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**Merjenje notranjega električnega polja v izolacijskih materialih - Metoda širjenja tlačnega vala**

Measurement of internal electric field in insulating materials - Pressure wave propagation method

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TITLE:

**Measurement of internal electric field in insulating materials - Pressure wave propagation method**

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NOTE FROM TC/SC OFFICERS:

This A-version CDV is circulated due to some texts in Figure-7 of 112/606/CDV were missing.

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## MEASUREMENT OF INTERNAL ELECTRIC FIELD IN INSULATING MATERIALS – PRESSURE WAVE PROPAGATION METHOD

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Draft	Report on voting
112/XXX/FDIS	112/XXX/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications](http://www.iec.ch/standardsdev/publications).

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180 • withdrawn,  
181 • replaced by a revised edition, or  
182 • amended.

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## INTRODUCTION

187 High voltage insulating structures, especially high voltage DC cables and capacitors etc., are subjected  
188 to charge accumulation and this may lead to electrical breakdown if the electric field produced by the  
189 charges exceeds the electrical breakdown threshold. With the trend to multiply power plants, especially  
190 green power plants such as wind or solar generators, more cables will be used for connecting these  
191 power plants to the grid and share the electric energy between countries. Therefore, the materials for  
192 the cables, and even the structure of these cables, when considering electrodes or the junction between  
193 cables, need a standardized procedure for testing how the internal electric field can be characterized.  
194 The measurement of the internal electric field would give a tool for comparing materials and help to  
195 establish thresholds on the internal electric field for high voltage applications in order to avoid risks of  
196 breakdown as much as possible. The pressure wave propagation (PWP) method has been used by  
197 many researchers to measure the space charge distribution and the internal electric field distribution in  
198 insulators. However, since experimental equipment, with slight differences, is developed independently  
199 by researchers throughout the world, it is difficult to compare the measurement results between the  
200 different equipment.

201 The procedure outlined in this Standard provides a reliable point of comparison between different test  
202 results carried out by different laboratories in order to avoid interpretation errors. The method is suitable  
203 for a planar plaque sample as well as for a coaxial sample, with homogeneous insulating materials. The  
204 IEC has established a project team to develop a procedure for the measurement of PWP.

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## MEASUREMENT OF INTERNAL ELECTRIC FIELD IN INSULATING MATERIALS – PRESSURE WAVE PROPAGATION METHOD

### 211 1 Scope

212 This document provides an efficient and reliable procedure to test the internal electric field in the  
213 insulating materials used for high-voltage applications, by using of the pressure wave propagation (PWP)  
214 method. It is suitable for a planar and/or coaxial geometry sample with homogeneous insulating  
215 materials and an electric field higher than 1 kV/mm, but it is also dependent on the thickness of the  
216 sample and the pressure wave generator.

### 217 2 Normative references

218 There are no normative references in this document.

### 219 3 Terms, definitions and abbreviated terms

220 For the purposes of this document, the following terms, definitions and abbreviated terms apply.

221 ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- 222 • IEC Electropedia: available at <http://www.electropedia.org/>
- 223 • ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 224 3.1 Terms and definitions

##### 225 3.1.1

##### 226 pressure wave propagation

227 PWP

228 pressure wave that is propagated in a material containing electric charges and measurement of the  
229 induced electrical signal from electrodes

#### 230 3.2 Abbreviated terms

231 CB carbon black  
232 EVA ethylene-vinyl acetate  
233 LDPE low density polyethylene  
234 LIPP laser induced pressure pulse  
235 PE polyethylene  
236 PIPP piezoelectric induced pressure pulse  
237 PMMA poly (methyl methacrylate)  
238 PWP pressure wave propagation  
239 S/N signal to noise ratio

240

#### 241 4 Principle of the method

242 The principle of the PWP method is shown schematically in Figure 1, which is for a planar sample.  
 243 Figures 1 a) shows the principle and the relation between the measured current of PWP method and  
 244 the electrical field distribution in the sample without space charge. Figure 1 b) shows the principle and  
 245 the relation between the measured current of PWP method and the space charge distribution in the  
 246 sample without applied voltage. Figure 1 c) show the measuring schematics of PWP method.

