, structure design, and size all have an important bearing on the most economical conductor to be employed. Having even greater influence, however, may be load carrying capabilities, line reactance, stability considerations, and the corona power loss with disturbing radio and television interferences.

In order to successfully design transmission lines and adequately solve the problems with which he is confronted, the design engineer may find the use of single conductors in steadily increasing diameters reaching a practical limit. Consequently, a multiple number of smaller conductors per phase, spaced short distances apart, but metallically connected is gaining increasing prominence. This arrangement, popularly referred to as bundling, offers many advantages over single conductor per phase arrangements. The application of bundled conductors to transmission lines was first introduced in this country by Mr. Percy H. Thomas nearly fifty years ago.¹ A more complete consideration of the electrical characteristics of bundling was discussed in a paper presented at the Northeastern District Meeting of A.I.E.E. in May 1932, by Edith Clark entitled "Three Phase Multiple Conductor Circuits".² More recently analyses and investigations of the relationship between bundled conductor assemblies and radio interference has been made. This is reported in A.I.E.E. Transaction Paper "Colorado High Altitude Corona Tests, Part II, Insulators and Associated Hardware" by L. M. Robertson and A. D. Lantz.³ This latter paper deals primarily with a comparison between the R.L.V. and corona performance of shielded bundled assemblies and that arising from line conductors.

It is the purpose of this paper, however, to make investigations, studies and comparisons of corona onset voltages and radio influence voltages on various appurtenances for supporting bundled conductors on suspension assemblies and to develop methods for improving these characteristics.

EQUIPMENT AND MEASUREMENTS

Dictated by practical considerations, the scope of this study has been limited to a conductor suspension bundled arrangement with a sixteen inch horizontal displacement conductor center lines. The investigations feature the characteristic behavior of a 16 inch Iron Pipe Size thin wall aluminum (tubing) conductor having a 1.9" outside diameter. This selection was made to conform as nearly as possible to the diameters of transmission line conductors including armor rods presently being considered for use in bundled arrangements.

Mr. Kungstman

GENERAL ENGINEERING LABORATORY

SUPPLEMENT TO BIBLIOGRAPHY ON CORONA

by

J. E. Doolittle

Report No. DF56GL47

February 1, 1956

GENERAL  ELECTRIC



GENERAL ENGINEERING LABORATORY

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR Doolittle, J.E.	SUBJECT CLASSIFICATION Bibliography-Corona	NO. DF56GL47 DATE 2/1/56
TITLE SUPPLEMENT TO BIBLIOGRAPHY ON CORONA		
ABSTRACT Approximately 200 open literature references on corona have been accumulated. The references have been divided into eight subject classifications, and are listed chronologically in each classification. These references are a supplement to DF55GL80 entitled, "Bibliography on Corona" by J. W. Ryan.		
G.E. CLASS I	REPRODUCIBLE COPY FILED AT General Engineering Laboratory Library Schenectady, N.Y.	NO. PAGES 36
GOV. CLASS. None CONCLUSIONS		

For list of contents—drawings, photos, etc. and for distribution see next page (FN-610-2).

INFORMATION PREPARED FOR W. T. Starr

TESTS MADE BY _____

AUTHOR J. E. Doolittle

COUNTERSIGNED Aaron Cohen *Aaron Cohen* 2/10/56

SECTION Technical Literature Comp. LOCATION Schenectady, N.Y.

GL-16-B (4-52)

TELEVISION INTERFERENCE IN RURAL AREAS



U. S. DEPARTMENT OF AGRICULTURE RURAL ELECTRIFICATION ADMINISTRATION

DEC. 1951

GENERAL ENGINEERING LABORATORY

CORONA

By

B. V. Bhimani

Report No. 59GL11

January 13, 1959

GENERAL  ELECTRIC

Recent Radio Interference Investigations
High Voltage Transmission Lines

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OCT 19 1956

H. A. FREY

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APR 9 1956

H. A. FREY

G. E. Adams
Engineer, Analytical Engineering
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~~W B Weaver~~
~~R Heller~~
~~J Kaminsky~~
~~J M Jesette~~
~~R A Anderson~~
~~J C Voss~~
~~H J Walters~~
~~B E Kingsbury~~
~~R L McCoy~~
~~H A Frey~~

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GENERAL ENGINEERING LABORATORY

Mr. Kingsbury

Corona

TEST METHODS FOR CORONA, ARCING AND TRACKING INTERACTIONS WITH INSULATING MATERIALS

By

W. T. Starr
J. J. Hinchey
H. S. Endicott
M. W. Albright

Report No. R56GL180

September 26, 1956

GENERAL  ELECTRIC

GENERAL ELECTRIC

General Engineering Laboratory

SCHENECTADY, NEW YORK

TECHNICAL INFORMATION SERIES

TRACKING
RESISTANCE

CORONA
TESTING

CORONA
RESISTANCE

ARC
RESISTANCE

AUTHOR W.T. Starr J.J. Hinchey H.S. Endicott M.W. Albright		SUBJECT CLASSIFICATION Dielectric - Tab 8		NO. R56GL180	
				DATE Sept. 26, 1956	
TITLE Test Methods for Corona, Arcing and Tracking Interactions with Insulating Materials					
ABSTRACT This report contains three formalized test methods and one descriptive report intended for submission to the Corona Resistance and Arc Resistance Sections of the "American Society for Testing Materials".					
G.E. CLASS I		REPRODUCIBLE COPY FILED AT LIBRARY OF GENERAL ENGINEERING LABORATORY SCHENECTADY, NEW YORK		NO. PAGES	
GOV. CLASS. None					
CONCLUSIONS The "Dust and Fog" test rates electrical insulations with respect to their suitability for use in wet, contaminated atmospheres. The method was developed in the Lynn Measurements Laboratory and it belongs in ASTM. The test methods for measuring the resistance of insulations to corona grew out of our work on a Navy contract with the development of ASTM methods as one of its objectives. The test method for corona measurements is not new to GE engineers except in a few details. E.B. Curdts and C.W. Ross of Biddle Company are the original authors. An arc resistance test method which provides a better measure of insulation quality in certain arcing conditions than ASTM D-495-48T is also included.					

FORMATION PREPARED FOR _____

TS MADE BY _____
 HOR W. T. Starr *W.T. Starr* H. S. Endicott *H. S. Endicott* M. W. Albright *M. W. Albright* J. J. Hinchey *J. J. Hinchey*

INTERSIGNED P. D. George *P.D. George* J. A. Coffman *J.A. Coffman*

MPONENT _____
 Insulation Properties - Chemistry and Metallurgy

Part I

Corona

and its Effect on Insulation

—a Résumé

By T. W. Liao, Consulting Engineer, High Voltage Laboratory, Transformer Division, General Electric Company, Pittsfield, Mass.

Foreword: This article tells what corona is and how it occurs, as well as covering its inception and effect on insulation. Corona in electrical equipment is also discussed. The paper reviews the subject of corona and its effects based on some of the pertinent published articles in this field. The references cited give leads to many findings which broaden what is briefly discussed here. This article is of a comprehensive nature primarily written for the users and manufacturers of electrical and electronic equipment who are not very familiar with the subject.

What Corona Is

Once, a questionnaire was sent to several people asking them to give their description of what "corona" is. There were a variety of answers such as: (1) corona gives a hissing sound and an ozone smell; (2) corona is a bluish glow discharge in air; (3) corona is an electromagnetic phenomenon causing radio interference; (4) corona is a form of ionization in a piece of electrical equipment sometimes causing damage to its insulation; and (5) corona is the luminous envelope surrounding the sun, seen only during a total eclipse. Apparently the last statement came from an astronomer. All of these answers are right and strangely, there are many more right answers, each signifying a method of sensing or detecting the phenomenon known as "corona." However, this article will deal primarily with the subject matter of the fourth answer—

corona is a deadly enemy to electrical insulation.

How Corona Occurs

Corona can occur only in insulating media such as air or other gases, oil or other liquids, and paper or other insulating materials. Under normal conditions, all such substances consist of myriads of neutral molecules and a relatively small number of free harmless electrons bearing negative electric charges. However, under high electric stress, the electrons are accelerated to such high speeds that by virtue of collision, they can break up the neighboring neutral molecules into two types of charged particles—positive ions and more free electrons which in turn can break up more neutral molecules. This chain reaction gives rise to millions of

free ions and electrons existing in a turbulent condition, called corona, which manifests itself in many different ways.

Corona Inception

The question of how high an electric stress this chain reaction will start is of great importance to the design of an electrical system. For instance, the critical voltage (V_c) for a transmission line of smooth conductors in terms of the spacing between conductors (S), the radius (r), and the air density (d) is given by¹:

$$V_c \text{ (KV rms to neutral)} = 123 \text{ rd log } \frac{S}{r}$$

For a more complicated system, in which corona may occur in an air gap between solid insulating materials, the corona starting voltage can be determined by means of a graph^{2,3} as shown in Figure 1. For an electrode system consisting of two 1/2-inch diameter square edge electrodes on opposite sides of a sheet of insulation, the voltage (V_c) at which corona starts on the surface of the insulating materials is given by⁴:

$$V_c \text{ (V-rms)} = 720 \left(\frac{t}{k} \right) 0.46$$

Internal Corona Spaces in Cables

Manometric Detection of Internal Corona and Autographic Mapping of Corona Spaces

D. W. KITCHIN
ASSOCIATE MEMBER AIEE

O. S. PRATT
NONMEMBER AIEE

Synopsis: This paper describes two methods of studying corona spaces in cables between insulation and conductor. The manometric method makes it possible to determine the internal corona level unambiguously. Effects of outside electrical disturbances are excluded. There appears to be no upper voltage limit to the applicability of this test. It is performed by observing on a sensitive manometer the pressure decrease inside the cable that results from absorption of oxygen activated by corona discharge. These studies have been carried out principally with polyethylene, but also with rubber, polyvinyl chloride, silicone, Teflon, and glass. In the autographic method silver is deposited on all copper surfaces accessible to the silver cyanide solution. This clearly maps the projection of the corona spaces on the conductor. The method is extremely simple and the results are direct and conclusive.

IN THE MANUFACTURE, and especially in the development of high-voltage cables, it is necessary to be able to measure the voltage at which corona, or ionization, occurs. Discharges can take place outside the insulation, in voids entirely within the insulation, or between insulation and conductor. If there is strand shielding, corona may exist between this and the insulation wherever they are separated, for example, by severe bending.

Much interest is attached to the problem of eliminating internal corona spaces between insulation and conductor. The conventional method at present is to use semiconducting strand shielding. This is done on the theory that the insulation is not sufficiently tight on the conductor, or at any rate may become so loosened during installation that corona spaces are formed. The other approach to this problem is to try to apply the insulation in such a way that it remains tight even

after bending at least as severe as any likely to occur during installation. Whether or not this has been accomplished in any particular case seems at present to be a matter of conjecture based on results of indirect tests. If real progress is to be made it is necessary to have an unambiguous means of detecting this type of corona and distinguishing it from corona in other regions of the cable, or even from corona in the test equipment. The manometric test accomplishes this.

