



Edition 1.0 2012-06

TECHNICAL REPORT RAPPORT

TECHNIQUE

Electrostatics – **iTeh STANDARD PREVIEW** Part 1: Electrostatic phenomena – Principles and measurements (standards.iteh.al)

Electrostatique – Partie 1: Phénomènes électrostatiques – Principes et mesures 9ac5bb897639/iec-tr-61340-1-2012





THIS PUBLICATION IS COPYRIGHT PROTECTED Copyright © 2012 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur. Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office	Tel.: +41 22 919 02 11 Fax: +41 22 919 03 00
CH-1211 Geneva 20	info@iec.ch
Switzerland	www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

Useful links:

IEC publications search - www.iec.ch/searchpub

The advanced search enables you to find **IEC publications rCLS**. The world's leading online dictionary of electronic and by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and committee additional languages. Also known as the International withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished/b897639/iec-tr-6Customer/Service Centre - webstore.iec.ch/csc

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Liens utiles:

Recherche de publications CEI - www.iec.ch/searchpub

La recherche avancée vous permet de trouver des publications CEI en utilisant différents critères (numéro de référence, texte, comité d'études,...).

Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

Just Published CEI - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.





Edition 1.0 2012-06

TECHNICAL REPORT

RAPPORT TECHNIQUE

Electrostatics – **iTeh STANDARD PREVIEW** Part 1: Electrostatic phenomena – Principles and measurements

Electrostatique – <u>IEC TR 61340-1:2012</u> Partie 1: Phénomènes électrostatigues and Principes et mesures 9ac5bb897639/iec-tr-61340-1-2012

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE CODE PRIX



ICS 17.200.99; 29.020

ISBN 978-2-83220-195-4

Warning! Make sure that you obtained this publication from an authorized distributor. Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

 Registered trademark of the International Electrotechnical Commission Marque déposée de la Commission Electrotechnique Internationale