247 The space charge in the dielectric and the interface charge are forced to move by the action of a  
 248 pressure wave. The charge displacement then induces an electrical signal in the circuit which is an  
 249 image of the charge distribution in short-circuit current measurement conditions. The expression for the  
 250 short-circuit current signal with time  $t$  is

$$251 \quad i(t) = C_0 \int_0^d B E(x) \frac{\partial p(x, t)}{\partial t} dx, \quad (1)$$

252 where

253  $E(x)$  is the electric field distribution in the sample at position  $x$ ;

254  $d$  is the thickness of sample;

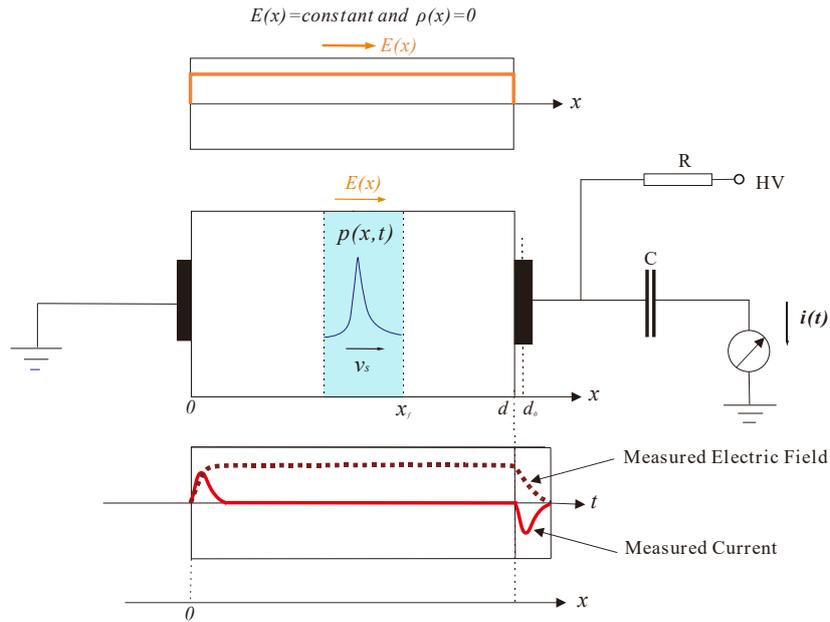
255  $p(x, t)$  is the pressure wave in the sample, which depends on the electrode materials, dielectric  
 256 sample material, the condition of coupling on the interface, etc.;

257  $C_0$  is the sample capacitance with the action of a pressure wave.

258  $C_0$  depends on the thickness of the sample, and its surface area which is equal to the area of action of  
 259 the pressure wave.

260 The constant  $B = \chi(1 - a/\varepsilon)$  only depends on the characteristics of the dielectric materials. In this  
 261 formula,  $\chi$  is the coefficient of compressibility of the material,  $\varepsilon$  is the permittivity of the material and  
 262  $a$  is the coefficient of electrostriction of the material. For heterogeneous dielectric materials,  $B$  is a  
 263 function of position. For homogeneous dielectric materials,  $B$  is not a function of position and can be  
 264 put outside of the integral. In this proposition, only homogeneous dielectric materials are considered,  
 265 so  $B$  is a constant.