The autographic mapping applies only to cable without strand shielding. It marks distinctly those regions where there are gaps between conductor and insulation in which corona will occur above some threshold stress. It is a destructive test, but it requires only a few feet of sample, and it appears to be more sensitive than the manometric test. As evidence of presence or absence of corona spaces around the conductor it is conclusive. This paper is concerned exclusively with the detection of this type of internal corona, and with mapping the spaces where it can occur. All ratings and test voltages in this study are 60-cycle rms.

Principle of the Manometric Method

The manometric method differs from the customary corona tests in that it depends on chemical rather than electrical effects. The only electric equipment involved is the source of voltage.

When corona occurs in air spaces between conductor and insulation there is an immediate and irreversible decrease in internal gas pressure. It is convenient to call this "corona absorption." The rate of pressure drop increases rapidly as the voltage is raised above the onset value. If a stopcock is connected at one end of a cable and a sensitive manometer at the other, the pressure changes observed at various stresses can be used as a criterion of existence of internal corona.

Corona absorption is a result of the action of electrical discharges on the oxygen present in the corona spaces.

If the air is replaced by pure nitrogen there is no absorption even though severe corona is present. Traces of oxygen, whether residual oxygen, or oxygen that diffuses in through the wall, produce a detectable pressure drop as soon as there is internal corona. Two mechanisms can contribute to this pressure decrease: (1) chemical reaction of activated oxygen with the insulation, and (2) contraction resulting from the reaction $3O_2 \rightarrow 2O_3$. In cables with the usual organic insulation both actions probably occur, with chemical absorption the predominant one. Fortunately, an exact understanding of the chemistry is not necessary in order to take advantage of the phenomenon.

Whatever the mechanism, the manometric test provides an unambiguous criterion of internal corona. This method has been used successfully up to 120 kv on cables with polyethylene insulation. The upper limit is set only by the breakdown strength of the test sample or the power of the voltage supply. Cables insulated with polyethylene, rubber, silicone and polyvinyl chloride have been tested.

This test can reveal whether the insulation is originally tight, or the strand shielding effective, and how much bending a cable can tolerate without suffering a dangerous lowering of the internal corona level.

Principle of Autographic Mapping

Since corona in the spaces involved in this study manifests itself by a change in the manometer reading, these spaces must be connected by channels, so that they are accessible to a liquid. Wherever silver cyanide solution can contact the copper conductor a bright silver coating deposits. Thus gaps between insulation and the outside surfaces of a stranded conductor can be mapped, so that they can be examined or photographed after removal of the insulation. To make certain that the solution reaches the voids one end of the sample is connected to a vacuum pump while the other dips in the solution.

This method of detecting corona spaces is more searching than the manometric test. If in a given cable the amount of corona space is very small the pressure change resulting from corona absorption may be masked by fluctuations caused by variations in ambient temperature or pressure. The silver mapping method is free of these troubles. It can serve equally well where insulation having high dielectric loss would develop too much heat to permit use of the manometric test.

Paper 57-711, recommended by the AIEE Dielectrics Committee of the Communication and Electronics Division and approved by the AIEE Technical Operations Department for presentation at the AIEE Summer General Meeting, Montreal, Que., Canada, June 24-28, 1957. Manuscript submitted March 25, 1957; made available for printing April 26, 1957.

D. W. KITCHIN and O. S. PRATT are with the Simplex Wire and Cable Company, Cambridge, Mass.

Carona

~~Fred Vose~~

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AUG 21 1958

ENG. DEPT.

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>JL Wiesztort</i> JL Wiesztort	SUBJECT CLASSIFICATION 1. Insulators, Suspension 2. Radio Interference 3. Noise, Radio	NO. 59PT137 DATE 7/9/59
TITLE RADIO NOISE TESTS ON STANDARD AND PLASTIC ROD SUSPENSION INSULATOR STRINGS		

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GENERAL  ELECTRIC

TRANSFORMER DIVISION



TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>JL Wiesztort</i> JL Wiesztort		SUBJECT CLASSIFICATION 1. Insulators, Suspension 2. Radio Interference 3. Noise, Radio		NO. 59PT137
				DATE 7/9/59
TITLE RADIO NOISE TESTS ON STANDARD AND PLASTIC ROD SUSPENSION INSULATOR STRINGS				
ABSTRACT Reported are results of dry tests on 22 and 30 unit porcelain insulator strings and also on comparative lengths of new type plastic rod insulators. Incidental data on 34 and 45 standard unit strings are also included.				
G.E. CLASS IV M		REPRODUCIBLE COPY FILED TECHNICAL DOCUMENTS		NO. PAGES
GOV. CLASS None		Pittsfield, Works		10
CONCLUSION Listed below are radio noise results on the various configurations for 460 kv line-to-line (265 kv line-to-ground) and 650 kv line-to-line (375 kv line-to-ground)				
Type Units		Radio Noise (μvolts)		
		265 kv applied	375 kv applied	
22 - 15,000 lb.		200	580	
22 - 36,000 lb.		140	500	
30 - 15,000 lb.		150	340	
30 - 36,000 lb.		75	250	
4 - plastic rod		65	7500	
5 - plastic rod		65	80-3500	
6 - plastic rod		90	105	

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents-drawings, photos, etc. and for distribution see reverse side.

INFORMATION PREPARED FOR EHV / J. J. LaForest

TESTS MADE BY JL Wiesztort, J. Stevens Tests Completed: 4/24/59

COUNTERSIGNED HE Fiegel *X/E. Fiegel* SECTION High Voltage Laboratory

BUILDING and ROOM No. 9-102 LOCATION Pittsfield, Mass.

ENGINEERING LABORATORY

Corona

ACTIVITIES IN CORONA STUDIES,
MEASUREMENT AND DEVELOPMENT SINCE JANUARY 1957

BY

V.R. MULHALL

DQF58AD-11

12 JUNE 1958

CANADIAN GENERAL ELECTRIC COMPANY LIMITED
APPARATUS DEPARTMENT



CANADIAN GENERAL ELECTRIC COMPANY LIMITED

APPARATUS

DEPARTMENT

TECHNICAL DATA

Title Page

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SEE NEXT PAGE.

AUTHOR V.R. MULHALL	SUBJECT CLASSIFICATION INSULATION CORONA TESTING	NO. DQF58AD-11
		DATE 12 JUNE 58
TITLE ACTIVITIES IN CORONA STUDIES, MEASUREMENT AND DEVELOPMENT SINCE JANUARY 1957		
ABSTRACT THIS REPORT SUMMARIZES ACTIVITIES IN CORONA STUDIES - MEASUREMENT AND DEVELOPMENT SINCE JANUARY 1957, AS A CONTINUATION OF THAT REPORTED IN DQF57AD-5, DATED 30 JANUARY 1957. THESE ACTIVITIES INCLUDE REVISION AND MODIFICATION OF		
CGE CLASS II	REPRODUCIBLE COPY FILED AT ENGINEERING LABORATORY PETERBOROUGH WORKS CANADIAN GENERAL ELECTRIC CO LTD	NO. PAGES 43
GOV. CLASS NONE		
XXXXXXXXXX LABORATORY TEST EQUIPMENT, EXPERIMENTAL EVALUATION OF CORONA IN A NUMBER OF SYSTEMS AND PRODUCTS, STUDY OF CORONA LITERATURE AT MORE DEPTH, AND LIAISON WITH ACTIVITIES WITHIN THE COMPANY, AND IN ORGANIZATIONS SUCH AS A.S.T.M., A.I.E.E., C.E.M.A., ETC. OSCILLOGRAMS ARE INCLUDED AND DESCRIBED, AND FUTURE PLANS INDICATED.		

For list of contents — drawings, photos, etc., see next page.

ATION PREPARED FOR ENGINEERING INFORMATION

DE BY R.E. TURNER, S.A. SAGE, V.R. MULHALL

V.R. MULHALL *V.R. Mulhall*

SIGNED V.R. MULHALL

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Mr. King

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MAY 28 1956

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GENERAL ENGINEERING LABORATORY

Corona

PULSE DISTRIBUTION ANALYZER FOR CORONA ANALYSIS

by

W. T. Starr

L. W. Johnston

Report No. R55GL294

October 10, 1955

GENERAL  ELECTRIC

PULSE DISTRIBUTION ANALYZER FOR CORONA ANALYSIS

ABSTRACT

This report describes a new instrument which can determine the amplitude distribution of electrical pulses generated by corona discharges. The corona signal is fed from a wide band amplifier to the "Pulse Distribution Analyzer" which counts the number of pulses that fall within a specified band width. This band (or window) can be continuously moved from 0 until the largest pulse amplitude has been reached, counting only those pulses whose amplitudes fall at any voltage in this range. The pulse distribution is displayed on an oscilloscope. The amplitude of the pulses being counted positions the trace on the X axis of the oscilloscope. A count rate voltage, proportional to the number of pulses whose amplitudes fall within the window, positions the trace on the Y axis of the oscilloscope. Photographs are shown of the pulse distribution of corona produced using melamine glass laminate stressed at 8,400 volts and of corona produced using polyethylene stressed at 7,000 volts.

CONTROL OF CORONA AND RADIO INFLUENCE VOLTAGE ON DISCONNECTING SWITCHES FOR 330 KV

J. B. OWENS*
MEMBER AIEE

INTRODUCTION

The development of electrical equipment for operation at 330,000 volts has placed new emphasis on the problem of control of visual corona particularly as it relates to radio influence. The close relation between the start of corona and the threshold of radio influence has been demonstrated, 1, 2 and the maintenance of satisfactory levels of radio noise depends upon proper attention to corona control in apparatus design. The widespread use of television receivers in fringe areas has intensified this problem.

This design of disconnecting switches to operate at this voltage required the development of several new shielding techniques for various switch components. A new switch has been tested which demonstrates a high corona starting voltage and an exceptionally low level of radio influence at normal operating voltages. The data gathered on effective shield sizes, and the techniques employed, may well find application on other high voltage apparatus.

PRELIMINARY TESTS

Work by Pakala and Fahrnkopf in the Trafford laboratory of the Westinghouse Electric Corporation to determine the radio influence threshold voltage for conductors of various diameters was of great value in determining the design specification for a switch to operate at 330 kv. Their work indicated that a stranded dry conductor requires a 1/2 inch minimum radius to achieve an r.i. threshold of 330 kv. To allow for adverse effects of rain and field discontinuities in practical switch design a one inch minimum radius was established for all unshielded parts.

To determine the proper termination of a tubular switch blade standing vertically in the open position, a test was made using a 3-inch outside diameter tube 13 feet in length mounted on an insulator column of seven 14-1/2 inch high insulator units. The tube was vertical and its upper end was approximately 30 feet below the ceiling beams in a shielded room. Spun brass spheres of various diameters were attached to the end of the tube and the start of visual corona determined with the following results:

SPHERE DIAMETER INCHES	CORONA STARTING VOLTAGE KV
3	175
5	227
6	285

* Westinghouse Electric Corporation, East Pittsburgh, Pa.