CONTENTS

INTRODUCTION 7 1 Scope 8 2 Normative references 8 3 Terms and definitions 9 4 Fundamentals of static electricity 11 4.1 General 11 4.2 Contact electrification 12 4.3 Charging by induction 13 4.4 Charge transfer by conduction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.2 In situ measurements 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 16 4.7.4 Brush discharges 17 4.7.5 Orona discharges 17 4.7.6 Cone discharges 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.3 Electrostatic ignition + Hazards 21 5.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from conducting objects 21 <tr< th=""><th>FO</th><th>REWC</th><th>)RD</th><th></th><th>5</th></tr<>	FO	REWC)RD		5
1 Scope 8 2 Normative references 8 3 Terms and definitions 9 4 Fundamentals of static electricity 11 4.1 General 11 4.2 Contact electrification 12 4.3 Charging by induction 13 4.4 Charge transfer by conduction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.7.1 General 16 4.7.2 Spak blecharges 16 4.7.3 Corona discharges 16 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 17 4.7.6 Cone discharges 17 4.7.6 Cone discharges 17 4.7.6 Cone discharges 13 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electrostatic charges from conducting objects 21	INT	RODU	JCTION		7
2 Normative references 8 3 Terms and definitions 9 4 Fundamentals of static electricity 11 4.1 General 11 4.2 Contact electrification 12 4.3 Charging by induction 13 4.4 Charging by induction 13 4.4 Charge transfer by conduction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges and and streth at) 17 4.7.4 Brush discharges and and streth at) 17 4.7.5 Propagating brush discharges and and streth at) 17 4.7.6 Cone discharges and and streth at) 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 <	1	Scope			8
3 Terms and definitions 9 4 Fundamentals of static electricity 11 4.1 General 11 4.2 Contact electrification 12 4.3 Charging by induction 13 4.4 Charging by induction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 16 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 17 4.7.6 Cone discharges 17 4.7.7 Propagating brush discharges 17 4.7.6 Cone discharges 17 4.7.7 Propagating brush discharges 17 4.7.8 Mechanical forces in an electrostatic field 30.1.20.2 18 5 Electrostatic ingition – Hazards 19 5.2 I Ge	2	Normative references			8
4 Fundamentals of static electricity 11 4.1 General 11 4.2 Contact electrification 12 4.3 Charging by induction 13 4.4 Charge transfer by conduction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 17 4.7.4 Brush discharges 16 4.7.5 Propagating brush discharges 17 4.7.6 Cone discharges 131.4cc0.4cc0.4cc0 5 Electrostatic problems and hazards 19 5.1 General 19 5.2.1 General 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 21 5.3.4 Bicand discharges from conduc	3	Terms and definitions 9			9
4.1 General 11 4.2 Contact electrification 12 4.3 Charging by induction 13 4.4 Charge transfer by conduction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 17 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 17 4.7.6 Cone discharges 17 4.7.6 Cone discharges 19 5.1 Electrostatic problems and hazards 19 5.2 Electrostatic problems and systems 19 5.2 Electrostatic ignition – Hazards 20 5.3 Electrostatic ignition – Hazards 21 5.3.4 Brush discharges from conducting objects 21 5.3.5	4	Fund	amenta	Is of static electricity	11
4.2 Contact electrification 12 4.3 Charging by induction 13 4.4 Charging by induction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 16 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 17 4.7.6 Cone discharges are table statallostsst.1131.4cc0.403.5035 18 4.8 Mechanical forces in an electrostatic field 30.12012 18 5 Electrostatic problems and hazards 19 5.2 Electrostatic ignition – Hazards 19 5.2.2 Types of failure 19 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from conducting objects 21 5.3.5 Fropaga	•	4 1	Genera		11
4.3 Charging by induction 13 4.4 Charge transfer by conduction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 16 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 17 4.7.6 Cone discharges action branches intellinities 18 4.8 Mechanical forces in an electrostatic field 30.1.2002 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Types of failure 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition - Hazards 21		 4 2	Contac	at electrification	12
4.4 Charge transfer by conduction 14 4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges and and stretch.ati 17 4.7.4 Brush discharges and and stretch.ati 17 4.7.5 Propagating brush discharges and stretch.ati 17 4.7.6 Cone discharges and addischarges and stretchered 30.12.2012 17 4.7.6 Cone discharges and hazards 19 5.1 General 19 5.2.1 General 19 5.2.1 General 19 5.2.2 Types of failure 19 5.3.1 General 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 <td></td> <td colspan="3">4.2 Contact electrification</td> <td>13</td>		4.2 Contact electrification			13
4.5 Retention of charge 14 4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 16 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 17 4.7.6 Cone discharges 17 4.7.6 Cone discharges 17 4.7.6 Cone discharges 18 4.8 Mechanical forces in an efectrostatic field 30.1.2012 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 19 5.2.2 Types of failure 19 5.3.3 Corona discharges fr		4.4	Charge transfer by conduction		
4.6 Influence of environmental humidity 16 4.6.1 General 16 4.6.2 In situ measurements 16 4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges 16 4.7.3 Corona discharges 16 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 17 4.7.6 Core discharges discharges 17 4.7.6 Core discharges discharges 17 4.7.6 Cone discharges discharges 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electrostatic ignition – Hazards 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from insulating surfaces 22 5.3.4 Brush discharges from insulating surfaces 22 5.3.4 Brush discharges from insulating surfaces <td></td> <td>4.5</td> <td colspan="3">5 Retention of charge</td>		4.5	5 Retention of charge		
4.6.1 General 16 4.6.2 In situ measurements 16 4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges ANDARD PREVIEW 16 4.7.3 Corona discharges and and site then ai) 17 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges and and site then ai) 17 4.7.6 Cone discharges accurate and and site then ai) 17 4.7.6 Cone discharges accurate and and site then ai) 17 4.7.6 Cone discharges accurate and and site then ai) 17 4.7.6 Cone discharges accurate and and site then ai) 17 4.7.6 Cone discharges accurate and and site then ai) 17 4.7.6 Cone discharges accurate and site and site and site and accurate		4.6	Influen	ce of environmental humidity	.16
