10th Eco-Energy and Materials Science and Engineering Symposium


On December 5-8, 2012
Sunee grand hotel,
Ubon-ratchathani

Organized by

Co-organized by
PREFACE:
Message from the President of
Rajamangala University of Technology Thanyaburi

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10th EMSES). This international conference is not only giving an opportunity for Thai and foreign researchers to present and discuss their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Our program consists of six research tasks: (1) Energy Technology, (2) Environmental and Social Impact, (3) Nanotechnology and Materials Science, (4) Energy Economics and Management, (5) New Energy technology and (6) Nuclear Technology.

I would like to take this opportunity to express our sincere gratitude to our two distinguished Plenary Speakers for kindly accepting our invitation. I deeply appreciate the very strong support given by Kyoto University. Thanks to the tireless works of the Organizing Committee, the Technical Program Committee, the invited speakers and paper and poster contributors, and excellent program been assembled to cover a broad spectrum of interesting topics.

We warmly welcome you to the 10th EMSES on December 5-8, 2012, Ubon Ratchathani, Thailand.

Numyoot SONGTHANAPITAK, Ph.D.
President of Rajamangala University of Technology Thanyaburi
and Conference Chairman of 10th EMSES 2012
PREFACE:
Message from the Director of
Institute of Advanced Energy, Kyoto University

It is my great pleasure to have the 10th Eco-Energy and Materials Science and Engineering Symposium (EMSES) with Rajamangala University of Technology Thanyaburi (RMUTT) under the long-term collaboration between RMUTT and Kyoto University. The 1st EMSES was held in 2001 in Thailand and the symposium has been expanded in its scientific contents as well as the academic network. I believe that the 10th EMSES gives a good opportunity to all participants to exchange their knowledge and idea to realize eco-friendly energy system in society. I would like to express my welcome to all participants and sincere thanks to the 10th EMSES organizing committee and all supporting organizations to make us having this symposium.

I hope that the symposium will be successful and lead to further progress in energy science and technology and also in friendships of participants.

Professor Yukio Ogata, Ph.D.
Director of Institute of Advanced Energy, Kyoto University
PREFACE:
Message from the Former Dean of
Graduate School of Energy Science, Kyoto University
Program Leader,
Global COE “Energy Science in the Age of Global Warming”

I want to express my hearty welcome to all participants of Eco-Energy
and Materials Science and Engineering Symposium (10th EMSES). This
symposium is aiming the realization of importance of energy and
materials technology through the academic, science and technology
network among the world communities. The symposium gives an
opportunity for researchers to discuss their research works and also to
initially stimulate the development of research works on eco-energy and
materials science and engineering. Once the cooperation among
researchers has been created, the further cooperation work will be
developed.

I would like also extend my sincere thanks to all who made the meeting
possible, including the 10th EMSES organizers, the SEE forum
committee members, and the Japanese Government, JSPS, for their kind
support. I am looking forward to seeing you in Ubon Ratchathani,
Thailand.

Professor Takeshi YAO, Ph.D.
Former Dean of Graduate School of Energy Science, Kyoto
University
and Program Leader, Global COE “Energy Science in the Age of
Global Warming”
Message from the Chairperson of
10th EMSES Organizing Committee

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10thEMSES).

RMUTT has a major mission on encouraging and supporting all areas of research. One of the key reasons is to assist in developing capability in science and technology in order to cope with recent rapid change in this field. We have jointly set up an academic symposium on the 10thEMSES with the perception on the significance of exchanging knowledge and research experiences between researcher in the field of energy, materials technology and environmental science. This symposium is not only giving an opportunity for Thai and foreign researcher to present and discussion their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Once the cooperation among researchers has been created, the closer future cooperation incorporate with joint-research works will be developed. Thus, to support the aforesaid role, the symposium working committee would like to invite you to participate in this academic symposium.

I would like to express our sincere thanks to the organizing committee, participants and contributors for your kind corporation to this symposium. I wish this symposium proceeding will be a useful reference for future scientific research development.