GENERAL  ELECTRIC

Corona

General Engineering Laboratory

RADIO NOISE REDUCTION WORK ON D-C MACHINES

P. C. Gardiner

June 12, 1951

SCHENECTADY, NEW YORK

FOR USE OF G-E EMPLOYEES ONLY



GENERAL ENGINEERING LABORATORY

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR Gardiner, P.C.	SUBJECT CLASSIFICATION Radio Noise in D-c Machines	NO. DF51GL103 DATE June 12, 1951
TITLE Radio Noise Reduction Work on D-c Machines		
ABSTRACT Radio noise is broadly discussed in the introduction. Present technical knowledge in coordination with representative results from recent work is presented. Probable effective means of future basic radio noise reduction are suggested and discussed. A list of references is included.		
G.E. CLASS III	REPRODUCIBLE COPY FILED AT General Engineering Laboratory Library, Schenectady, N.Y.	NO. PAGES 12
GOV. CLASS. None		
CONCLUSIONS Information given is basic for definite gradual design changes that will result in substantial radio noise reduction in d-c machines.		

For list of contents—drawings, photos, etc. and for distribution see next page (FN-610-2).

INFORMATION PREPARED FOR High Voltage & Nucleonics Division

TESTS MADE BY T.J. Perkins, K.L. Scofield, P.C. Gardiner and others.

AUTHOR P. C. Gardiner

COUNTERSIGNED G. W. Dunlap

DIVISIONS High Voltage & Nucleonics

LOCATION Schenectady, New York

C. W. F.

*Mr. J. W. Ryan
c. King
Feb
Kearney*

GENERAL ENGINEERING LABORATORY

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APR 13 1955

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BIBLIOGRAPHY ON CORONA

by

J. W. Ryan

Data Folder No. DF55GL80

February 10, 1955

GENERAL  ELECTRIC



GENERAL ENGINEERING LABORATORY

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR Ryan, J.W.	SUBJECT CLASSIFICATION Bibliography- Corona	NO. 55GL80 DATE 2/10/55
TITLE Bibliography on Corona		
ABSTRACT Approximately 500 references on Corona have been accumulated. The references are listed chronologically in sections. An author index is included. The references listed here are a composite of the bibliographies of Dr. Cobine and P. Elson. (DF-53GL116)		
G.E. CLASS II GOV. CLASS.	REPRODUCIBLE COPY FILED AT General Engineering Laboratory Library	NO. PAGES 73
CONCLUSIONS		

For list of contents—drawings, photos, etc. and for distribution see next page (FN-610-2).

INFORMATION PREPARED FOR W. T. Starr

TESTS MADE BY Elson, Cobine

AUTHOR Ryan, J.W.

COUNTERSIGNED R. L. Francisco *R. L. Francisco*

SECTION _____ LOCATION _____



ts at the Coldwater ehv test
n up to 350 kv to ground, the
measurement on each phase.

Carson
Fred C. Vore

ONTARIO HYDRO

Research News

Vol. 11

No. 1

JANUARY - MARCH, 1959



Coupling capacitor for radio-noise measurements at the Coldwater ehv test project, in assembly stage. Designed for operation up to 350 kv to ground, the capacitor will be movable for convenience of measurement on each phase.

GENERAL ELECTRIC COMPANY

INSULATOR DEPARTMENT

Technical Report No. IK-659-DR

September 29, 1959

SUBJECT

CORONA AND RIV TESTS ON BUNDLED CONDUCTOR ASSEMBLIES

Joseph Kaminski, Jr.

This report contains:

5 typewritten pages

7 curves

3 drawings

Baltimore, Maryland

Signed

Joseph Kaminski, Jr.

Approved

Fred C. Vase

Corona

1-18-60

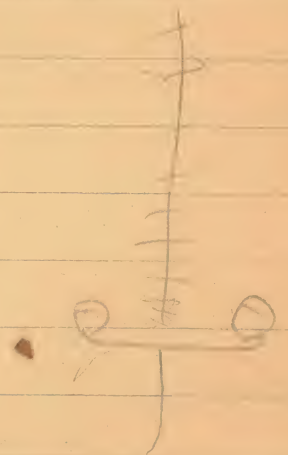
- 1- Caps. near Oil Tank - 383 KV. - 65 yv.
- 2- " away (5'') fin " " - 396 KV. - 65 yv.
- 3- with extension tube for caps. supported with rope - 347 KV. 35 yv.
- 4- Glass rope away from sphere - camera off end of sphere @ 343 KV. -
- 340 KV. - 30 yv.
- 5- Sphere removed, and large shield used. - Glass rope supporting for time.
Ferris - -75 to 90 yv. @ 402 KV.
Stod. - -20 to 85 yv. @ 402 KV.

Background N.L. curve, set up same as (5)

Ferris

Stod.

KV.	Black (yv.) Scale	Rdg. (yv.)	x
801	35	40	1
351	40	50	1
361	45	55	1
370	60	65	1
380	65	70	1
389	70	75	1
402	80-100	7 to 9	10



6- Setting No. 1 - 34-1840 S - 300KV. - 80-100 yv. @ 402 KV. - 50 yv.

31	47	63	78	93	108	116	124	(Ring up)
100	131	201	280	301	351	375	402	Vertical
12	22	27	35	100	275	350	375	
35	40	45	45	7-9 ¹⁰	18-20 ¹⁰	30 ¹⁰	23 ¹⁰	
100	201	301					402	(Ring down)
100 yv.	30	100					550	
100 yv.	50	20 ¹⁰					50 ¹⁰	

Corona

GENERAL ELECTRIC COMPANY

INSULATOR DEPARTMENT

Technical Report No. LK-665-DR

May 23, 1960

SUBJECT

Visual Corona and RIV Tests
On Bundled Conductor Assemblies

Joseph Kaminski, Jr.

This report contains:

3 typewritten pages
2 curves
1 test result

Baltimore Maryland

Signed

Joseph Kaminski Jr.

Approved

Fred C. Vose

GENERAL ELECTRIC

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>L. Graham</i> L. Graham	SUBJECT CLASSIFICATION 1. Radio Interference 2. Corona 3. Conductors, Elect.	NO. 60PT150 DATE 7/28/60
TITLE EFFECT OF GREASE AND ARTIFICIAL AGING ON THE CORONA START AND RADIO NOISE FROM CURLEW TRANSMISSION LINE CONDUCTORS		
ABSTRACT Corona start and radio noise tests were made on a 1.246" dia. solid aluminum conductor and on Curlew (1.246" dia.) ACSR transmission line conductors with their surface conditions either clean, artificially aged, greased or organic material applied over grease coat.		
G.E. CLASS IV	FILE COPY AVAILABLE IN THE WILLIAM STANLEY LIBRARY, PITTSFIELD	NO. PAGES
GOV. CLASS None	Pittsfield Works	10
CONCLUSION 1. In general, all aging operations performed on the conductors reduced the corona start voltages. 2. The greatest reduction in corona start voltage was obtained when organic material was applied over a grease coated conductor.		

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents-drawings, photos, etc. and for distribution see reverse side.

INFORMATION PREPARED FOR PROJECT EHV / J.J. LAFOREST

TESTS MADE BY C. Reilly, L. Graham Tests Completed: 4/21/60

COUNTERSIGNED H.E. Fiegel *H.E. Fiegel* SECTION High Voltage Laboratory

BUILDING and ROOM No. 9-102 LOCATION Pittsfield, Mass.

-mjb

B. E. Kingsbury
Corona

GENERAL ELECTRIC COMPANY
INSULATOR DEPARTMENT

August 8, 1960

Technical Report No. LK-671-DR

SUBJECT

VISUAL CORONA AND RIV TESTS
ON
460 KV SINGLE AND BUNDLED CONDUCTOR ASSEMBLIES

This report contains:

4 Typewritten Pages
1 Data Sheet
5 Curve Sheets

Baltimore, Maryland

Signed

Joseph Kaminski Jr

Approved

Fred C. Vane

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GENERAL  ELECTRIC

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>L. L. Jandran</i> LF Jandran		SUBJECT CLASSIFICATION 1. Transmission Lines 2. Noise, Radio	NO. 60PT155 DATE 9/19/60
TITLE Radio Noise and Leakage Current Investigation of Wooden and Concrete Transmission Line Tower Members and their Associated Hardware			
ABSTRACT Reported are the results of radio noise and leakage current measurements made on wooden and concrete tower members with a ground wire and various combinations of hardware.			
G.E. CLASS IV M		FILE COPY AVAILABLE IN THE WILLIAM STANLEY LIBRARY, PITTSFIELD	NO. PAGES
GOV. CLASS None		Pittsfield Works	16
CONCLUSION The results of these tests are presented in the tables of the report.			

By cutting out this rectangle and folding on the center line, the above information can be fitted
into a standard card file.

For list of contents-drawings, photos, etc. and for distribution see reverse side.

 INFORMATION PREPARED FOR Project EHV / J.J. LaForest

 TESTS MADE BY LF Jandran, LJ Wiesztort

 Tests Completed: 1/4/60

 COUNTERSIGNED HE Fiegel *H E Fiegel*

 SECTION High Voltage Laboratory

 BUILDING and ROOM No. 9-102

LOCATION

Pittsfield, Massachusetts

-mfw

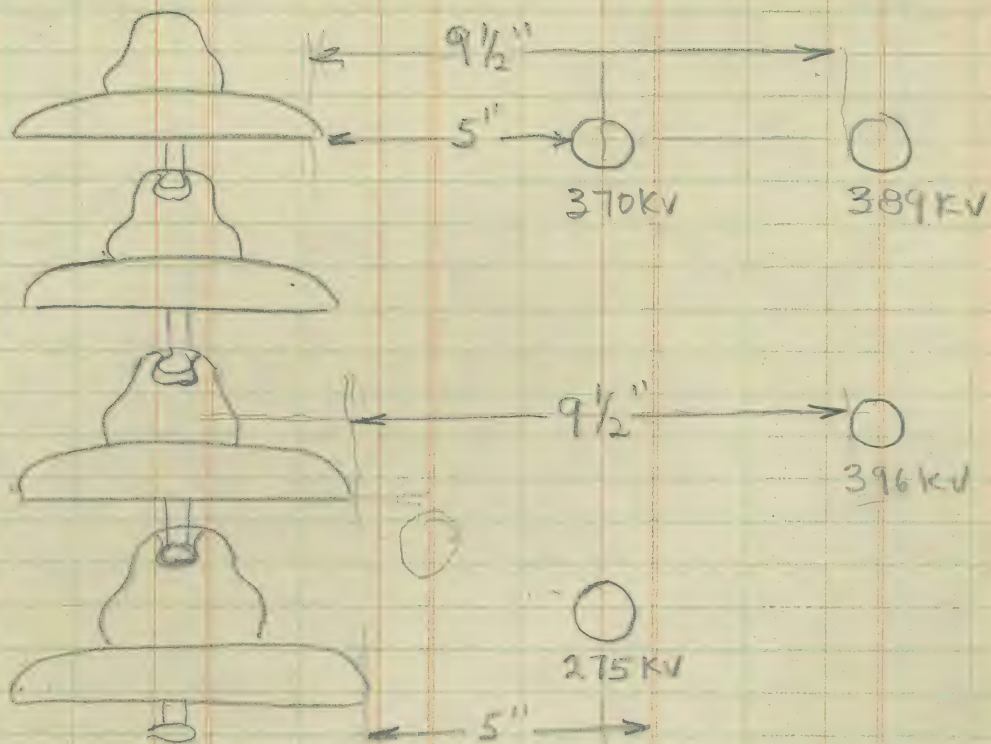
Corona

47

38

19

4-Strings
outside string



11 1/2
14 3/4
17 1/2



GENERAL ELECTRIC COMPANY
INSULATOR DEPARTMENT

August 8, 1960

Technical Report No. LK-671-DR

SUBJECT

VISUAL CORONA AND RIV TESTS
ON
460 KV SINGLE AND BUNDLED CONDUCTOR ASSEMBLIES

This report contains:

