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FEBRUARY 10TH, 1985
ENGLISH

Mexico.

TESTING OF POWER CABLES WITH EXTRUDED INSULATION

DP/MEX/82/011/11-54/31.9.C

M E X I C O

F I N A L R E P O R T

PPEPARED FOR THE GOVERNMENT OF MEXICO BY THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION ACTING AS EXECUTING AGENCY FOR THE UNITED NATIONS

DEVELOPMENT PROGRAMME

BASED ON THE WORK OF MANFRED J. HOELZER

CONSULTANT IN TESTING OF POWER CABLES WITH EXTRUDED INSULATION

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

VIENNA

ABSTRACT

Title: CONSULTANT IN TESTING OF POWER CABLES WITH EXTRUDED INSULATION.

Number of the Project: DP/MEX/82/011/11-54/31.9.C

Duration: Six months.
September 5th, 1984 to February 24th, 1985

Duty Station: Cuernavaca, (Morelos province), MEXICO

Purpose of Project: To assist Instituto de Investigaciones Eléctricas (IIE) in developing skills aimed at promoting quality aspects of locally manufactured electrical power instruments, machinery and associated products.

Main Conclusions:

1. In order to increase the quality of the products of the electrical industry -specifically the cable industry- the prompt application of the recommendations would be most advisable, although this seems not to be so easy in the actual given economical situation.

2. Undoubtedly Mexico has the optimal conditions to improve their own raw materials -indispensable for the production of these items- so as to diminish the present import.

3. Glass Fiber Optic Cables. Mexico's biggest company of glass fiber optic cables (CONDUMEX) produces this type of cables with up to 12 numbers of cores with the importation of glass fiber elements, joints and terminations and cutting devices.

With the support of highly specialized field experts, Mexico would be in the position to develop its own technology in the field of glass fiber optic cables.

Main Recommendations:

1. The establishment of a central national cable-testing laboratory for life-time tests and the evolution of aging techniques for a more efficient development of the cable industry.

2. When developing a semiconducting compound, it became obvious that the quality of the mexican raw materials have not yet achieved the required level.

   To obtain better results in this field in Mexico, it is essential that research and development should be urged for the refinement of mexican raw materials, in order to diminish the expensive importation. As a result, Mexico would count on a higher quality.

3. The potential to raise new generations of specifically trained specialists (preferably trained at the UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO and the INSTITUTO POLITECNICO NACIONAL).

CONTENTS

INTRODUCTION

According to the Job Description DP/MEX/82/011/11-54/31.9.C, the purpose of the project was to assist the Instituto de Investigaciones Eléctricas (IIE) in the development of skills aimed at promoting quality aspects of locally manufactured electrical power instruments, machinery and associated products.

The consultant's assistance at the Institute lasted from September 5th, 1984, to February 14th, 1985.

The consultant had the following duties:

1. To assist the envolved staff at IIE developing aging techniques for electric power cables; to stimulate normal operating conditions at an accelerated pace and thus obtain a standard of a usable lifespan of cables as well as of the residual lifespan of the cables in operation.

2. To prepare a comprehensive list of equipment items required in the cable laboratory for life testing of power cables. Quality control equipment is to be included.

3. To prepare a final report setting out the findings of his mission and listing recommendations for future operations of the cable laboratory.

The main activities of the consultant to perform the foreseen project, were:

1. Proposals of measuring equipments and electrical circuits for the evaluation of semiconductive materials.

2. Development of local (Mexico) materials for semiconductive shields used in power cables (electrical evaluation of the raw materials as well as the final product - 15 KV class).

3. Elaboration of a comprehensive list of equipment items destinated to a laboratory for life testing of power cables.

4. Contribution to the design, development and testing of a high voltage cable termination to be used in the 150 KV test circuit for pollution tests in the high voltage laboratory of the Materials Department.

5. Calculation and development of a tunable high voltage reactor for aging tests set for power cables (35 KV; 1000 Hz; 50 KVA).

6. Essential support at the development of a 35 KV, 2 kA wall bushing for the short circuit laboratory of Salazar (some kilometers to the west of Mexico City); these wall bushings will be manufactured using thermocontractil materials.

7. Quality testings of the insulation of transformer coils.

8. Lecture courses and seminars on cable technology and test methods (extruded insulations).

9. Visits to several factories and institutions, intending the improvement of quality of cables and transformers.

When arriving at the duty station on September 5th, the project was not yet as advanced as expected, which meant that all the above mentioned goals could not be reached during those six months, since there was not yet the necessary technical documentation available for the life-tests of electric power cables and no engineering group ready for cable testing and aging techniques research.

This situation was discussed extensively with the UNIDO JPO in Mexico City, considering the guiding principles of the briefing in Vienna. All activities of the consultant were directed to increase the quality of tests for locally manufactured electrical power instruments, machinery and associated products; especially for power cables and transformers.

During several concentrated talks with Dr. K. B. Wolf (UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO - IIMAS) and Dr. T. Seligman, Dr. M. Berrondo (INSTITUTO DE FISICA - UNAM), it became quite clear that research and development in the field of glass fiber optics in Mexico have to be centralized and intensified.