4.6.2 In situ measurements 16 4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges ANDARD PREVIEW 16 4.7.3 Corona discharges and and stitch and states and			4.6.1	General	16
4.7 Electrostatic discharges 16 4.7.1 General 16 4.7.2 Spark discharges ANDARD PREVIEW 16 4.7.3 Corona discharges and ands.itch.ait 17 4.7.4 Brush discharges and ands.itch.ait 17 4.7.5 Propagating brush discharges.etc.tonic 17 4.7.6 Cone discharges arcate/stat			4.6.2	In situ measurements	16
4.7.1 General 16 4.7.2 Spark discharges ANDARD PREVIEW 16 4.7.3 Corona discharges and and stricth rait 17 4.7.4 Brush discharges and and stricth rait 17 4.7.5 Propagating brush discharges and and stricth rait 17 4.7.6 Cone discharges and and stricth rait 17 4.7.6 Cone discharges and and strict rait 18 4.8 Mechanical forces in an electrostatic field 340-1-2012 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from insulating surfaces 22 5.3.4 Brush discharges from insulating surfaces 22 5.3.7 Ig		4.7	Electro	ostatic discharges	16
4.7.2 Spak discharges A.D.A.RD. P.R.EVIE.Y 16 4.7.3 Corona discharges and ands. item.ai) 17 4.7.4 Brush discharges and ands. item.ai) 17 4.7.5 Propagating brush discharges and ands. item.ai) 17 4.7.6 Cone discharges and the discharges and			4.7.1	General	16
4.7.3 Corona discharges and and strike h.ai 17 4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges from conducting objects 18 5.3 Electrostatic discharges from conducting objects 19 5.3.4 Brush discharges from conducting objects 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.3.8 Discharges for ignition energy measurements 26 5.5.1 General 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements <			4.7.2	Spark discharges ANDARD PREVIEW	16
4.7.4 Brush discharges 17 4.7.5 Propagating brush discharges 40.12012 17 4.7.6 Cone discharges at catalog tradade/at 33194583.031.4cc0.a035 18 4.8 Mechanical forces in an electrostatic field 340.1.2012 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from insulating surfaces 21 5.3.4 Brush discharges from insulating surfaces 22 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5			4.7.3	Corona discharges malarde iteh ai)	17
4.7.5 Propagating brush discharges 4(b) 12(1)2 17 4.7.6 Cone discharges al catalog bradiede/bit 33194583-f131-4cc9-a035 18 4.8 Mechanical forces in an electrostatic field 340-1-2012 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from insulating surfaces 21 5.3.4 Brush discharges from insulating surfaces 22 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.4 Bischarges from people 22 5.3.5 Simulation of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25			4.7.4	Brush discharges	17
4.7.6 Cone discharges alcatalogistation dede/sist33104583-f131-4ce0-a035. 18 4.8 Mechanical forces in an electrostatic field 340-1-2012. 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 26 5.5.			4.7.5	Propagating brush discharges _{40-1:2012}	17
4.8 Mechanical forces in an electrostatic field 340-1-2012. 18 5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 26 5.5.3 Human body model 26 5.5.4 Machine model 26 <td></td> <td></td> <td>4.7.6</td> <td>Cone/discharges.ai/catalog/standards/sist/3319d583-f131-4ec9-a935-</td> <td>18</td>			4.7.6	Cone/discharges.ai/catalog/standards/sist/3319d583-f131-4ec9-a935-	18
5 Electrostatic problems and hazards 19 5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 5.5.4 Machine model 26 <		4.8	Mecha	nical forces in an electrostatic field 340-1-2012	18
5.1 General 19 5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 21 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.3.7 Ignition of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.4 Machine model 26 5.5.5 Charged device model	5	Elect	rostatic	problems and hazards	19
5.2 Electronic components and systems 19 5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 5.5.5 Charged device model <td< td=""><td></td><td>5.1</td><td>Genera</td><td>al</td><td>19</td></td<>		5.1	Genera	al	19
5.2.1 General 19 5.2.2 Types of failure 19 5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 5.5.5 Charged device model 26		5.2	Electro	onic components and systems	19
5.2.2 Types of failure. 19 5.2.3 Problems and threats at different life cycle periods. 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 5.5.5 Charged device model 26			5.2.1	General	19
5.2.3 Problems and threats at different life cycle periods 20 5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 5.5.5 Charged device model 26 5.5.5 Charged device model 26			5.2.2	Types of failure	19
5.3 Electrostatic ignition – Hazards 21 5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26			5.2.3	Problems and threats at different life cycle periods	20
5.3.1 General 21 5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26		5.3	Electro	ostatic ignition – Hazards	21
5.3.2 Spark discharges from conducting objects 21 5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 5.5.5 Charged device model 26			5.3.1	General	21
5.3.3 Corona discharges from conducting objects 21 5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 5.5.5 Charged device model 26			5.3.2	Spark discharges from conducting objects	21
5.3.4 Brush discharges from insulating surfaces 21 5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26			5.3.3	Corona discharges from conducting objects	21
5.3.5 Propagating brush discharges from insulating surfaces 22 5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26			5.3.4	Brush discharges from insulating surfaces	21
5.3.6 Discharges from people 22 5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26			5.3.5	Propagating brush discharges from insulating surfaces	.22
5.3.7 Ignition potential of electrostatic discharges 22 5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 6 General solutions to problems and hazards 27			5.3.6	Discharges from people	22
5.4 Physiological sensation 24 5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 6 General solutions to problems and hazards 27		- 4	5.3.7	Ignition potential of electrostatic discharges	22
5.5 Simulation of electrostatic discharges 25 5.5.1 General 25 5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 6 General solutions to problems and hazards 27		5.4 5.5	Physio	tion of electrostatic discharges	24
5.5.1 General solutions to problems and hazards 25 5.5.1 General solutions to problems and hazards 27		5.5			25
5.5.2 Capacitive discharges for ignition energy measurements 26 5.5.3 Human body model 26 5.5.4 Machine model 26 5.5.5 Charged device model 26 6 General solutions to problems and hazards 27			5.5.1 5.5.2	Consistive discharges for ignition energy measurements	20
5.5.4 Machine model			5.5.2 5.5.2	Capacitive discharges for ignition energy measurements	20 26
5.5.5 Charged device model			5.5.4	Machine model	26
6 General solutions to problems and hazards 27			5 5 5	Charged device model	26
	6	Gene	eral solu	tions to problems and hazards	27