4 Typewritten Pages
1 Data Sheet
5 Curve Sheets

Baltimore, Maryland

Signed

Joseph Kaminski Jr

Approved

Fred C. Vore

GENERAL ELECTRIC COMPANY

INSULATOR DEPARTMENT

Technical Report No. LK-659-DR

September 29, 1959

SUBJECT

CORONA AND RIV TESTS ON BUNDLED CONDUCTOR ASSEMBLIES

Joseph Kaminski, Jr.

This report contains:

- ✓ 5 typewritten pages
- ✓ 7 curves
- 3 drawings

Baltimore, Maryland

Signed

Joseph Kaminski, Jr.

Approved

Fred C. Vase

DISCUSSION OF CONFERENCE PAPER NO. 60-1273

"EFFECT OF BUNDLED CONDUCTOR FIELD

INFLUENCE ON E. H. V. TRANSMISSION

LINE DESIGN"

BY

R. W. HARMON
THE OHIO BRASS COMPANY
BARBERTON, OHIO

DISCUSSION BY:

R. L. MC COY
AND
J. KAMINSKI
INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY
BALTIMORE, MARYLAND

OCTOBER 12, 1960

INDEX FOR: CONDUCTORS (Trans. & Distrib) (See Corona)

Number	Title	Author	Company	Date
-6307-17	CONDUCTOR SPACERS FOR HIGH AND EXTRA HIGH TWIN OR MULTIPLE CONDUCTOR TRANSMISSION LINES		A. Salvia & Co. Milano, Italy	
	HIGH VOLTAGE TEST REPORT - 500 KV THREE CONDUCTOR SUSPENSION ASSEMBLIES		Betha Co. Birmingham, AL	
(2)	BUNDLED CONDUCTORS		General Electric Baltimore, MD	
	EHV BUNDLED CONDUCTOR SPACER		Clevite Corp. Milan, Ohio	
IEEE 51-195 (2)	COMPARISON OF HEATING EFFECTS & POWER LOSSES BETWEEN FORGED STEEL & FORGED ALUMINUM (MPL) SUSPENSION CLAMPS	Rensselaer Poly. Inst.		
IEEE 51-294	CURRENT CARRYING CAPACITY OF ACSR CONDUCTORS	JH Wagborne VE Ogorodnikov	Hydro-Elec Power Co	5/11/51
IEEE 52-252	INCREMENTAL METHOD FOR SAG-TENSION CALCULATIONS	M. Landau	Dept of Water & Power Los Angeles, CA	7/6/51
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IEEE 55-153	MEASUREMENT OF RESISTANCE AND REACTANCE OF EXPANDED ACSR	J. Tompkins BL Jones PD Tuttle	Aluminum Co of Am Massena, NY	2/16/55
IEEE 55-159	JOINT TESTING FOR HIGH VOLTAGE TRANSMISSION LINES	AS Runciman H. Westman	Shawinigan Water Montreal, Canada	2/16/55
	A METHOD FOR DETERMINING ECONOMICAL ACSR CONDUCTOR SIZES FOR DISTRIBUTION SYSTEMS	AW Funkhouser RP Huber	Indianapolis P & L Indianapolis, In	2/16/55
	THE USE OF AND EXPERIENCE WITH BUNDLED CONDUCTOR LINES	NH Erlandson	Carolina P & L Raleigh, NC	4/7/55
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IEE 56-213	PROGRESS REPORT ON THE INVESTIGATION OF GALLOPING OF TRANSMISSION LINE CONDUCTORS	AT Edwards A. Madeyski	Hydro-Elec Pow Com Toronto, Ont. Canada	2/15/56
IEE 56-222	THE CALCULATION OF THE RADIO INTERFERENCE LEVELS OF TRANSMISSION LINES CAUSED BY CORONA DISCHARGES	GE Adams	General Electric Schenectady, NY	2/15/56
IEE 56-706	PRESENT PRACTICES IN ELECTRICAL AND MECHANICAL DESIGN OF BUSES FOR EXTRA HIGH VOLTAGE SUBSTATIONS	Work Group Project 53.1	AIEE	7/11/56
IEE 57-156	CONDUCTOR ECONOMICS ON HIGH-VOLTAGE TRANSMISSION SYSTEMS	JM Henderson AJ Wood	General Electric Schenectady, NY	2/6/57
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IEE 58-191 CP	DEVELOPMENT OF CORONA SHIELDS FOR SUSPENSION ASSEMBLIES OF BUNDLED CONDUCTOR TRANSMISSION LINES	J. Kaminski	General Electric Baltimore, MD	2/19/58
IEE 58-191 CP	THE RESISTANCE & REACTANCE OF ALUMINUM CONDUCTORS, STEEL REINFORCED	WA Lewis PD Tuttle	IL Inst of Tech ALCOA Research Lab	11/18/57
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CP IEE 61-823	THERMAL LIMITS OF OVERHEAD CONDUCTORS AT VARIOUS METEOROLOGICAL CONDITIONS	JA McEllyea	Illinois Power Co Decatur, IL	4/24/61
CP IEE 61-813	THE ELECTRICAL PROPERTIES OF SINGLE-LAYER ALUMINUM CONDUCTORS, STEEL-REINFORCED (ACSR), HAVING SINGLE STEEL CORE WIRES WITH HEAVY ALUMINUM COATING	CH Jensen RE demuth RW Mowery	Copperweld Steel Battelle Mem Inst Columbus, OH	4/25/61
IEE 61-1090	CONDUCTOR VIBRATION - A STUDY OF FIELD EXPERIENCE	CB Rawlins KR Greathouse RE Larson	ALCOA Massena, NY	8/18/61
ELECTRICAL WORLD CP IEE 62-107	CHART FINDS TRANSMISSION GRADIENT FACTOR	KW Schmidt	Winnipeg, Manitoba Canada	5/14/62
IEE 62-284	SAG & TENSION CALCULATIONS BY THE NOMOGRAPHIC METHOD	RH Sarikas	Illinois Power Co	12/20/61
CP IEE 62-251	FAULT & LOAD CURRENT TESTING OF A BUNDLE CONDUCTOR SPACER	RL Retallack TR Fry CA Popeck	Am Elec & Power AB Chance Centralia, MO	12/11/61
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CP IEE 63-1075 (2)	ON THE DESIGN OF BUNDLE CONDUCTOR SPACERS	AT Edwards JM Boyd	Hydro-Elec Power Toronto, Ont. Canada	4/19/63
Report #2	CONDUCTOR CHARACTERISTICS FOR 1000/1100-KV A-C TRANSMISSION	LO Barthold	General Electric	8/20/63
IEE 31 PP 66-307	A PROPOSED FRICTION DAMPER FOR GALLOPING CONDUCTOR WAVES	AH Kidder	Phila Electric Co Philadelphia, PA	3/22/66
IEE 69 CP 8- PMR	EVALUATION OF SPACERS FOR BUNDLED CONDUCTOR TRANSMISSION LINES	RA Krahn MB Bessler	US Dept Interior Bureau of Reclamation Denver, Colorado	10/13/68

ALUMINUM COMPANY OF CANADA LIMITED
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A. SALVI & C.
C.C.I.A. Milano N. 75138Via Cosenz, 32
Telef.: 97.05.61 - 97.05.95

MILANO

Telegr.: SALVIFI
Raccordo Ferr.: BOVISTA-NORDCONDUCTOR SPACERS FOR HIGH AND EXTRA HIGH TWIN OR MULTIPLECONDUCTOR TRANSMISSION LINES.CONSIDERATIONS.

- 1 - The problem of Spacers for multiple conductor installation for high and extra high transmission Systems is certainly of equal if not of superior importance in the choice of fittings.
- 2 - The experience about Spacers in the international field is still limited and so little known, and the opinion so contradicting among electrical line Engineers, that it is not possible to draw statistical data, which might be taken as a basis for the projecting and the choice of Spacers, which may give ample certainty of dependable service operation, also under the most precarious climatic conditions.
- 3 - The report of an experienced French Engineer, after the tests carried out on a twin experimental horizontal line, is really not very encouraging, and its conclusions give once more great evidence to the above problem.
- 4 - It is believed that the pessimism of many well known Engineers, specialized in the construction of high transmission lines, is due to the fact that they have not been able, so far, to dispose of Spacers summarizing all the necessary requirements.

The troubles which have been disclosed in those countries where multiple conductor lines have been built, have however permitted to determinate the characteristics a dependable Spacer should have to embody.

- 5 - Our own experience in this field has led us to the conviction that a reliable Spacer should summarize the following main requirements:
 - a) - The clamps connected with the conductors must absolutely avoid any slipping, also under the action of most violent wind, irregular snow and ice overloads.

BETHEA COMPANY, INC.
BIRMINGHAM, ALABAMA

HIGH VOLTAGE TEST REPORT
500 KV THREE CONDUCTOR
SUSPENSION ASSEMBLIES

REPORT NO. T-6307-17

NO. _____

BETHEA COMPANY, INC.
BIRMINGHAM, ALABAMA

HIGH VOLTAGE TEST REPORT
500 KV THREE CONDUCTOR
SUSPENSION ASSEMBLIES

REPORT NO. T-6307-17

FOR: _____

Corona

Insulator Department

BUNDLED
CONDUCTORS

General Electric Co.