RECOMMENDATIONS

The recommendations as the result of the work done, are:

1. In Mexico there are 5 cable testing laboratories, i.e., each cable company with one, plus one at the IIE, which do all work independently; it would be advisable not only to have these institutions work together closely, but also to establish a central national cable-testing laboratory for life-time tests and the evolution of aging techniques, for a more efficient development of the cable industry.

   Conditions for research:

   1.1 Indispensable equipments (see list).

   1.2 Highly qualified specialists (preferably trained at the UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO).

   1.3 Potential to raise new generations of specifically trained specialists.

2. Research in the realization of life-time-tests to improve the quality of cable manufacturing materials.

   2.1 Research in the development of new test-methods for an independent efficient cable industry.

3. Better quality.
   In Mexico there are four cable companies:

   1) CONDUMEX
   2) CONELEC
   3) LATINCASA
   4) CONDUCTORES MONTERREY

CONDUMEX invited the consultant to conduct a symposium which counted with the assistance of highly interested engineers from all kinds of areas.

During this symposium, the consultant raised the question why cables in Mexico have only a guarantee of one year. Answer: Consumers generally do not make the appropriate use of the cables, as prescribed.

This seems to be a national problem. The recommendation would be a closer control on the usage of electric energy in general.

4. Further Development.

The Instituto de Investigaciones Eléctricas had already obtained the order from Condumex to develop a semiconducting compound for conductor -and insulation- shields to make the country independent from the costly importation from abroad.

When developing these compounds -with the direct involvement of the consultant- it became obvious that the quality of the mexican raw materials has not yet achieved the required level.

To obtain better results in this field in Mexico, it is essential that research and development should be urged for the refinement of mexican raw materials, in order to diminish the expensive importation. As a result, Mexico would count on a higher quality.

C H A P T E R I

ASSISTANCE TO THE INSTITUTO DE INVESTIGACIONES ELECTRICAS IN CUERNAVACA

A. ASSISTANCE TO THE DEVELOPMENT OF SEMICONDUCTIVE SHIELDS USED IN POWER CABLES

The work of the consultant was started under the following conditions:

- The Instituto de Investigaciones Eléctricas had already obtained the order by the mexican company CONDUMEX, to develop a semiconducting compound for conductor -and insulation- shields.

- The results of the so far developed compounds were not hundred per cent satisfactory.

- The equipments available are not the required ones for testing and measuring.

- These conditions made it necessary to concentrate the efforts on the following aims:

  a) The elaboration of proposals for measuring equipments and electrical circuits for the evaluation of semiconductive materials.

  b) To support the development of materials in Mexico of several semiconductive compounds.

  c) To carry out tests of newly developed semiconductive compounds.

During the development of these compounds, it became obvious that the quality of the mexican materials has not yet achieved the required level.

B. ASSISTANCE TO THE ESTABLISHMET OF A BASIC LABORATORY FOR AGING TESTS

- The consultant prepared a comprehensive list of equipment items for a basic laboratory.

- Some equipment items for the basic laboratory were already available, but there was no documentation of testing methods for aging tests.

- The implementation of this laboratory still requires the purchase of some foreign equipment, as well as of some locally made ones.

C. CONTRIBUTION FOR THE DESIGN, DEVELOPMENT AND TESTS OF A HIGH VOLTAGE CABLE TERMINATION

The consultant has contributed to the design, development and proposals for the testing of a high voltage cable termination to be used in the 150 KV test circuit for pollution tests in the high voltage laboratory.

Up to now, the above mentioned development is not yet concluded since some special materials, like-glass fibertubing- for instance, are needed and not yet available.

The IIE is trying hard to get this material, in order to continue the development.

D. CALCULATION AND DEVELOPMENT OF A TUNABLE HIGH VOLTAGE REACTOR

The IIE has asked the consultant to carry out a calculation and development of a tunable high voltage reactor for aging tests set for power cables (35 KV; 1000 Hz; 50 KVA).

After working out during three weeks in the calculation and design, it appeared that the IIE is not able to build up this reactor because, again, it needs special equipment and materials.

Conclusion: It is necessary to purchase this aging test set from a company, which could be HAEFELY, ASEA, or MICAFIL, for instance.

E. ASSISTANCE FOR THE DEVELOPMENT OF A WALL BUSHING

The consultant has given an essential support for the development of a 35 KV, 2 KA wall bushing to be used in the short circuit laboratory.

These wall bushings will be manufactured using thermocontractil materials.

Several tests were carried out with different thermocontractil materials. The results were positives and this development is almost concluded.

F. QUALITY TESTS OF THE INSULATION OF TRANSFORMER COILS

Several quality testings (particularly partial discharge test) of the insulation of dry-type-transformer coils were carried out by

the IIE (750 KVA; 500 KVA; 250 KVA; 23 KV/440 V - 250 V; 60 Hz) in the company IESA (INDUSTRIA ELECTRICA SOCIEDAD ANONIMA), and besides in the Instituto de Investigaciones Eléctricas also.

The results were showing that the measured values did not reach the required standard level, due to the quality of the used insulation material, the design and the process of manufacture.

For the further development of dry-type-transformers, this company will work together with the IIE.

G. PROBLEMS OF KNOWLEDGE IN THE FIELD OF POWER CABLE TESTS

In order to fulfil the conditions for adequate research in this field, it is fundamental tnat all the higher educational institutions (e.g. UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO; INSTITUTO POLITECNICO NACIONAL) review their educational programs and extend them in this direction, if possible, with specialists from abroad.