	6.1 General			27
	6.2	Commo	on approaches	27
7	Usefi	ful applications of electrostatic effects		
Q	Gono			
0	Gene			
	8.1	Genera	f	
	8.2	Electric		
		8.2.1		
		8.2.2	Application	
	8.3	Potentia	al	
		8.3.1	General	
		8.3.2	Surface voltage	
		8.3.3	Space potential	31
	8.4	Charge		31
	8.5	Charge	density	
		8.5.1	Surface charge density	32
		8.5.2	Volume charge density	32
	8.6	Charge	decay	
	8.7	Resista	nce and resistivity	34
	8.8	Charge	ability	34
	8.9	Current		35
	8.10	Energy	in capacitive discharges DARD PREVIEW	35
	8.11	Ignition	energy	
		8.11.1	General	
		8.11.2	Equivalent energyFC TR-61340-1:2012	
	8.12	Charge	transferred in electrostatic discharges 9d583-f131-4ec9-a935-	
		8.12.1	General	
		8.12.2	Discharge electrode	
		8.12.3	Measuring circuit	
		8.12.4	Alternative charge transfer measuring arrangements	
	8.13	Capacit	ance	
	8.14	Electric	strength	40
Bib	liograp	ohy	~ 	41
Fig	ure 1 -	- Chargi	ng by induction	14
Fig	ure 2 -	- Charge	e transfer by conduction when objects 1 and 2 are conductors	14
Fig	ure 3 -	- Equiva	elent electrical circuit for an electrostatically charged conductor	15
Fig	ure 4 -	- Examp	bles of brush discharge waveforms measured with a fast digital	24
5.01	aye 0	Oireut	for simulation of electrostatic discharges	
rigi	ure 5 -		ior simulation of electrostatic discharges	25
Fig	ure 6 -	- Basic a	arrangements for measuring charge transferred in electrostatic	20
⊦ıgı	ure 7 -	- Uscillo	oscope voltage/time traces	