GENERAL  ELECTRIC

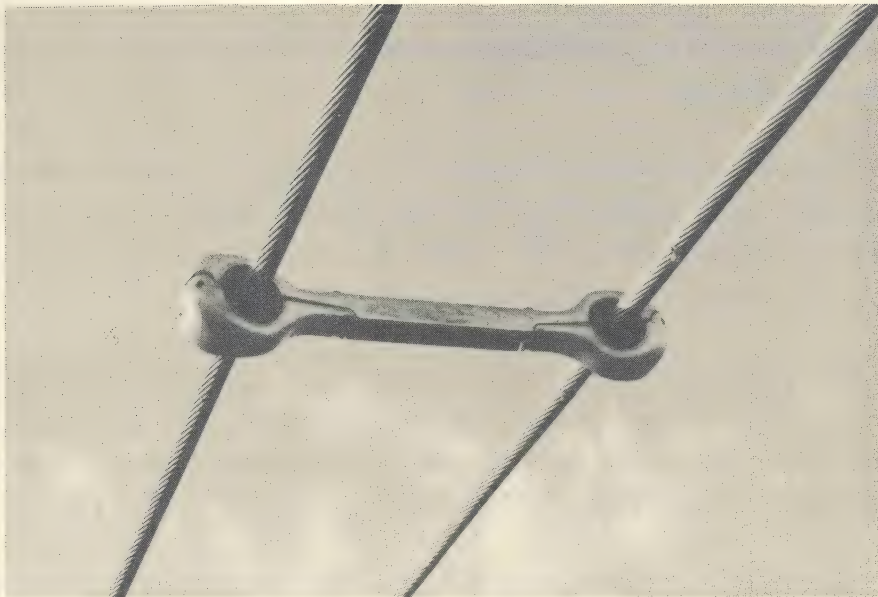
BUNDLED CONDUCTORS

GENERAL  ELECTRIC

CLEVITE
CORPORATION

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EHV BUNDLED CONDUCTOR SPACER

COMPARISON OF HEATING EFFECTS & POWER
LOSSES BETWEEN FORGED STEEL & FORGED
ALUMINUM (MPL) SUSPENSION CLAMPS.

May 1951
Litho in USA



CURRENT CARRYING CAPACITY OF ACSR CONDUCTORS

J. H. Waghorne
Nonmember AIEE

V. E. Ogorodnikov
Nonmember AIEE

Both of:
The Hydro-Electric Power Commission of Ontario
Toronto, Ont., Canada

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J. H. Waghorne
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V. E. Ogorodnikov
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STRUCTURE LIMITATION CHARTS FOR TRANSMISSION LINES

Thomas M. Austin
Member AIEE
Bureau of Reclamation,
Denver, Colo.

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Transactions Paper

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Conductions



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MEASUREMENT OF RESISTANCE AND REACTANCE OF EXPANDED ACSR

Joel Tompkins
Member AIEE

B. L. Jones
Associate Member AIEE

P. D. Tuttle
Associate Member AIEE

All of:
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Massena, N. Y.

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55-98

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Conference Paper

Conductor



JOINT TESTING FOR HIGH VOLTAGE TRANSMISSION LINES

A. S. Runciman
Member AIEE

H. Westman
Associate Member AIEE

Both of:
The Shawinigan Water and Power Co.
Montreal, Que., Canada

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A METHOD FOR DETERMINING ECONOMICAL ACSR CONDUCTOR SIZES FOR DISTRIBUTION SYSTEMS

A. W. Funkhouser
Associate Member AIEE

R. P. Huber
Nonmember AIEE

Both of:
Indianapolis Power & Light Co.
Indianapolis, Ind.

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55-159

Discussion in Duplicate Due February 16, 1955.

THE USE OF AND EXPERIENCE WITH BUNDLED CONDUCTOR LINES

By

N. H. Erlandson, Transmission Engineer
Carolina Power & Light Company
Raleigh, North Carolina

Before Transmission & Large Substation Committee Meeting,
Engineering & Operation Section, Southeastern Electric
Exchange, New Orleans, Louisiana, April 7 & 8, 1955

GENERAL

Although bundled conductors are usually associated with transmission lines of 230 KV and above, our Company has made use of this type of construction as an economical means of handling increased loads on two existing transmission lines in the lower voltage class.

This paper will outline the reasons for the selection of bundled conductors on two of Carolina Power & Light Company's 110 KV transmission lines; some of the problems involved, which are common to bundled conductor lines irrespective of whether or not they are used in the high voltage class or as we made use of this type of construction; and our operating experience with these two lines.

ADVANTAGES OF BUNDLED CONDUCTORS

Some of the advantages offered by the use of bundled conductors as a means of handling increased loads on these two lines, as compared to other plans which were considered, all of which were the single-conductor type of construction, are as follows:

1. Lower construction cost.
2. The reuse of the existing conductor fittings and other accessories. This advantage was of real importance as it eliminated the return of these items to the Warehouse and the possibility of a slow turnover, and possible junking of the fittings and accessories.
3. A reduction in reactance in the order of 25%. Although this factor is of greater importance in the high voltage lines, it was still a very important factor in our application.

In addition to the above major factors, bundling offered the following advantages:

1. A reduction in conductor temperature for a given current value due to the increased surface area of multiple conductors.
2. An increase in capacitance to neutral.

BUNDLED CONDUCTORS FOR
TRANSMISSION CAPACITY INCREASE

By

H. L. Deloney

&

W. L. Rush

Louisiana Power & Light Company
New Orleans, Louisiana

The possibilities of using "Bundled Conductors" for increasing transmission line capacity had long intrigued us as being a means of augmenting capacity of some 2000 miles of 115 KV Transmission lines already in service and on new lines to be built in the future. So in the spring of 1951 we started an investigation to determine its feasibility. We had as a starting point, certain information available concerning some "Super-Voltage" applications in foreign countries where bundling of three or more conductors per phase had been employed to solve the corona problem, but had no information as to the use of "bundling" on lower voltage transmission for capacity purposes.

Determining electrical performance data for comparison with single conductor per phase construction was a matter of mathematics. The following tabulation will illustrate some of the electrical data for 115 KV "H" frame construction using different combinations of ACSR conductor sizes:

Type of Line	Weight Lbs/mile	Resistance Ohms/Mile 25°C	Reactance Ohms/Mile 0 Amps	Charging Micromhos per Mile	Approx. Current Carrying Capacity Amperes
Bundle 2-2/0	5820	.353	.685	6.90	540
Bundle 2-4/0	9252	.223	.657	7.07	680
Bundle 2-336.4 MCM	14652	.139	.591	7.24	1060
Bundle 1-2/0 1-336.4 MCM	10236	.219	.632	7.07	790
Bundle 1-4/0 1-336.4 MCM	11952	.185	.619	7.11	845
Standard 2/0 Line	2910	.706	.902	4.93	270
Standard 4/0 Line	4626	.445	.872	5.09	340
Standard 336.4 MCM Line	7326	.278	.799	5.30	530
Standard 666.6 MCM Line	13581	.147	.760	5.58	800

Note: (A) All bundle conductor lines use a 9" subconductor spacing
(B) Equivalent phase conductor spacing is 17.6 ft.

To determine some of the mechanical and magneto-motive effects, we decided to build about three spans of bundled constructions using 336,400 CM ACSR conductors for tests. Test conductors were pulled in on a section of readily accessible transmission circuit having span lengths of approximately 510'. Tests consisted of various current values with phase conductor spacings of 6, 9 and 12 inches with both horizontal and vertical conductor arrangements. The following Curves show the values at which conductors pulled together, or just held, after being brought together:

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RELATIONSHIP BETWEEN CORONA AND
RADIO NOISE ON TRANSMISSION LINES, LABORATORY STUDIES
PART I - POINT AND CONDUCTOR CORONA

T. W. Liao
Member

For Presentation as a Conference Paper at the 1956
General Winter Meeting of the AIEE

February 3, 1956

Conductors

Transactions Paper

(Reviewed and Accepted for Publication)



PROGRESS REPORT ON THE INVESTIGATION OF GALLOPING OF TRANSMISSION LINE CONDUCTORS

A. T. Edwards
Nonmember AIEE

A. Madeyski
Nonmember AIEE

Both of:
The Hydro-Electric Pwr. Com. of Ont.
Toronto, Ont., Canada

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(Reviewed and Accepted for Publication)



THE CALCULATION OF THE RADIO INTERFERENCE LEVEL OF TRANSMISSION LINES CAUSED BY CORONA DISCHARGES

G. E. Adams
Associate Member AIEE
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Schenectady, N. Y.

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Conductor

PRESENT PRACTICES IN ELECTRICAL AND MECHANICAL DESIGN OF BUSES FOR EXTRA HIGH VOLTAGE SUBSTATIONS

Working Group on Project 53. 1
of the
AIEE Committee on Substations

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The following are members of the Working Group on Project 53. 1:
F. C. Vose, Chairman; J. W. Erven, W. H. Fong, R. F. Gibbons, R. A. Harvie, S. C. Killian, A. H. Powell, J. A. Smith, R. F. Stevens, D. W. Taylor, C. P. Zimmerman.

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(Reviewed and Accepted for Publication)



*Vose
Kingsbury
Kaminishi
Weller
Jeatho
Walter
Weaver*

CONDUCTOR ECONOMICS ON HIGH-VOLTAGE TRANSMISSION SYSTEMS

J. M. Henderson
Associate Member AIEE

A. J. Wood
Associate Member AIEE

Both of:
General Electric Company
Schenectady, N. Y.

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57-156

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District Conference Paper



SOME ASPECTS OF SURFACE VOLTAGE GRADIENT ON POWER TRANSMISSION LINES

H. B. Dwight
Fellow AIEE
Massachusetts Institute of Technology
Lexington, Mass.

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Paper No. **DP**

57-533

Insulator Department

BUNDLED
CONDUCTORS

General Electric Co.

GENERAL  ELECTRIC

BUNDLED CONDUCTORS -- INDEX

Characteristic Sheet No. 1473 - #18360 Suspension Insulator
Characteristic Sheet No. 1479 - #18250 Suspension Insulator
Characteristic Sheet No. 1478 - #18251 Suspension Insulator
Characteristic Sheet No. 1480 - #18252 Suspension Insulator
Dwg. U-93206 - Single Suspension Bundled Conductor with Corona Shield
Dwg. U-93204 - Bundled Conductor Corona Shield
Dwg. U-93205 - Dead End Bundled Conductor
Dwg. U-93207 - Dead End Bundled Conductor
Dwg. V-43659 - Socket Eye
Dwg. V-43668 - Socket Clevis
Dwg. V-43657 - Ball Clevis
Dwg. V-43634 - "Y" Clevis Socket
Dwg. V-43633 - "Y" Clevis Ball
Dwg. U-93152 - Bundled Conductor Spreader
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Record of Tests - Radio Influence Voltage - Bundled Conductor Assemblies - Dwg. 1
Record of Tests - Radio Influence Voltage - Bundled Conductor Assemblies - Dwg. 2

Guide to RG-/U Cables

Kahn-Conductors

M. GOLDSTEIN, *Electronics Engineer, American TV, Inc., Chicago, Ill.*

The following tabulation of RG-/U Cable characteristics has been compiled from various manufacturers' literature and presents a cross-section of the values contained therein. For the sake of completeness, all available RG-/U numbers have been listed. Thus, the listings include waveguides and stub or bead supported coaxial lines. For RG-/U waveguide characteristics, the reader is referred to the Rigid Waveguide Standards and Comparisons chart that appeared on p. 51 of the Dec. 1956 issue of ELECTRICAL DESIGN NEWS.