266 In Equation (1), the electric field distribution can be obtained if it is deconvolved.



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268 **Key**

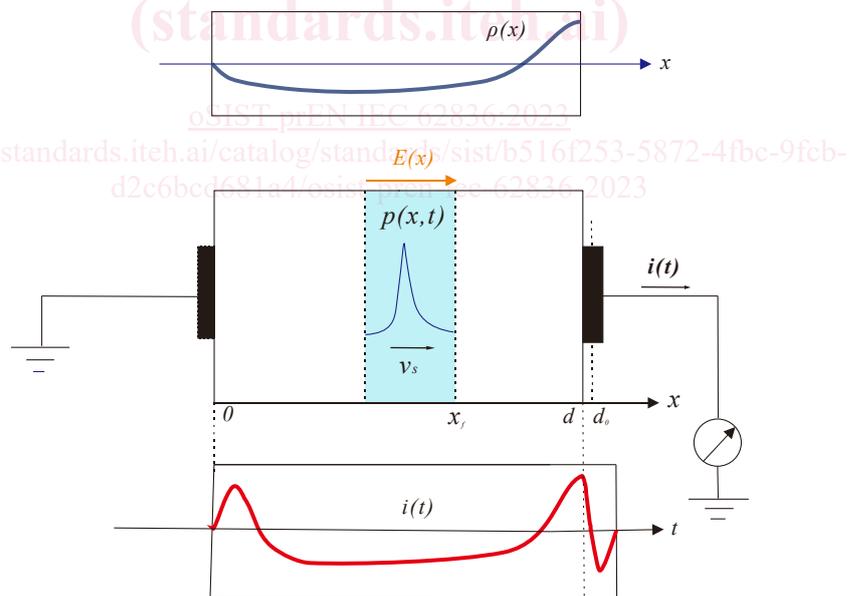
269  $x_f$  is the position of pulse front

270  $d_0$  is the original thickness of sample

271  $d_0 \approx d$  in the case of a narrow pulse

272 **a) Applied pressure pulse and measure short-circuit current with applied voltage but without space charge**

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275 **Key**

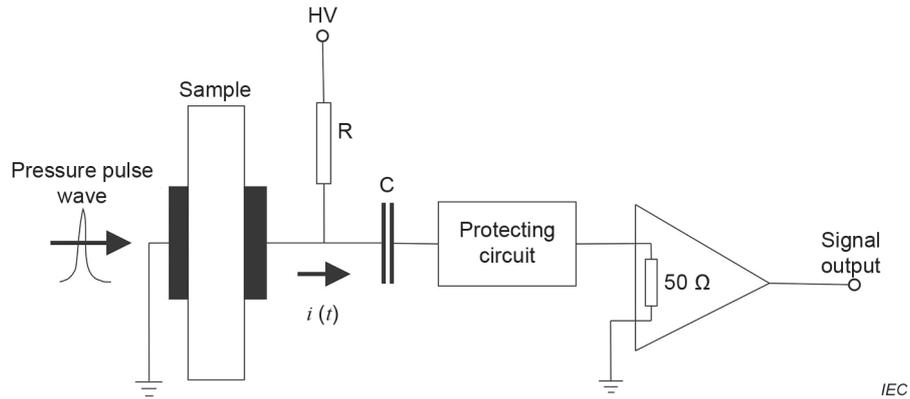
276  $x_f$  is the position of pulse front

277  $d_0$  is the original thickness of sample

278  $d_0 \approx d$  in the case of a narrow pulse

279 **b) Applied pressure pulse and measured short-circuit current with space charge but without applied voltage**

280



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283

c) Measuring schematics

Figure 1 – Principle of the PWP method

284 The applied pressure wave can be generated by different techniques, but the same kind of analysis can  
 285 be done for any of these techniques. The main practical PWP method can be divided into two ways: a  
 286 pressure pulse is induced by a powerful laser pulse, a technique called LIPP method, and a pressure  
 287 pulse generated by a piezoelectric device, a technique called PIPP. The sensibility and resolution of the  
 288 PWP method depends mainly on the amplitude and duration of the pressure pulse. The advantage of  
 289 the LIPP method is to produce highly sensitive measurements without contact. The advantage of the  
 290 PIPP method is to obtain the measurement with a high measuring rate and allow a low-cost  
 291 measurement system.

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