Table 1 – Example of triboelectric series	13
Table 2 – Typical electrical capacitances	17
Table 3 – Typical perception levels and physical responses of people to dischargesbased on a body capacitance of 200 pF	25
Table 4 – Typical values used in ESD simulation models	27

iTeh STANDARD PREVIEW (standards.iteh.ai)

IEC TR 61340-1:2012 https://standards.iteh.ai/catalog/standards/sist/3319d583-f131-4ec9-a935-9ac5bb897639/iec-tr-61340-1-2012

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROSTATICS –

Part 1: Electrostatic phenomena – Principles and measurements

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committee; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC/TR 61340-1, which is a technical report, has been prepared by IEC technical committee 101: Electrostatics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
101/344/DTR	101/355/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 61340 series, published under the general title *Electrostatics,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigenda 1 (March 2013) and 2 (December 2017) have been included in this copy.

iTeh STANDARD PREVIEW (standards.iteh.ai)

<u>IEC TR 61340-1:2012</u> https://standards.iteh.ai/catalog/standards/sist/3319d583-f131-4ec9-a935-9ac5bb897639/iec-tr-61340-1-2012

INTRODUCTION

Static electricity has been known for around 2 500 years but until recently had little impact on humankind. More recently in the last century the nature of static electricity became better understood and the principles of charge separation and accumulation could be described. Despite this improved understanding, it remains difficult to predict with certainty the polarity and magnitude of charges built up in any situation due to the many factors involved, and to, many electrostatics remains a "black art" rather than a science.

The development of modern materials, especially polymers, and their nearly ubiquitous application in fields such as floor materials, furnishings, clothing and engineering materials, has made static electricity an everyday phenomenon. In some industries, such as electronics manufacture and processes using flammable materials, unintended and invisible electrostatic discharges can lead to substantial component damage or unreliability, or fires or explosions. In everyday life, experience of electrostatic shocks to personnel has become commonplace. This has led to increasing need to understand such phenomena, and to specify materials, equipment and procedures for use in preventing and controlling electrostatic problems in the human environment.

This technical report gives an overview of the field of electrostatics and has been prepared to give the user a view of the background, principles, methods of measurement and industrial applications prepared in conformity with IEC TC101 publications.

iTeh STANDARD PREVIEW (standards.iteh.ai)

<u>IEC TR 61340-1:2012</u> https://standards.iteh.ai/catalog/standards/sist/3319d583-f131-4ec9-a935-9ac5bb897639/iec-tr-61340-1-2012

ELECTROSTATICS –

Part 1: Electrostatic phenomena – Principles and measurements

1 Scope

This part of IEC 61340, which is a technical report, describes the fundamental principles of electrostatic phenomena including charge generation, retention and dissipation and electrostatic discharges.

Methods for measuring electrostatic phenomena and related properties of materials are described in a general way.

Hazards and problems associated with electrostatic phenomena and principles of their control are outlined.

Useful applications of electrostatic effects are summarized.

The purpose of this technical report is to serve as a reference for the development of electrostatics related standards, and to provide guidance for their end-users.