Sommai PIVSA-ART, Ph.D.
Dean of Faculty of Engineering, RMUTT
Director of CoE on Sustainable Energy System (Thai-Japan)
Organizing Chairman of 10th EMSES 2012
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30 x 100 = 3,000
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# Conference Program of 10th Eco-Energy and Materials Science and Engineering

**5th December 2012**

<table>
<thead>
<tr>
<th>Time</th>
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<tr>
<td>01:00-05:00 pm</td>
<td>Registration</td>
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**6th December 2012**

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<tr>
<td>07:00-09:00 am</td>
<td>Registration</td>
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<td>09:00-09:40 am</td>
<td>Opening Ceremony at Taptim Siam 4 Hall</td>
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<td>Assoc. Prof. Dr. Numyoot Songthanapitak, President of RMUTT, Thailand and Chairperson of 10th EMSES conference</td>
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<tr>
<td>Prof. Dr. Kiyoshi Yoshikawa, Vice President of Kyoto University, Japan Co-Chairperson of 10th EMSES conference</td>
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<tr>
<td>09:45-10:45 am</td>
<td><strong>Keynote Speaker I:</strong> Japan Power Generation Mix and Energy Security after Fukushima Nuclear Accident, presented by Professor Dr. Keiichi N. Ishihara, Graduate School of Energy Science, Kyoto University, Japan</td>
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<td>10:45-11:00 am</td>
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<td>11:00-12:00 am</td>
<td><strong>Keynote Speaker II:</strong> Vertical Motions in Greater Bangkok Area after the 2004 Sumatra-Andaman Earthquake from GPS Observations and Its Prediction based on the Geophysical Modelling, presented by Professor Dr. Chaiermchon Satirapod, Chulalongkorn University, Thailand</td>
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<td>12:00-01:30 am</td>
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**Room**

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<td>Nano &amp; Materials Technology 1</td>
<td>New Technology 1</td>
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<td>Chair</td>
<td>Prof. Dr. Padungsak Ratthanachio</td>
<td>Assoc. Prof. Dr. Wisanu Pecharapa</td>
<td>Assoc. Prof. Dr. Seiichi Kawahara</td>
<td>Prof. Dr. DaeHee Park</td>
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<tr>
<td>Co-Chair</td>
<td>Dr. Wirachai Roynarin</td>
<td>Dr. Sorapong Pavasupree</td>
<td>Asst. Prof. Dr. Wanninee Anyawattan</td>
<td>Asst. Prof. Dr. Jakree Srisothonchart</td>
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<td>03:15-04:45 pm</td>
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<td>Assoc. Prof. Dr. Vijit Kinnares</td>
<td>Prof. Dr. Narongrit Somatsompol</td>
<td>Prof. Dr. Hideaki Ogaki</td>
<td>Prof. Dr. Susumu Yoshikawa</td>
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<tr>
<td>Co-Chair</td>
<td>Dr. Boonyang Plangklang</td>
<td>Dr. Supakij Suttiuengwong</td>
<td>Dr. Nithiwatthan Choosakul</td>
<td>Dr. Surawut Chuangchote</td>
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<td>05:00-06:30 pm</td>
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<td>Poster Session</td>
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<td>Asst. Prof. Dr. Krischomme Bhumkittipich</td>
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<td>Co-Chair</td>
<td>Dr. Sorapong Pavasupree and Dr. Sumonman Niamlang</td>
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<td>Assoc. Prof. Dr. Thawatch Kerdkuen</td>
<td>Dr. Seichi Aiba</td>
<td>Prof. Dr. Takeshi Yao</td>
<td>Asst. Prof. Dr. Somchai Hiranvarodom</td>
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<td>Co-Chair</td>
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<td>Dr. Leong Yew Wei</td>
<td>Dr. Supaporn Tomson</td>
<td>Dr. Nathabhat Phankong</td>
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<td>Dr. Arthit Sode-Yome</td>
<td>Assoc. Prof. Dr. Kawee Srikulkit</td>
<td>Prof. Dr. Jun Li</td>
<td>Prof. Dr. Hiroyuki Hamada</td>
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<tr>
<td>Co-Chair</td>
<td>Asst.Prof.Dr. Boonrit Prasartkeaw</td>
<td>Assoc. Prof. Dr. Yuji Aso</td>
<td>Dr.Sarocha Charoenvai</td>
<td>Dr. Narongchaisi O-Charoen</td>
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<td>Environmental&amp;Social Impact 1</td>
<td>Energy Economic &amp; Management 1</td>
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<td>ES09,ES10,ES11, ES13,ES14,ES15</td>
<td>EM02,EM03,EM04, EM07,EM08</td>
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<td>Chair</td>
<td>Prof. Dr. Chul-Su Kim</td>
<td>Prof. Dr. Yuichi Anada</td>
<td>Prof. Dr. Keiichi N. Ishihara</td>
<td>Assoc. Prof. Dr. Natha Kuptashien</td>
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<tr>
<td>Co-Chair</td>
<td>Dr. Winai Chanpeng</td>
<td>Assist. Prof. Dr. Kazushi Yamada</td>
<td>Asst. Prof. Dr. Sommai Pingarsart</td>
<td>Dr. Boonyang Plaeklang</td>
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<td>03:00-03:15 pm</td>
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<td>Coffee break</td>
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<tr>
<td>03:15-04:00 pm</td>
<td>Closing Ceremony at Taptim Siam 4 Hall</td>
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<td>08:00am-05:00 pm</td>
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Design of Support Insulator for L.T. Fuse Switch from Composite Material