Cable covering and conductor information has been listed in order from outermost covering to innermost conductor. The "Armor" is a metallic (usually aluminum) braid which protects the outer jacket of the cable against abnormally severe abrasion. The "Jacket" protects the cable from moisture, weather abrasion, and other mechanical and electrical effects. Jacket materials, as listed in the tabulation, are:

- C. Tube* Copper tube
- Chloro* Chloroprene
- Fiberglas* Fiberglas braid impregnated with a high temperature silicone varnish for operation to 500F.
- Kel-F* Extruded Trifluorochloroethylene. Operates from -370F to +390F and has a high chemical resistance.
- Lead* Lead sheath.
- L. T., Black* Non-contaminating thermoplastic for use at low temperatures (to -40C).
- Neoprene*
- Nylon* Extruded black nylon.
- Poly* Polyethylene.
- Rubber*
- "Teflon"* Tetrafluoroethylene. Operates from -100F to +500F. Has virtually no water absorption.
- Vinyl, Black* ... Polyvinylchloride (Vinylite) with a non-resinous plasticizer. Migration of the plasticizer may contaminate the dielectric,

thereby increasing attenuation and reducing the breakdown voltage.

Vinyl, Grey Non-contaminating Polyvinylchloride with resinous plasticizer.

The dielectric materials as listed are:

- Copo* Copolene, a combination of polystyrene and polyisobutylene.
- M.O.* Magnesium oxide.
- Poly* Extruded solid polyethylene.
- Rub* Synthetic rubber.
- SS Poly* Semi-solid polyethylene (air-spaced).
- SS "Teflon"* Semi-solid "Teflon".
- "Teflon"* Extruded tetrafluoroethylene. Has low losses, high breakdown voltage and good efficiency at high temperatures. "Teflon" dielectric is usually covered with one or two silver-coated or plain copper shield braids and two wrappings of "Teflon" tape for a moisture seal.
- "Teflon" T* "Teflon" tape.

Abbreviations employed for the inner conductors and the shield braids are as follows:

- C* Copper
- CW* "Copperweld" (copper covered steel wire).
- CWS* Silver coated "Copperweld."
- CWT* Tinned "Copperweld."
- F* Formex F, wound in helix.
- K* "Karma" wire.
- N* Nichrome
- S* Silver coated copper.
- T* Tinned copper.
- T and Galv*
- Steel* Three braid: tinned copper, galvanized steel, tinned copper.

(Continued on page 38)

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Transactions Paper

(Reviewed and Accepted for Publication)



DEVELOPMENT OF CORONA SHIELDS FOR SUSPENSION ASSEMBLIES OF BUNDLED CONDUCTOR TRANSMISSION LINES

J. Kaminski, Jr.
Member AIEE
General Electric Co.
Baltimore, Md.

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., February 2-7, 1958. Manuscript submitted October 14, 1957; made available for printing November 7, 1957.

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58-57

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Conference Paper



THE RESISTANCE AND REACTANCE OF ALUMINUM CONDUCTORS, STEEL REINFORCED

W. A. Lewis
Fellow AIEE
Illinois Institute of Tech.,
Chicago, Ill.

P. D. Tuttle
Member AIEE
Alcoa Research Laboratories
Massena, N.Y.

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58-191

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~~J. M. Jants~~
~~J. E. Jones~~
~~W. J. Jackson~~
~~B. E. Humphrey~~

W. A. Lewis
Fellow AIEE

P. D. Tuttle
Member AIEE

Please substitute the attached text for pages
29 to 31 inclusive of the original draft and
add APPENDIX IV between APPENDIX III and
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H. A. FREY

Conference Paper

Conductors

A
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I

THE MAGNETIC PROPERTIES OF ACSR CORE WIRE

L. W. Matsch
Fellow AIEE

University of Arizona
Tucson, Arizona

W. A. Lewis
Fellow AIEE

Illinois Institute of Technology
Chicago, Illinois

A paper submitted in abstract form only to the AIEE
Transmission and Distribution Committee for the AIEE
Winter General Meeting, New York, N.Y., February 2-7,
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58-360

Graduate

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>W.A. Keen, Jr.</i> W.A. Keen, Jr. <i>A.J. Damasca</i> A.J. Damasca	SUBJECT CLASSIFICATION Fields, Electrical Conductors, Electrical	NO. 58PT228 DATE 4-23-58
TITLE Electrolytic Field Analysis of Bundled Conductors In a Cylindrical Conductor		

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR <i>W.A. Keen, Jr.</i> W.A. Keen, Jr. <i>A.J. Damasca</i> A.J. Damasca	SUBJECT CLASSIFICATION Fields, Electrical Conductors, Electrical	NO. 58PT228 DATE 4-23-58
TITLE Electrolytic Field Analysis of Bundled Conductors In a Cylindrical Conductor		
ABSTRACT The electrolytic field analyzer was used to study the field near the conductors enclosed in a grounded cylindrical tank. The gradient distributions were determined for 2, 3, and 4 conductor bundles.		
G.E. CLASS III - M GOV. CLASS None	REPRODUCIBLE COPY FILED TECHNICAL SERVICE DIV. PITTSFIELD Pittsfield, Massachusetts	NO. PAGES 19
CONCLUSIONS 1. Surface gradients are distributed on the periphery of the conductors sinusoidally with the maximum gradients on the front side of the conductors in the area nearest the grounded cylinder. 2. The gradients on the inside of the bundle are not only lower than those on the outside of the bundle, but also decrease at a faster rate as the radial distance from the conductor increases.		

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For list of contents-drawings, photos, etc. and for distribution see reverse side.

INFORMATION PREPARED FOR Electrical Performance - Systems Research - P.T. Engineering

TESTS MADE BY W. A. Keen, Jr., A. J. Damasca

COUNTERSIGNED T. R. Walters

T.R. Walters
 Electrical Research
 High Voltage Laboratory

TRANSFORMER & ALLIED PRODUCT DIVISIONS

9 - 316

PITTSFIELD, Massachusetts

July 1951
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INCREMENTAL METHOD FOR SAG-TENSION CALCULATIONS

Maurice Landau
Member AIEE
Department of Water and Power
The City of Los Angeles
Los Angeles, Calif.

Advance Copy
Not Released for Publication

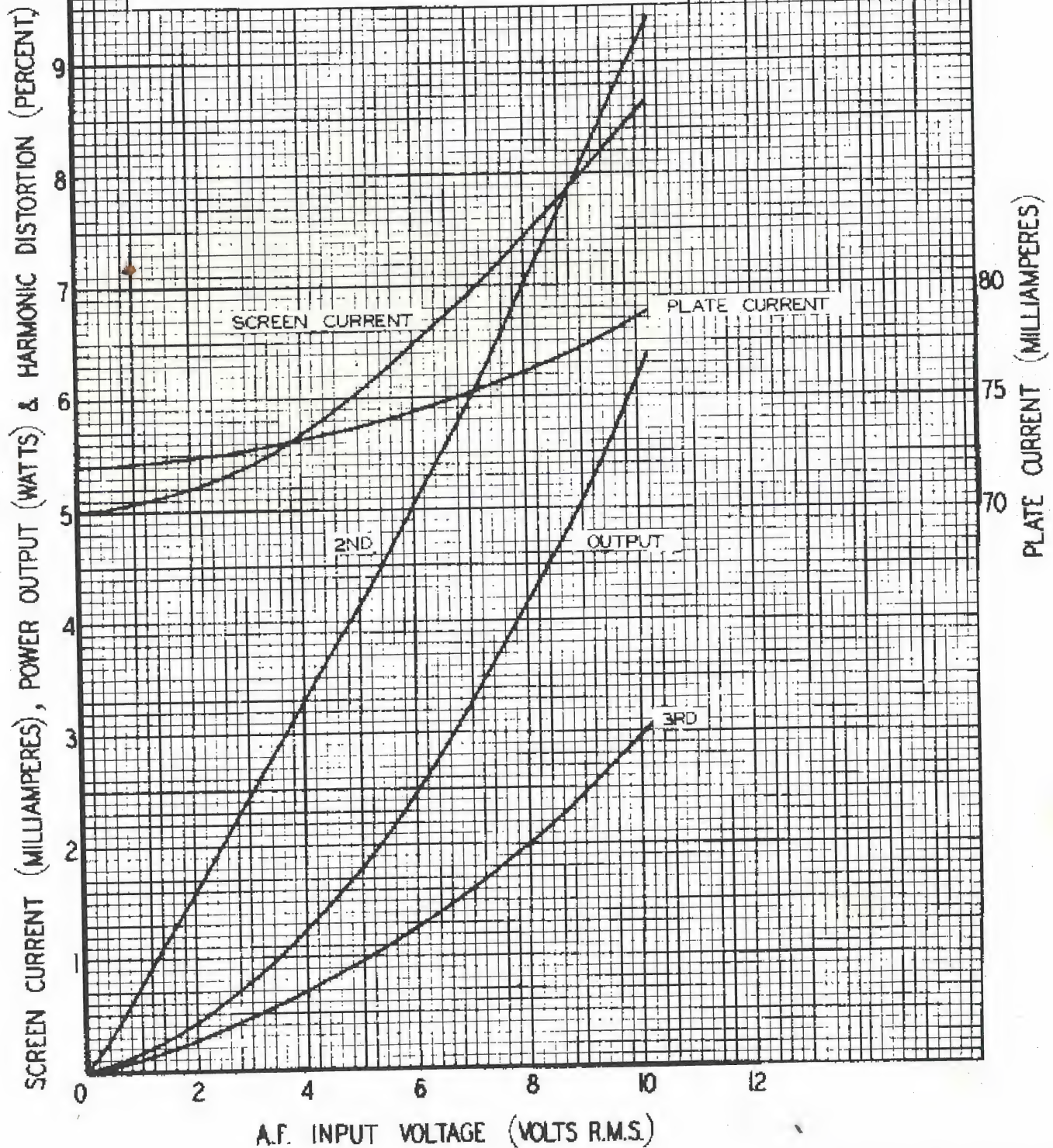
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A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, Portland, Oregon, August 20-23, 1951. Manuscript submitted May 17, 1951; made available for printing July 6, 1951.

PRICE: 30¢ To Members
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VALVE TYPE 807
CLASS "A" AMPLIFIER
POWER OUTPUT, DISTORTION, SCREEN CURRENT
& PLATE CURRENT VERSUS
A.F. INPUT VOLTAGE

PLATE VOLTAGE = 250 VOLTS
SCREEN VOLTAGE = 250 VOLTS
CONTROL GRID VOLTAGE = -14 VOLTS
PLATE LOAD = 2,500 OHMS



GENERAL ELECTRIC

INSULATOR DEPARTMENT
2525 Insulator Drive
Baltimore, Md. 21230



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R. Weller
J. Kaminski

File - BEK

February 3, 1967

Mr. J. J. LaForest
PITTSFIELD

As I discussed with you about ten days ago, we are interested in determining whether or not our standard suspension insulator, as per the attached drawing U-1840, can be designed to be more corona-free than is now the case.