(standards.iteh.ai)

2 Normative references

IEC TR 61340-1:2012

The following documents, in whole of in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-10-2, *Explosive atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61340-5-1, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC 61340-5-2, *Electrostatics – Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide*

IEC 60243-1, Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies

IEC 60243-2, Electric strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage

TR 61340-1 © IEC:2012

IEC 61241-2-3, Electrical apparatus for use in the presence of combustible dust – Part 2: Test methods – Section 3: Method for determining minimum ignition energy of dust/air mixtures

BS EN 13821, Potentially explosive atmospheres. Explosion prevention and protection. Determination of minimum ignition energy of dust/air mixtures

3 Terms and definitions

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

3.1

antistatic additive

antistatic filler, antistatic treatment

substance added to, or process applied to a liquid or solid in order to reduce its tendency to acquire a charge by contact and rubbing, or to promote more rapid charge migration and so to reduce its ability to retain significant charge when in contact with earth

3.2

antistatic

refers to the property of a material that inhibits or limits triboelectric charging

3.3

bonding iTeh STANDARD PREVIEW

electrical connection between two or more conducting objects that reduces the potential difference between them to an insignificant levels. Iten.al)

3.4

IEC TR 61340-1:2012

breakdown https://standards.iteh.ai/catalog/standards/sist/3319d583-f131-4ec9-a935failure, at least temporarily, of theainsulating/properties of an insulating medium under electric stress

3.5

breakdown voltage

voltage at which breakdown occurs, under prescribed conditions of test or use

3.6

charge decay

neutralization or migration of charge across or through a material leading to a reduction of charge density or surface potential at the point where the charge is deposited

3.7

charge decay time

charge relaxation time

time taken for charge to decay from a specified value to a specified lower value

Note 1 to entry: The specified lower value is commonly one tenth or 1/e of the starting value (e = 2,718).

3.8

conductivity

ability of the substance to conduct electrical current expressed as S×m⁻¹

3.9

conductor or conductive material

object or material providing a sufficiently high conductivity so that potential differences over any parts of it are not sufficiently large as to be of practical significance

Note 1 to entry: In general this is a material having a resistance below about ${}_{10}{}^{5}\Omega$ but different standards may define different resistance ranges for this term.

3.10

dissipative material

material which allows charge to migrate over its surface and/or through its volume in a time that is short compared to the timescale of the actions creating the charge or that will cause an electrostatic problem

Note 1 to entry: In general a material having a resistance approximately $10^5 \Omega$ and below approximately $10^{11} \Omega$ is considered to be dissipative. Different standards may disagree on the exact values of the limits.

3.11

earth, earthing, grounding

ground

electrical connection (bonding) of a conductor to the main body of the earth to ensure that it is at earth potential

3.12 **iTeh STANDARD PREVIEW**

ESD (standards.iteh.ai)

transfer of charge by direct contact or by breakdown from a material or object at a different electrical potential to its immediate surroundings_{0-1:2012}

https://standards.iteh.ai/catalog/standards/sist/3319d583-f131-4ec9-a935-9ac5bb897639/iec-tr-61340-1-2012

3.13

explosion groups

flammable gaseous atmospheres subdivided into explosion groups I, IIA, IIB and IIC to define their inflammability

Note 1 to entry: The most sensitive explosion group is Group IIC.

Note 2 to entry: See [9] to [11]¹ for definitions of classification method.

3.14

flammable substance

substance in the form of gas, liquid, solid or mixture of these, capable of propagating combustion when subjected to a sufficiently strong ignition source

3.15

hazard threshold voltage

minimum electrical potential of capacitive stored charge that may give rise to an electrostatic hazard

3.16

hazardous area

area in which flammable substance is, or may be expected to be, present in quantities such as to require special precautions against ignition

Note 1 to entry: Hazardous area zones are defined in IEC 60079-10-1 and IEC 60079-10-2.

¹ References in square brackets refer to the bibliography.