N. Panklang, N. Phankong and K. Bhumkittipich
Department of Electrical Engineering, Faculty of Engineering,
Rajamangala University of Technology Thanyaburi, Klong 6, Thanyaburi, Pathumthani 12110
E-mail: nilipong.p@en.rmutt.ac.th

Abstract—This paper presents a new design of support insulator for low-tension fuse switch. The developing insulator is composite material compounded between natural rubber 60% and EPDM rubber 40%. It has also been tested and approved for electrical and mechanical properties by using ASTM D2240, ASTM D412, ASTM D257 and ASTM D149 standard. From testing results, the hardness and maximum tensile strength of the insulator are approximately equal to 46.7 ± 3 Shore A and 10.09 ± 0.58 MPa, respectively. Furthermore, the volume and surface resistivity of it are more than $1.6 \times 10^{15} \Omega \cdot \text{cm}$ and $1.9 \times 10^{12} \Omega \cdot \text{square}$, respectively. And also, it can be withstanding a maximum AC power frequency voltage about 17.9 kV/mm. In addition, the low-tension fuse switch has been tested in laboratory referring to IEC 60947-3 standard. The low-tension fuse switch can be withstanding an impulse voltage (1.2/50µs) and AC power frequency voltage about 14.8 kV and 2.2 kV$_{p}$, 50Hz, respectively, in accordance with the temperature rise test at 400A rated current. Therefore, the new support insulator can be withstanding the voltage and current in power system, and also can reduce the weight of low-tension fuse switch about 13% by using the composite materials.

Keywords—L.T. Fuse Switch, Natural Rubber, Finite Element Analysis

1. INTRODUCTION

In power system, low tension fuse switch (L.T. fuse switch) is normally installed in low voltage distribution system of Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA) for being switching and protective device when short circuit occurring in low voltage side of 220/380 V distribution system, which is shown in Fig. 1. Generally, L.T. fuse switch is using with a high rupturing capacity fuse (HRC Fuse). HRC fuse has rated current from 32A to 400A, which is specified by DIN43620 standard. Presently, the support insulator of L.T. fuse switch has been produced from ceramic or porcelain insulator. It can be damaged during transportation or installation.

This paper purposes a design of new support insulator with developing composite material to be instead of the ceramic or porcelain insulator. Firstly, the design of new support insulator will be using computer aided design (CAD) software for building a 3-dimenisinal model. And then, the finite element analysis is simulated for approving electric field and voltage distribution. Finally, this developed composite material will be tested a mechanical and electrical properties by ASTM D2240, ASTM D412, ASTM D257 and ASTM D149 standard.

2. LOW TENSION FUSE SWITCH

The L.T. fuse switch is presently used in the system from IEC60947-3 standard as Low-Voltage Switchgear and Control Gear— Part 3: Switches, Disconnectors, Switch-Disconnectors, and Fuse-Combination Units [1]. The L.T. fuse switch, which is shown in Fig. 1(a), has 500 V rated voltage and 400 A rated current, respectively. The L.T. fuse switch is installed on the cable supporter closing to the position of distribution transformer as shown in Fig. 1(b).