H. GENERAL REMARKS

The consultant met a very friendly and open atmosphere at the IIE. The engineering staff was very cooperative. On the other hand, the efficiency of the consultant's task might have been higher for several reasons:

As already mentioned in the introduction, the group for cable-testing-engineering had not yet been formed and did not have enough technical documentation. If the whole programme had been carefully planned before hand, the consultant's assistance would have been of more use.

The suggestion is that in the future, consultants should be informed with all the details concerning background information at the Institute, its work plans, organization, connection with the industry, Mexican Government decisions, etc.

The consultant took the initiative to visit some industries, other research institutions, universities, etc., as suggested in the job description.

It is also important that the Institute itself should organize seminars for the direct participation of new consultants, so that members of the other departments and divisions may profit from this exchange of ideas with their consultant.

If the future consultants count on a closer cooperation of other staff within the Institute, his job will yield a maximum efficiency.

C H A P T E R II

ASSISTANCE TO INDUSTRIA ELECTRICA SOCIEDAD ANONIMA (IESA), CONDUMEX, CONDUCTORES COYOACAN AND FORRADOS FINOS, INSTITUTO DE FISICA (UNAM)

A. SPECIAL CONSULTATIONS ABOUT DESIGN, MATERIALS AND PROCESSES OF MANUFACTURE OF TRANSFORMER-COILS

Several tests of the insulation of transformer-coils have shown that the required standard level has not been reached.

After these tests, the consultant and an expert from the IIE had consultations with the producer of transformers -INDUSTRIA ELECTRICA SOCIEDAD ANONIMA (IESA)- about the design, materials and process of manufacture of transformer-coils.

As a result of these consultations, the company IESA is working hard to improve the quality of insulation of transformer-coils.

Consequently, IIE and IESA are at present working together intensely in this field.

B. SEVERAL TALKS ABOUT TEST-METHODS OF CABLES AND TECHNOLOGY OF GLASS FIBER OPTIC CABLES

CONDUMEX invited the consultant again for several talks about test-methods of cables and the technology of glass fiber optic cables. As mentioned above, Mexico imports almost all materials and equipment for the production of these cables. Up till now, the quantity of the production in this field has been very small (5 Kilometers).

CONDUMEX, being the biggest cable producer of Mexico, is very interested in improving its production and in changing over to the newest technology. It is advisable to import special technology from abroad (e.g. Japan, USA, BRD, DDR).

C. VOLTAGE TESTS OF CABLES PRODUCED BY "CONDUCTORES COYOACAN" (INDUSTRIAS MAC,S.A.) AND "FORRADOS FINOS",S.A. (FOFISA)

In the IIE were carried out several voltage tests of cables and cores produced by "Conductores Coyoacán" and "Forrados Finos" (FOFISA).

The result of these tests were up to the standard level and satisfying.

D. TALKS ABOUT GLASS FIBER OPTICS WITH EXPERTS OF THE INSTITUTO DE FISICA (UNAM)

The consultant had several talks about the research and development of glass fiber optics with Dr. Thomas Seligman and Dr. Manuel Berrondo. During these talks it became quite clear that in Mexico reserach, as well as practice in this field, have to be centralized and intesified.

If Mexico wants to progress up to a high level in this area, it absolutely needs to keep in touch with top class experts abroad (e.g. Japan, USA).

CHAPTER III

ANNEXES

A N N E X 1

JOB DESCRIPTION, WORK SCHEDULE AND A NOTE

OF BRIEFING OF THE CONSULTANT

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

PROJECT OF THE GOVERNMENT OF MEXICO

DP/MEX/82/011/11-54/31.9.C

JOB DESCRIPTION

Post title Consultant in Testing of Power Cables with Extruded Insulation

Duration Six months

Date required 1 July 1984

Duty station Cuernavaca (Morelos province), Mexico.

Purpose of project To assist IIE (Instituto de Investigaciones Electricas) in developing skills aimed at promoting quality aspects of locally manufactured electrical power instruments, machinery and associated products.

Duties The consultant's duties will be:

1. to assist counterpart staff at IIE with developing aging techniques for electric power cables, to stimulate normal operating conditions at an accelerated pace and thus obtain a measure of useful life of unused cables as well as residual life of cables in operation.

2. to prepare a comprehensive list of equipment items required in the cable laboratory for life testing of power cables. Quality control equipment is to be included.

3. to prepare a final report setting out the findings of his mission and listing recommendations for future operations of the cable laboratory.

Applications and communications regarding this Job Description should be addressed to:

Project Personnel Recruitment Section, Industrial Operations Division

UNIDO, P.O. Box 707, A-1010 Vienna

Qualifications

Qualified electrical engineer with long-standing professional experience in the technology of electric power cables in general and that of power cables with extruded insulation in particular.

Also the candidate should have experience in accelerated aging tests as part of life-cycle analysis of power cables.

In addition, the candidate should have a background in didactics to enable him to undertake training of counterpart personnel.

Language

English and/or Spanish

Background Information

The development of industries which produce electric power equipment and machinery has been accorded high priority in Mexico's industrialization efforts and the requirement that equipment of this kind, produced in Mexico, would be of a quality acceptable worldwide led to the formation of IIE and its laboratories in Cuernavaca.