Let me digress for just a moment to give you a little background on the overall problem. As you know, our scope of business covers all types of line hardware, such as clamps, yoke plates, and fittings, as well as insulators. In fact, we are concerned with the entire assembly which supports the power conductor to the tower. Sometimes a customer specification will demand that the assembly, when subjected to a given voltage, will have less than a specified amount of RIV. At other times the specification will demand that there be no corona at the specified test voltage. The third possibility is that both a specified RIV level and no visual corona will be required at the test voltage level.

Generally speaking, it is quite feasible to design an assembly to meet the RIV levels specified, and the hardware parts can also be designed to meet the visual corona requirements. But, it becomes quite impossible to design to eliminate visual corona from the insulators, even when using quite elaborate shielding (grading rings). The amounts of visual corona on the insulators do not usually cause very much noise (RIV), at least in comparison with the noise caused by a brush discharge on a piece of hardware.

See the attached curve sheet which shows a generalized plot of RIV versus Test Voltage. The lower section of the curve will be created solely by insulator noise, and the upper part by corona on hardware parts. Usually, the RIV, as caused by the insulators, is about as shown, increasing linearly with test voltage.

As far as I am concerned, where there is RIV there must be corona (at least 10-15 microvolts). Then, the question arises, can we correlate the visual corona levels on the insulators with the RIV curves? The answer is no. The visual corona levels obtained on the insulators depend upon a variety of things such as how dark the laboratory is, how good the observers vision is, and how long the observer has waited to allow his eyes to adjust to the darkness. This situation has created some

INSULATOR DEPARTMENT
GENERAL ELECTRIC COMPANY

April 3, 1964

RADIO INTERFERENCE FROM E. H. V.
TRANSMISSION LINES AND SUBSTATIONS

ML-9, Tabs L and N

As most of you are by now already aware, the subject of radio noise generated by conductors and insulator assemblies on E. H. V. transmission lines has been one which has been very controversial for some two or three years and there has undoubtedly been a tendency to go way overboard by many utility and consulting engineering organizations in the specification of very severe corona and radio influence voltage requirements on insulator assemblies of all kinds.

This undoubtedly has arisen from the fear that E. H. V. lines may produce tremendous amount of radio interference and thus be a cause of poor public relations between the utility and people living in areas adjacent to or near E. H. V. transmission lines.

The relationship between radio influence voltage on insulator components measured in the laboratory on a directly coupled basis to the radio field intensity which these devices would produce on the line has not been well understood in the past and it now appears that radio noise suppression on insulator assemblies and components has in most cases been greatly overemphasized far beyond the actual needs.

At the inception of E. H. V. work in the early years after World War II, with the almost complete lack of knowledge and understanding about these things, the concept was that insulator assemblies should never show any visible or audible corona at a voltage at least 10% above line to neutral voltage and that the R. I. V. on the components as measured in the laboratory should be held at 50 to 100 microvolts or lower when the assembly was energized at 110% of line to ground voltage. This has resulted in a lot of costly designs with all components made with either large and bulky radii at the edges or else has involved rather complete and thorough shielding.

More recently, these R. I. V. specifications for insulator assemblies for E. H. V. projects have been somewhat liberalized where specifications have permitted the R. I. V. levels to go to 350 to 500 microvolts at voltages applied equal to 110% of the maximum line to ground operating voltage.

It now becomes apparent that these liberalized specifications are requiring much better performance radio interference wise than is actually needed, which is causing the cost of insulator assemblies to be higher than is necessary for the actual performance of the line.

In the final analysis, the utility building an E. H. V. circuit is concerned with what the radio interference field is at the edge of the transmission line right-of-way, usually 100 to 150 ft. from the centerline of the transmission circuit.

*Mr. Joseph Kaminski, Jr.
Insulator Dept.
Baltimore*

Transactions Paper

(Reviewed and Accepted for Publication)

Discussion in Duplicate Due February 19, 1965.



THE EFFECT OF STATION RADIO NOISE SOURCES ON TRANSMISSION LINE NOISE LEVELS

J. J. LaForest
Senior Member IEEE
General Electric Company
Schenectady, N. Y.

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A paper recommended by the IEEE Transmission and Distribution Committee of the IEEE Power Group for presentation at the IEEE Winter Power Meeting, New York, N. Y., January 31-February 5, 1965. Manuscript submitted November 2, 1964; made available for printing December 8, 1964.

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Pittsfield, January 24, 1964

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JJ LaForest
F Olsen

"CONTRIBUTION TO THE STUDY OF RADIO NOISE GENERATED BY MEDIUM VOLTAGE LINES"

By

MM. C. Gary and M. Moreau

Article from "Revue Générale de L'Électricité", October 1963, pages 503 to 518 Inclusive

Translation by D. D. MacCarthy

Giving account of work showing the possibility of evaluating the radio noise fields created by high frequency currents which are generated by insulators on medium voltage lines. In the first part, the authors analyze the process of forming these currents both in rigid insulators and then in suspension insulators; they show that the spectrum of the disturbing current is characterized by the line geometry and by the capacitance between the two metal parts of the insulator. An equivalent circuit of the insulator and line proves that they behave as a current generator injecting high frequency current in the two halves of the line on each side of the insulator. This current, determined by a series of laboratory tests, is the principal characteristic of insulator noise.

In the second part of the article, the authors reveal the possibility of obtaining correlation between the disturbance field measured under the medium tension line and the disturbance current injected in the line and determined from laboratory tests. A formula is established allowing the prediction of attenuation of the disturbance field in a direction perpendicular to the line as well as the absolute value of the disturbance field.

PART I: STUDY OF INSULATORS

Radio noise disturbances observed under lines of medium voltage cannot be attributed to the conductors, as is the case for high voltage lines, because the gradient to which they are subjected, of the order of 3 to 6 kv/cm, is much too low to generate, except during rain, leakage currents caused by corona. In the present work, we propose to demonstrate the possibility of evaluating the disturbance field of a medium voltage line due to the insulators, basing it on the laboratory measurements of the high frequency currents generated by the latter.

I. THEORETICAL STUDY OF INSULATORS.

Experience shows that the disturbance field of a medium voltage line does not vary in the same way, depending on whether the line is equipped with rigid [pin?] or suspension insulators: in the first case the disturbance field decreases markedly in fog or rain, whereas the opposite occurs beneath lines with suspension insulators. It seems then that insulators are, according to their type, the seat of different phenomena, phenomena that we are going to attempt to explain in what follows:

A. Rigid Insulators [pin type?]: - In the case of rigid insulators, the conductor is simply supported at the insulator neck by a lashing-like attachment, so that, if some portions of the conductor are in intimate contact with the insulator body, others must be separated by small air gaps. Because the insulation resistance is very high, it is justifiable to represent by independent capacitors the lines of force bordering on the zones of intimate contact and the lines of force bordering upon the air spaces. The same representation is valuable in the case of a defective insulator, where air gaps are caused



TECHNICAL INFORMATION SERIES

Title Page

AUTHOR JJ LA FOREST	SUBJECT CLASSIFICATION IV File 6-J	NO. DF-63-AD-51 DATE 12-23-63
TITLE THE EFFECT OF INSULATOR NOISE CURRENTS ON THE RADIO NOISE LEVEL OF A TRANSMISSION LINE		
ABSTRACT An analysis is made to show what the lateral radio noise profile would be for a 3-phase transmission line as a result of noise currents generated solely by the insulator strings. Typical cases for 345-, 500-, and 700-kv lines are examined. At distances generally used to evaluate the RI field from a transmission line, the effect of insulator noise currents is seen to be low.		
G.E. CLASS IV GOV. CLASS.	REPRODUCIBLE COPY FILED AT Pittsfield Works Project EHV	NO. PAGES 19
CONCLUSIONS The use of modal analysis has enabled the computation of the effect of insulator noise on the radio noise performance of a transmission line. The computation is facilitated by using eigen roots, field factors, and attenuation values obtainable from the General Electric Radio Noise Program. Values of insulator noise currents are obtained from laboratory tests. This analysis can also be used to determine the effect on line radio noise performance of point sources other than insulator strings such as station equipments.		

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For list of contents—drawings, photos, etc. and for distribution see next page (FN-610-2).

INFORMATION PREPARED FOR POWER SYSTEMS ENGINEERING OPERATION

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DIVISIONS _____ LOCATION Pittsfield, Massachusetts

Transactions Paper

(Reviewed and Accepted for Publication)

Discussion in Duplicate Due February 21, 1964.



RADIO NOISE STUDIES ON POWER LINES WITH THE CORONAPHONE

J. R. Leslie
Senior Member IEEE

H. O'Beirne
Member IEEE

Both of:
The Hydro-Elec. Pwr. Com. of Ontario
Toronto, Ont., Canada

A paper recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Winter Power Meeting, New York, N. Y., February 2-7, 1964. Manuscript submitted November 1, 1963; made available for printing December 4, 1963.

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Paper No.

64-52

411.—CORONA LOSS AND RADIO INTERFERENCE MEASUREMENTS AT HIGH VOLTAGE A.C. ON TEST LINES IN SWEDEN

by N. KNUDSEN,

Chalmers University of Technology
(Sweden)

SUMMARY

On a test plant erected by the Swedish State Power Board in connection with the Chalmers University of Technology in Gothenburg comprehensive corona tests have been carried out during the last years. Beside the general intention to broaden the theoretical and practical knowledge about the corona phenomenon there has been a special purpose namely to compare the behaviour of double and triple conductors of the types used in Sweden which contain cables with a diameter of 3,2 cm and a spacing of 45 cm.

The results of the experiment indicate that by use of triple conductors instead of double conductors the yearly losses, apart from ice losses, are reduced from about 1,4 kW/km to about 0,4 kW/km and the radio interference level is reduced by about 8 dB in fair weather, and probably somewhat more in bad weather. Expressed in another way the triple conductor has given approximately the same losses and radio disturbances at 460 kV as the double conductor at 400 kV.

Variations between 40 and 95 % in the humidity in the air did not seem to affect the losses noticeably but a slight decrease in radio interference with increasing humidity was observed. Bad weather has given increasing losses in the following order: fog, dry snow, rain, wet snow, hoar frost.

A method for calculating fair weather losses is proposed and future work is outlined.

SUSPENSION INSULATOR FLASHOVER
UNDER HIGH IMPULSE VOLTAGES

B. E. Kingsbury

Some of the unpredicted flashovers on high voltage transmission lines which have been experienced during the last few years have raised questions as to the flashover performance of suspension insulators when subjected to impulse voltages considerably higher than the normal critical impulse flashover value. There has been some indication that on some of these circuits the flashovers may have occurred due to very high impulse voltages of very brief duration. These have been commonly spoken of as steep wave front surges.