An original L.T. fuse switch has been used for insulator development, which is composed of 12 parts as shown in Fig. 2. An old porcelain insulator of L.T. fuse switch has weight about 0.52 kg. From hardness testing by using durometer, porcelain insulator has hardness about 88 shore D. Total weight of original L.T. fuse switch is equal to 2.42 kg. The weight of each part of original L.T. fuse switch is shown in Fig. 2.

Fig.1. A L.T. fuse switch using in distribution system
(a) currently L.T. fuse switch (b) installation position.
3. INSULATION MATERIAL AND TESTING

The insulation compounding material, which is the natural rubber (NR) and the ethylene propylene diene monomer (EPDM) rubber, is developed in this research. The EPDM is used for increasing weather resistance properties of NR. The compounding rubber consists of 60% NR and 40% EPDM ratio that is a suitable ratio for blending together. The materials and chemical substances are utilized to blend a compounding rubber as shown in Tab. 1.

### Table 1 Materials and chemical substances for compounding rubber.

<table>
<thead>
<tr>
<th>Material</th>
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<tr>
<td>Natural Rubber STR SL</td>
<td>60</td>
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<tr>
<td>High-Density Polyethylene</td>
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<td>Zinc Oxide</td>
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<td>Stearic Acid</td>
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<td>Cyclohexylbenzothiazole sulfonamide</td>
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<td>Tetramethylthiuramdisulfide</td>
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</tr>
<tr>
<td>Carbon Black</td>
<td>1</td>
</tr>
</tbody>
</table>

The compounding rubber has been proceeded to be the vulcanized rubber sheet. It has the dimension about 150x150x2.5 mm for mechanical and electrical properties testing. The insulation tests are composed of hardness, tensile strength, surface and volume resistivity, and dielectric strength. The testing process refers to ASTM D2240, ASTM D412, ASTM D257 and ASTM D149. All testing processes were performed by Department of Science Service (DSS) and Research and Development Center for Thai Rubber Industry (RDCTRI). The testing results will be compared the properties with other materials, such as NR and HDPE with a same ratio of blending. Table 2 shows the properties of NR+EPDM material that has 60% NR, 40% EPDM rubber.

### Table 2 Properties of vulcanized rubber from testing.

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>NR</th>
<th>NR+EPDM (60:40)</th>
<th>NR+HDPE (60:40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness, Shore A</td>
<td>20 - 90</td>
<td>46.7 ± 3</td>
<td>83.7 ± 0.9</td>
</tr>
<tr>
<td>Tensile Strength, MPa</td>
<td>20 - 30</td>
<td>10.09 ± 0.58</td>
<td>4.28 ± 5.4</td>
</tr>
<tr>
<td>Elongation at Break, %</td>
<td>750 - 800</td>
<td>548 ± 29</td>
<td>92 ± 29</td>
</tr>
<tr>
<td>Surface Resistivity, $\Omega$ /square</td>
<td>$1 \times 10^5$</td>
<td>$1.9 \times 10^7$</td>
<td>5.56 \times 10^8</td>
</tr>
<tr>
<td>Volume Resistivity, $\Omega$ - cm</td>
<td>$1 \times 10^7$</td>
<td>$1.6 \times 10^1$</td>
<td>2.14 \times 10^6</td>
</tr>
<tr>
<td>Dielectric Strength, kV/mm</td>
<td>1.0</td>
<td>17.9</td>
<td>19.7</td>
</tr>
</tbody>
</table>

4. DESIGN AND COMPUTER SIMULATION

In Fig. 4, the 2-dimensional model of L.T. fuse switch is utilized to be a mathematical model. This model has been used to analyze electric field strength and voltage distribution by means of finite element analysis (FEA) [3,4]. The simulation region is defined as an air boundary. It has relative permittivity 1.0. The support insulator (NR+EPDM rubber) has relative permittivity 2.92 calculating by using 60:40 blending ratio [5]. Wire terminal defined as a conductor whereas the voltage across the terminal is equal to 220 V. Installation hook is grounding. All conductor and insulator defined as perfect conductor and perfect dielectric. There are no space charge and electrical conductivity. It can be specified as zero. The mathematical model has been neglected a high rupture capacity fuse part. The tolerance of solution of computation electric potential and electric field is less than 1x10^-6. The surface of mathematical model has been bisected to triangular element equal to 60,172 elements and 30,413 nodes. The successive over-relaxation (SSOR) preconditioner and iterative method are utilized to solve equation of system. Figs. 5 and 6 show the simulation results from FEA.
Insulator, 104.2 V/mm. This electric field strength cannot be damaged a support insulator because the maximum electric field strength is less than dielectric strength of NR+EPDM rubber, as shown in Tab. 2. Since the developed support insulator has withstand dielectric strength under normal usage voltage, Fig. 6 shows the voltage distribution when applied support insulator under normally operation voltage.