From this original concept developed a new idea, namely that of establishing an integral system of specialized testing laboratories in Mexico, near industrial areas where electric power equipment and machinery is being manufactured. The purpose of these specialized testing facilities is to reduce or eliminate problems associated with one central testing organization.

The design and development necessary to create the basis for each of these specialized testing facilities is being carried out at the central organization in Cuernavaca where the following research laboratories have been - or are in the process of being - established:

- a high voltage laboratory;
- a high power (short circuit) laboratory;
- a laboratory to evaluate finished products;
- a prototype testing laboratory;
- a materials testing laboratory;
- a turbine laboratory;
- a transformer laboratory;
- a laboratory to investigate the operation of circuit breakers, fuses, lightning arresters;
- a cable evaluation laboratory;
- a rotary electrical machines laboratory.

The principal purpose of these activities is to avoid duplication of national investments and co-ordination of long-term programmes to avoid duplication and/or overlapping. The overriding principle which has been established is that these facilities will not carry out routine testing, but rather be concerned with performance, design and prototype testing of locally - and imported - electrical equipment and machinery.

Furthermore, IIE assists in disseminating knowledge of the kinds of technology best suited to Mexico's needs as well as to encourage their adoption in the electrical engineering industry in Mexico.

It maintains relations with similar organizations in other countries and with academic and research institutions in Mexico, whose work its own activities are designed to complement.

With regard to the cable laboratory, the work being carried out in this sector is aimed at developing national expertise not only in testing but also in quality control and quality assurance of locally manufactured electric power cables.

INSTITUTO DE INVESTIGACIONES ELECTRICAS

MR. J. PETTERSON
UNITED NATIONS INDUSTRIAL
DEVELOPMENT ORGANIZATION
UNIDO - REPRESENTATIVE (RESIDENT)

MEXICO - CITY.

REF : EQ/M/GR/061/84

Cuernvaca, Mor., Octubre 4, 1984

Dear Sir,

Regarding the work of Mr. M. H. HOELZER, Field Adviser (Consultant) from UNIDO. We would like to inform you that his WORK-PROGRAMME has been slightly modified given the present situation and needs of our institute.

We are enclosing the proposed new WORK-PROGRAMME, which does include part of the original one, but is considerably different.

Please let us know if you have any objections to these changes, which we regrettably had to make at such a late date.

Looking forward to hearing from you.

I remain.

Sincerely yours,

ING. GUILLERMO RIVERA NOVA
HEAD OF THE MATERIALS DEPT.

Enclosures : - Proposal of the new WORK-PROGRAMME
- JOB DESCRIPTION of the UNIDO for Consultant.

c.c.p. Mr. Hoelzer.

INSTITUTO DE
INVESTIGACIONES
ELECTRICAS

WORK SCHEDULE FOR MR. MANFRED J. HOELZER.

1. A mexican cable manufacturer is interested in the development of local materials for semiconductive shields used in power cables. This project includes electrical evaluation of the raw materials as well as the final product, a 15 KV class cable, insulated with a polymeric material.
   To asses the raw materials test cells and adequate procedures that are needed for cable evaluation, prototype tests will be required.

2. To prepare a comprehensive list of equipment items for a basic laboratory for aging tests of polymer cables. This is required in the IIE. The implementation of the laboratory will require buying some foreign equipment and some locally made.

3. Contribution on the design, development and tests of a high voltage cable termination to be used in the 150 KV test circuit for pollution tests in the high voltage laboratory of the Materials Department.

4. Assistance at the development of a 35 KV, 2 KA wall bushing for the short circuit laboratory of Salazar, this wall bushings will be manufactured using thermocontractil materials.

5. Visits to cable factories, in order to see if improvements can be suggested by him.

6. Carrying out lecture courses and seminars of cable [illegible] and test-methods (extruded insulation).

7. Prepare a final report setting out the findings of his mission and listing recommendations for future operations of the cable laboratory.

NOTE FOR THE FILE

To Mr. V. Smirnov

From E. Krajenbrink

Ref: Briefing Mr. M.J. Hoelzer - DP/MEX/82/C11: Post 11-54

Mr. Hoelzer will be attached to the IIE Institute at Cuernavaca (some 200 km. south of Mexico City), where he will provide advice on techniques for ageing of power cables through simulation of normal operating conditions at an accellerated pace.

The Institute at Cuernavaca is in the process of establishing a number of separate R + D laboratories, amongst which the cable evaluation laboratory where Mr. Hoelzer will be working.

Cuernavaca is a good place to work, well away from the pollution and other problems of Mexico City.

The staff at the Institute are highly trained and very dedicated people. Most of them are under 40 years of age. Some excellent results, particularly in the ceramics and plastics sector, have already been obtained, as well as in the test instrumentation lab.

Mr. Hoelzer will meet a colleague from the DDR, who went there about a month ago (Dr. Neumann) to work on turbo generator development.

Visits to cable factories are advisable, to see if improvements can be suggested by him. IIE - people can arrange these visits and transport as part of the Government contribution to the project.

A copy of this Note for the File should be given to Mr. Hoelzer.