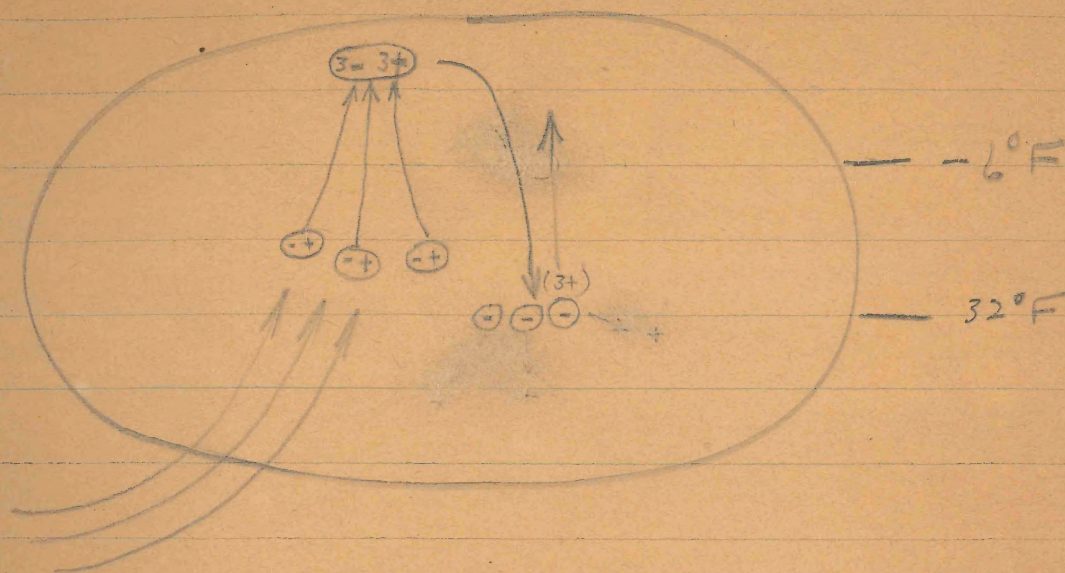
The rated impulse flashover voltage of a suspension insulator string is based upon the application of a 1-1/2 by 40 microsecond wave applied to the line end of the insulator string with the tower end grounded. This so called critical impulse flashover rating is the voltage at which an insulator string may be expected to flashover on 50% of the applications under standard test conditions.

On transmission structures which are protected by ground wire, it is most likely that the lightning discharge will occur to the tower or the ground wire so that the impulse is applied to the tower end of the insulator string, and, relatively, the conductor end may be considered to be grounded. There is some question as to whether the normal critical flashover voltages which are established in the laboratory by standard test methods properly measure the performance of an insulator string when subjected to this condition.

The curve, Figure 1, shows the normal critical impulse flashover voltage of insulator strings tested under standard laboratory conditions. In this curve, arcing distance is plotted as abscissa, and it is recognized that with a good degree of accuracy the flashover voltage of conventional suspension insulators

Theory of Cloud Charge

Lightning



The air stream moving in from lower left of cloud during a storm creates a strong updraft within the cloud and carries moisture vapor (which carries neutral charge) upward. As the vapor enters the cold stratum, condensation commences and the combination of droplets until they reach such size as their mass overcomes the air stream force and they fall. As the drops fall they may increase in size by recombination until they reach a critical size and split. Also by this time they might be back in the warmer cloud stratum and tend to evaporate (which is aided by the splitting). Upon ^{partial} evaporation of a water drop, there is left on the water drop a negative charge, and it necessitates then that there is a positive

CALCULATED
CURVE

EFFECTS OF GUNFIRE
ON INSULATING STRUCTURES
FORT MEADE FEB. 13, 1963

Baltimore, March 26, 1963

SUBJECT:

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On February 13, 1963, at Fort Meade, Md., our Engineering Section staged a test to determine the relative resistance of several insulating structures to gunfire. All firing was done by expert riflemen stationed at Ft. Meade. Tests were conducted on each of the following:

1. Lapp Strut Insulator, Cat. No. 73770, a 12 unit equivalent suitable for 230 kv application, 15,000 lb. ultimate tensile strength.
2. Locke Unispar, Cat. No. 18713, a 13 unit strut suitable for 230 kv application, 13,000 lb. ultimate tensile strength.
3. Locke unit-type Polymer suspension insulator (developmental) suitable for 69 kv application, 15,000 lb. ultimate tensile strength.

All shots were made at a distance of 60 feet. The guns and ammunition used were as follows:

1. 22 long rifle - 40 grain lead match bullet, velocity 1300 ft./sec.
2. 45 cal. service pistol - 230 grain lead match bullet, velocity 830 ft./sec.
3. 308 Magnum service rifle - 180 grain lead match bullet, velocity 2650 ft./sec.
4. 30 cal. type M-1 service rifle - 173 grain lead bullet, velocity 2640 ft./sec.

The first firings were made at the bottom of each insulator structure, and successive shots were made up the structure as to be hitting undamaged parts as the tests progressed.

The following series of photographs show the damage sustained by each of the insulators.



CURVE 10 LSV-1-A

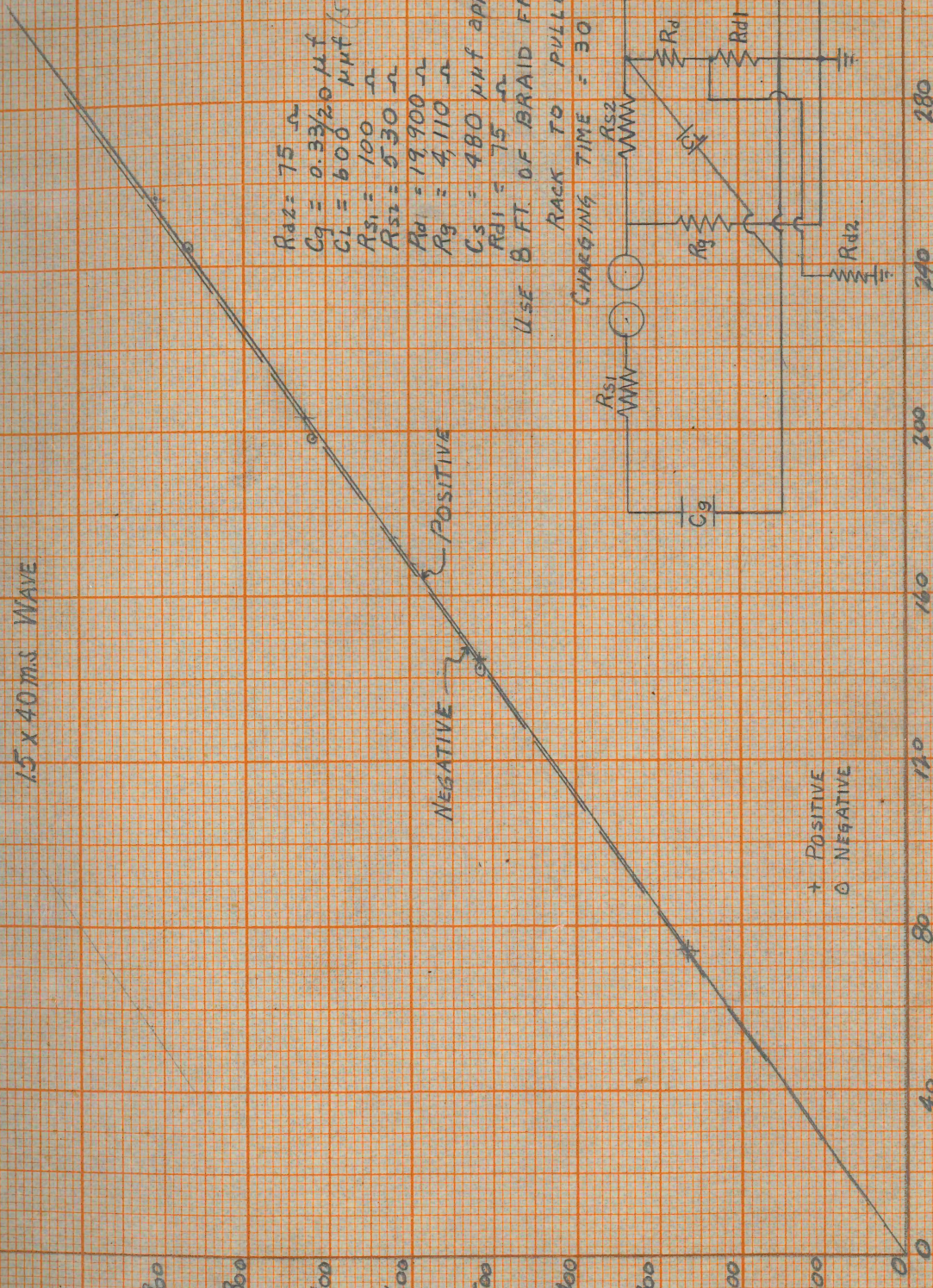
CALIBRATION CURVE FOR

10 UNIT GENERATOR

15 x 40 ms WAVE

KV
CREST

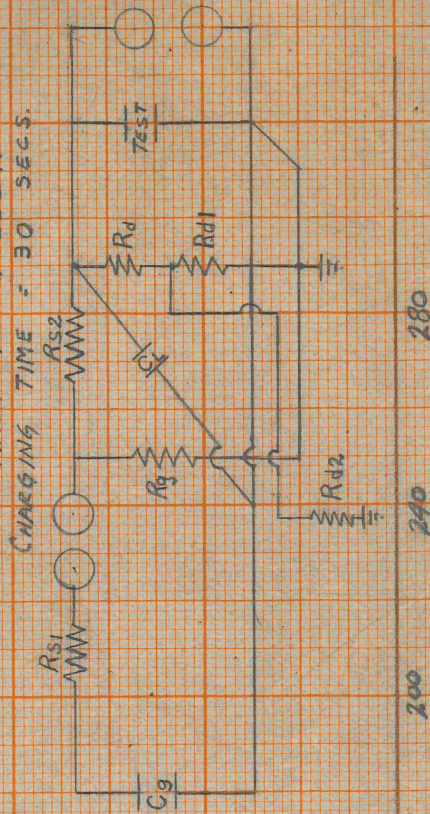
900
800
700
600
500
400
300
200
100
0



$R_{d2} = 75 \Omega$
 $C_g = 0.33/20 \mu f$
 $C_L = 600 \mu f$ (5 units)
 $R_{s1} = 100 \Omega$
 $R_{s2} = 530 \Omega$
 $R_{d1} = 19900 \Omega$
 $R_g = 4110 \Omega$
 $C_s = 480 \mu f$ approx
 $R_{d1} = 75 \Omega$
 USE 8 FT. OF BRAID FROM TOP OF R_g
 RACK TO PULLEY.
 CHARGING TIME = 30 SECS.

RESISTORS

18 - 30's
40 - 500's
33 - 12.5's



LOWER SIDE VOLTS (R.M.S)

+ POSITIVE
0 NEGATIVE

2-27-52
3-7-88
C.2.