From 2-dimension mathematical model, the relative permittivity of NR+EPDM support is defined about 2.92. This value is calculated from the equation by using blending 60:40 ratio neglecting the effect of other chemical substances. Otherwise, the ratio between NR rubber and EPDM rubber has been changed to test the effect of relative permittivity of compound material. To study the effect of relative permittivity to electric field strength, the relative permittivity of compound material is varied by changing blending NR: EPDM ratio 80:20, 70:30 and 60:40. From the different blend ratios, the values of the relative permittivity of compound material are equal to 2.81, 2.87 and 2.92, respectively. Tab. 3 shows the maximum electric field strength from FEA when the compound ratio is varied. In Tab. 3, the maximum electric field strengths have no the different values. Therefore, the maximum electric field is insignificant for simulation.

**Table 3. Maximum electric field strength when varies compound ratio.**

<table>
<thead>
<tr>
<th>Compound Ratio, NR:EPDM</th>
<th>NR-EPDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Field Strength(V/mm)</td>
<td>80:20</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------</td>
</tr>
<tr>
<td>105.8</td>
<td>104.97</td>
</tr>
</tbody>
</table>

Fig. 7 shows the prototype of L.T. fuse switch. The weight of the support insulator produced from the composite material between NR rubber and EPDM rubber is equal to 0.31 kg. It is lighter than the old support insulator. It can be reduced total weight of L.T. fuse switch from 2.54 kg to 2.11 kg or about 13%.

The L.T. fuse switch has been tested in laboratory referring to IEC 60947-3 standard. The selected testing processes are composed of (1) temperature rise test, (2) impulse withstand voltage test, and (3) power frequency withstand voltage test. For temperature rise test, the 400 A rated current is applied to the L.T. fuse switch by means of current injection equipment until reaching the point of steady temperature condition. The temperature has no increasing more than specified value in IEC 60947-3 standard when is compared with ambient temperature. The temperature measurement position can be defined eight points by using thermocouple as shown in Fig. 8. Impulse voltage withstand is tested by applied impulse voltage 1.2/50 μs to wire terminal of L.T. fuse switch. The rated of tested impulse voltage is equal to 14.8 kV. Finally, the power frequency withstand voltage test is applied AC voltage 50Hz to wire terminal for 5 seconds. The tested voltage is equal to 2.2 kVrms and applied to L.T. fuse switch. Both of withstand voltage test did not damage the NR+EPDM support insulator. When applied test voltage, there is no flashover and breakdown arise to insulator.
5. CONCLUSION

The new design and material of support insulator for L.T. fuse switch is presented in this paper. The support insulator is produced from the composite material combined with natural rubber 60% and EPDM rubber 40%. This support material can be used instead of original porcelain insulator and reduced weight of L.T. fuse switch from 2.42 kg to 2.11 kg. For evaluated properties of this composite material, the insulator material has been tested by using ASTM D2240, ASTM D412, ASTM D257 and ASTM D149 standard. The test results shown that the new insulator material has suitable properties for using as electrical insulation. This insulator material has surface resistivity $1.9 \times 10^{12} \ \Omega/$square and volume resistivity $1.5 \times 10^{15} \ \Omega$-cm. It can be withstanding a maximum AC power frequency voltage about 17.9 kV. In addition, the L.T. fuse switch has been passed laboratory testing by using IEC 60947-3 standard. The L.T. fuse switch can be withstand an impulse voltage and AC voltage 50Hz about $14.8 \text{kV}$ and $2.2 \text{kV}_{max}$, respectively.

REFERENCES