E. Krajenbrink

26 August, 1984

A N N E X 2

A COMPREHENSIVE LIST OF EQUIPMENT ITEMS REQUIRED IN THE CABLE LABORATORY FOR LIFE TESTING

1. STANDARDS

1.1 INTERNATIONAL ELECTROTECHNICAL COMISSION (IEC STANDARD)

38 IEC Standard Voltage
60 High-Voltage Test Techniques
141 Tests on Oil-Filled and Gas-Pressure Cables and Their Accessories
183 Guide to the Selection of High-Voltage Cables
228 Conductors of Insulated Cables
229 Test on Cable Oversheath which have a Special Protective Function and are Applied by Extrusion
230 Impulse Tests on Cables and Their Accessories
270 Partial Discharge Measurements
287 Calculation of the Continuous Current Rating of Cables (100% Load Factor)
332 Tests on Electric Cables under Fire Conditions
502 Extruded Solid Dielectric Insulated Power Cables for Rated Voltages from 1 KV up to 30 KV
540 Test Methods for Insulations and Sheaths of Electric Cables and Cords (Elastomeric and Thermoplastic Compounds)
541 Comparative Information on IEC and North American Flexible Cord Types
754 Test on Gases Envolved during Combustion of Electric Cables

1.2 VDE - STANDARDS (in English available)

VDE 0207 Isolier-und Mantelmischungen für Kabel und isolierte Leitungen - VPE - Isoliermischungen
VDE 0209 Bestimmungen für Isolierhüllen und Mäntel aus thermoplastischem Isolierstoff
VDE 0250 Bestimmungen für Isolierte Starkstrom Leitungen
VDE 0271 Bestimmungen für Kabel mit Isolierung und Mantel aus Kunststoff auf der Basis von PVC
VDE 0272 Kabel mit Isolierung aus vernetztem Polyäthylen

VDE 0273 Kabel mit Isolierung aus thermoplastischem oder vernetztem Polyäthylen

VDE 0472 Leitsätze für die Durchführung von Prüfungen an isolierten Leitungen und Kabeln

1.3 BRITISH STANDARDS (BS)

BS 5467 Armoured Cables with Thermosetting Insulation for Electricity Supply

BS 5468 Cross Linked Polyethylene Compounds

BS 5469 Hard Ethylene Propylene Rubber Compounds

BS 6746 BS 6791 BS 1442 and BS 4066

1.4 ASTM - STANDARDS (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

D 149 Tests for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies

D 257 Tests for D-C Resistance or Conductance of Insulating Materials

D 471 Test for Rubber Property - Effect of Liquids

D 573 Test for Rubber-Deterioration in an Air Oven

D 638 Test for Tensile Properties of Plastics

D 1248 Specification for Polyethylene Plastics Molding and Extrusion Materials

D 2436 Specification for Forced-Convection Laboratory Ovens for Electrical Insulation

D 2633 Thermoplastic Insulations and Jackets for Wire and Cable

D 3755 Test for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct Voltage Stress

1.5 ICEA/NEMA - STANDARDS (INSULATED CABLE ENGINEERS ASSOCIATION/NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION)

WC 7-1982 Cross-Linked-Thermosetting-Poyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

WC 8-1976 (R-1982) Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

S-19-81 WC 3-1980 Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

1.6 IMPORTANT RESEARCH REPORTS

- Electric Power Research Institute (EPRI) USA
  EPRI EL-3154
  Project 1357-1
  Final Report: January 1984
  Estimation of Life Expectancy of Polyethylene-Insulated Cables

- EPRI EL-3415
  Contract WS 80-165
  May 1984
  Workshop Proceedings: Electrical Testing of Extruded-Dielectric Power Transmission Cables

- EPRI EL-619
  Project RP 671-1
  Cable Neutral Corrosion
  Selection and Evaluation of Semiconducting Thermoplastic Jacket Compounds for Concentric Neutral URD Primary Cables

- EPRI EL-3333
  Project 1519-1
  February 1984
  Maximum Safe Pulling Lengths for Solid Dielectric Insulated Cables

- And all new publications of EPRI-Reports in the field of Life-Time-Tests

- ALCOA LABORATORIES, Marshall, Texas
  81 WM 115-5
  An Accelerated Life Test for Evaluating Power Cable Insulations

- IEEE Transactions on Electrical Insulation
  Vol. ; Canada, NRC
  EI-15 No.4, August 1980
  Toward a Credible Aging Test for Extruded Cable

- IEEE
  EI-16 No.4, 1980
  The Voltage Breakdown Characteristics of Miniature XLPE-Cables Containing Water Trees

- IEEE
  EI-16 No.6, 1981
  Environmental Effects on the Rate of Aging of EP-Insulated Power Cable

2. EQUIPMENTS

2.1 FOR ROUTINE TESTS

- Precision measuring bridge (Thomson)
  Measuring range: 1m Ω up to 1k Ω

- Electronic galvanometer (Type EG 01)
  Measuring range: 5 µV up to 50 V

- D.C. - Voltage regulator (Type 3217)
  Tunable voltage: 0.05 V up to 30 V
  Tunable current: 0.05 A up to 10 A

- Temperature-printer (Type DMKV 101)

- Ohmmeter

- A.C. - Voltage-test-equipment (Type WP 500/100/4-1)
  500 KVA; 0.4/50 KV

- A.C. - Voltage-test-equipment
  330 KVA; 0.4/6 KV

- Insulation indicator (inductor)

- Test time watch

- Water tank (3m x 3m x 2m) - to be heated up to 90°C

- Cable fault locator (P.D. faults) for H.V. cables
  (Type KF 01)
  Test cable length: 20....3000 m

Input voltage:

Operating value $U_{E_{min}}$ > 0.1 V at

t_h > 50 ns

t_A > 100 ns

Maximum value $U_{E_{max}} \leq$ 5 V at

t_h > 200 ns

t_A > 300 ns

Dynamic input resistance

R_E > 10 k Ω

Time resolution:

Minimum time between impulses

$t_{A_{min}}$ > 50 ns at t_h > 20 ns; U_E > 0.2 V

Maximum time between impulses

$t_{A_{max}} \leq$ 10 µs at t_h < 100 ns; U_E > 0.2 V

Max measuring error:

$\Delta l = \pm (0.005\ l_k + 5m)$

l_k- length of cable

Output signals:

for observation by oscilloscope

for triggering of oscilloscope

for detector of direction

- Partial discharge measuring unit (Type MTE 3)

Measured quantities:

Impulse duration:

t_i = 30....3000 ns

mode of evaluation "short" t_i < 300 ns

mode of evaluation "long" t_i > 300 ns

Mode of evaluation "short":

Minimum operating charge
(indication by means of external oscilloscope
at the input of the measuring unit $R_E \simeq 350\ \Omega$,
cable not terminated)
0.05 pC
0.15 to more than 1000 pC
t_i = 60....300 ns ; 16....75 kHz
t_i = 30.... 60 ns ; 75....100 kHz

Mode of evaluation "long":

Minimum operating charge
(external oscilloscope)
$R_E \simeq 350\ \Omega$, cable not terminated
0.13 pC
0.4....2500 pC
t_i = 300....1750 ns
t_i = 1750....3000 ns

Range of repetition rate:

$\leq$ 10 kHz
Measurble p.d. with indicating instrument or
with external equipment: 2....20000 pC
Pulse repetition rate: without disturbance
suppression: single imp. up to 200000 s^{-1}
Pulse repetition rate: with disturbance
suppression: single imp. up to 100000 s^{-1}

Mains supply:

supply voltage	220 V $\pm$ 10%
frequency	50 to 60 Hz
input power	35 KVA

Application:

A.C. Test voltage: 16 to 500 Hz
(up to 1200 Hz on special requested)
D.C. voltage: Switching impulse voltage

Amplifier/integrator:

Amplification: 55 dB
Rise time with rectangular pulse: 80 ns
(corresponding upper limiting frequency 4 MHz)
Minimum time distance between p.d. impulses:
- without disturbance suppression: 10 µs
- with disturbance suppresion: 100 µs

Internal calibrator:

Synchronized rectangular impulses: 0.001 to 10 V
Rise time < 50 ns
Decay time < 50 ns
Duration impulse
- with frequency of testing voltage: f < 80 Hz:1 ms
- without frequency of testing voltage: f > 80 Hz:0.1 ms

- Measuring impedance (Type H 253)

Load current at 50 Hz:	10 A
Rise time with rectangular pulses:	< 50 ns
Impulse duration:	3 µs
Wave impedance:	75 Ω

- External calibrator (Type PET 2)

Impulse charge:	5; 25; 50; 250 pC
Polarity:	negative
Rectangular voltage decay time:	<50 ns
Amplitude:	$\approx U_b$ - 0.5 V
Repetition rate:	100 Hz
Voltage of the battery:	4.3 to 4.8 V

- Dual-bean oscilloscope (Type EO 213)

Frequency range	0 to 12 MHz
Input impedance	1 M Ω/32 pF
Accelerating voltage	3 KV
(additional voltage component to increase signal brightness)	
Sensibility	10 m V/cm to 10 V/cm
Time-base deflection	0.2 µs/cm to 100 ms/cm

- Coordinate plotter (Type "endim" 620.02)

Plotting area	270 mm x 400 mm
Max. plotting speed X	45 cm/s
Max. plotting speed Y	35 cm/s
Measuring ranges	0.1 m V/cm to 10 V/cm

- Universal voltage measuring equipment (Type MU 9)
  Suitable for measuring D.V. voltage (arithmetic mean values) and A.C. voltage (peak value) with digital display
  D.C. voltage: range 120/60/30 V
  input resistance 5 M Ω
  A.C. voltage: range 100/50/25 V (r.m.s.)
  Frequency of voltage to be measured: 15 to 500 Hz
  Input capacitance: 24 nF

- Combination of coupling capacitor with blocking impedance (Type WMCF) and cable termination (Type EKP)

1)	WMCF 8000/50 sp:	U_n = 50 KV
		C_k = 8000 pF
	EKP 50	U_n = 50 KV
2)	WMCF 1000/100 sp:	U_n = 100 KV
		C_k = 1000 pF
	EKP 100	U_n = 100 KV

3) WMCF 4000/100 sp U_n = 100 KV
C_k = 4000 pF

EKP 100 U_n = 100 KV

- Screened measuring cabin
  Dimensions 5m x 5m x 3m
  Divided in two parts: test room and control room

- Filters:

Control filter	(Type SF 1/T)
Supply filter	(Type IF 3.380/220)
High-current filter for low frequency	(Type NHF 400/130)
High-voltage filter for P.D. Measurment	(Type TEF 60/5)

- High-voltage testing equipment 60 KV; 300 KVA

High-voltage test transformer	(Type TMZ 12)
Rated voltage	0.38/15/30/60 KV
Rated current	15 A at 60 KV
	10 A at 30 KV and 15 KV
Compensation reactors	60 + 120 + 240 K Var
Regulating transformer	60 KVA
Peak voltmeter	(Type 53 or MU9)

- Analysis-balance (division scale: 0.0001 g)

- Laboratory-press (Type 300 S)

- For mechanical testing:
  INSTRON
  Instruments and Systems for Advanced Materials Testing
  Model 1125 - Universal Testing Instrument
  0.1 to 100 KN
  0.05 to 1000 mm/min (± 0.1%)

2.2 FOR SPECIAL TESTS

- High-resistance-measuring-equipment (Type 6202)

- Climate-thermo-light-chamber (Type KTLK 1250)

- Staff of insulation material 17 cm long
  Diameter in mm: 6; 6.5; 7.5; 8; 9; 9.5; 10; 11; 12
  13; 14 ; 15 ; 16; 17; 19; 20; 21; 23
  24; 27 .

- Heating-equipment for water bath
  20....90°C

- A.C. Test-voltage regulator
  0....35 KV

- D.C. Test-voltage regulator
  0....10 KV

- Measuring-microscope (10 times; scale division 0.01 mm)

- Mechanical measuring equipments (division of scale 0.01 mm)

2.3 FOR TYPE TESTS

- Air oven (Type WSU 100)

Range of temperature:	30 up to 300°C
Time for heating up:	Apprx. 25 min.
Duration for one complete air change:	Apprx. 5s (with max. air supply)
Max. supply of air:	70 m^3 per hour
Nominal contents:	100 L

- Flowmeter for air-flow control in air oven:

  A calibrated capillary tube with an internal calibrated diameter of about 2mm and a calibrated lenght of about 70 mm.

- Stop watch.

- Voltmeter (for measuring of mains supply)

- Amperemeter (power consumption)

$$V = 3590 \frac{(P1-P2)}{d\ (t_2-t_1)}$$

- Stop-watch

- Equipment (press) for cutting of the cumb-bell test pieces according to IEC-Standard 540, figure 7, page 105.

- Single screw laboratory extruder:

  Screw 3/4" (19.05 mm) or 1" (25.40 mm)
  Temperature range up to 400°C
  Lenght/diameters 10:1
  20:1
  25:1
  with a complete line of standard dies.

- Laboratory mixer: Single batch and continuous

  Chamber bor diameter apprx. 40 mm
  Chamber length approximately 48 mm
  Bowl capacity 125 mL
  Maximum temperature 400 °C

- Process Monitor and controller

- Multi-strand
- Laminating and coating equipment
- Pelletizer
- Tape, sheet and ribbon equipment
- Measuring microscope: A reading of 0.01 mm and an estimated reading to three decimal places. Magnification power of at least 10.
- Cold-bend test apparatus: It is represnted in IEC-Standard 540, page 110, figure 15.
- Impact-test apparatus: It is represented in IEC-Standard 540, page 111, figure 16.
- Hydrometer: Calibrated at 23°C
- Thermometer: 0.1 degree Celsius divisions
- Balance: With a precision of 0.1 mg
- Pan straddle or other stationary support
- Pycnometer: 50 mL capacity
- A liquid bath provided with a thermostatic control
- Apparatus for determining melt flow index: It is represented in IEC-Standard 540, p.112, fig.17 and 18.
- Apparatus for ozone resistance test: It is represented in IEC-Standard 540, p.113, fig.20.

- Electronic ozonometer: See IEC-Standard 540, p.114, figure 21.

- Indentation device: See IEC-Standard 540, p.108, figure 11.

- Desiccator: Range of Temperature -70 to 180°C ± 0.5 K
  Deep = 965 mm
  Breath = 1050 mm
  Height = 1000 mm

2.4 FOR LIFE-TIME-TESTS

- Motor generator set: Motor 6.6 KVA; 440 V/60 Hz 3-ph
  Generator 6.6 KVA; 440 V/1000 Hz 15A; 1-ph

- Voltage regulator: 0 to 440 V

- Exciter transformer.

- Tunable high voltage reactor: 0 to 35 KV
  1.66 A
  1000 Hz

- Control unit.

ANNEX 3

SCHEDULE OF LECTURE COURSES

1. **INSULATING COMPOUNDS**

   1.1 Thermoplastic

   1.2 Elastomeric or Thermosetting

   1.3 Applications and Properties

2. **XLPE - CABLES**

   2.1 Technology and Equipments

   2.2 Testing

3. **TEST-METHODS FOR POWER CABLES AND MATERIALS**

   3.1 Test Conditions

   3.2 Routine Tests

   - General
   - Electrical resistance of conductors
   - Partial discharge test
   - Voltage test

   3.3 Special Tests

   - General
   - Frequency of special tests
   - Repetition of tests
   - Conductor examination
   - Measurement of thickness of insulation and of non-metallic sheath

- Measurement of thickness of lead sheath
- Measurement of armouring wire and tapes
- Measurement of external diameter
- Voltage tests for 4h
- Hot set tests for EPR and XLPE insulation and sheaths of SE_1

3.4 Type Tests

3.4.1 Electrical

- Cables insulated with PE or XLPE and PVC or EPR
- Sequence of tests (pd-test; bending-test; tan δ measurement; heating cycle test; impulse withstand test; high-voltage-ac-test)
- Special provisions
- Insulation resistance measurement

3.4.2 Non-Electrical

- Measuring of thickness of insulation and sheath
- Tests for determining the mechanical properties of insulation and sheaths before and after aging
- Additional aging test on pieces of completed cables
- Loss of mass test on PVC sheaths of type ST_2
- Tests for the behaviour of PVC insulation and sheaths at high and low temperatures
- Test for resistance of PVC insulation and sheaths to cracking (heat shock test)
- Measurement of melt flow index of PE insulation and sheaths
- Ozone resistance test for EPR insulation
- Hot set test for EPR and XLPE insulation and sheaths of SE_1
- Oil immersion test for elastomeric sheaths
- Water absorption test on insulations

- Flame retardance test
- Measurement of carbon black content of PE sheaths
- Shrinkage test for PE and XLPE insulation
- Special bending test
- Thermal stability test for insulation of PVC/B

3.5 Electrical Tests After Installation

3.6 Aging-Test-Methods

4. LIFE - TIME - TESTS

4.1 High-Voltage

4.2 High-Frequency and High-Voltage

4.3 Electrochemical

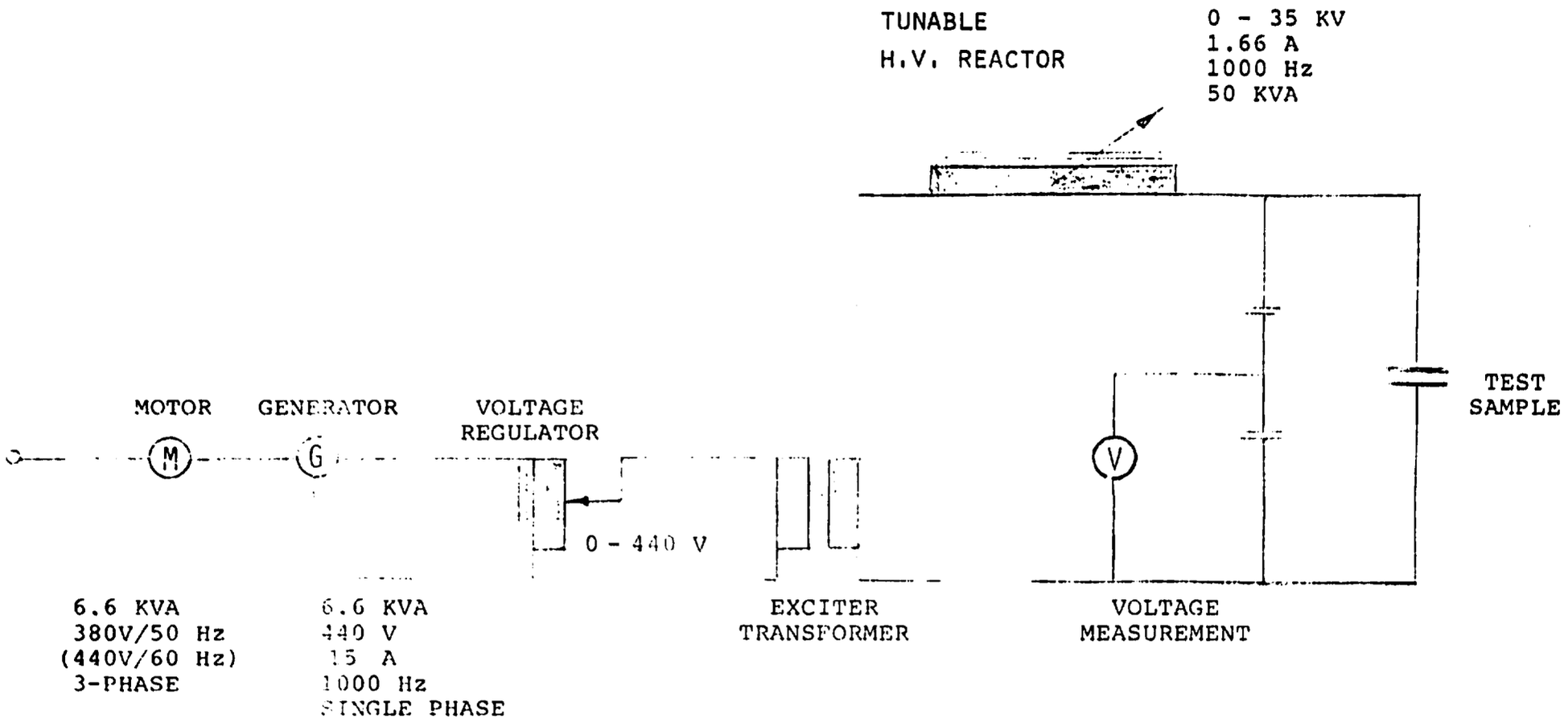

DIAGRAM FOR 1000 Hz AGING TEST SET (LIFE-TIME-TESTS)