TR 61340-1 © IEC:2012

3.17

insulator

insulative material

material with very low mobility of charge so that any charge on the surface will remain there for long time

Note 1 to entry: Connecting an insulator to earth does not help charge migration.

3.18

minimum ignition energy

MIE

smallest amount of energy released in a capacitive electrical spark that can ignite a mixture of a specified flammable material with air or oxygen, according to a defined procedure

3.19

relaxation of charge

migration or neutralization of charge over and/or through a solid, liquid or gaseous material causing a reduction in surface charge density and energy

Note 1 to entry: If the potential of a surface is defined then this is also reduced.

3.20

surface charge density

 σ_{s}

net quantity of charge per unit area of surface of a solid or liquid

3.21

surface resistivity

Ω

resistance between opposing sides of a square on theis urface of a material

https://standards.iteh.ai/catalog/standards/sist/3319d583-f131-4ec9-a935-9ac5bb897639/iec-tr-61340-1-2012

(standards.iteh.ai)

3.22

triboelectric charging

electrical charging process in which charge is generated by the contact and separation of two surfaces which may be solid, liquid or particle-carrying gases

3.23 volume charge density

 σ_v

net quantity of charge per unit volume of a solid, liquid or gas

3.24

volume resistivity

Ω×m

resistance between opposing sides of 1 m³ of the material

4 Fundamentals of static electricity

4.1 General

Generally, electrostatic charge on a material, product or object is the result of:

- contact and rubbing;
- charge transfer;
- induction in an electric field;

- effect of polarization;
- photoelectric effect;
- pyroelectric effect;
- piezoelectric effect;
- ionization and ions adsorption;
- electrochemical processes.

However, the primary source of electrostatic charge is triboelectric charging. If two previously uncharged substances come into contact, charge transfer will, in general, occur at their common boundary. If a gas containing solid particles or liquid droplets in suspension becomes charged by contact and separation, then the gas can be seen as carrying an electrostatic charge. On separation, each surface will carry an additional charge of equal magnitude but of opposite polarity. Conducting or dissipative objects can become charged by induction if they reside in an electric field produced by other charged objects or conductors at high potential in their vicinity. Any object can become charged if charged particles or molecules accumulate on it.

It is very important to have some appreciation of these phenomena in order to enable the proper implementation of test procedures and unambiguous interpretation of the resultant data. It is also important with regard to choice of electrodes, protection of current measuring devices from the initial capacitive surge and the time at which the value is recorded. The latter should, of course, be appropriate to meet the practical circumstance for which the data are required. Further comments are included in this technical report with the descriptions of the individual test methods, where considered necessary.

4.2 Contact electrification

Contact electrification can occur at solid/solid, liquid/liquid or solid/liquid interfaces. Clean gases cannot charge materials in this way. If a gas contains solid particles or liquid droplets in suspension, however, these may be charged by contact so that such a gas can carry an electrostatic charge by virtue of these particles.

(standards.iteh.ai)

In the case of solids of different materials, initially uncharged and normally at earth potential, charge is transferred from one material to the other when they make contact. When they separate, a net positive charge remains on the one surface and a net negative charge on the other surface. The quantity of charge is increased by the size of the contact areas and the size is affected by the contact pressure. Additional rubbing also increases the effective contact area.

The relative amounts and polarity of charge transferred between materials can be presented as a list, referred to as the triboelectric series. A material is expected to charge positively against materials lower in the series, and negatively against materials higher in the series. It should be noted that the position of a material in the triboelectric series is an approximation, dependent on test conditions, and that two samples of the same material rubbed against each other can result in quite strong charging.

Examples of triboelectric series are shown in Table 1.

Item	Charge
Rabbit fur	Positive
Glass	
Human hair	
Polyamide (nylon)	
Wool	
Fur	
Silk	
Aluminum	
Paper	
Cotton	
Steel	
Wood	
Rubber	Negative
Acetate rayon	
Polyethylene (PE) and polypropylene (PP)	
PET	
PVC iTeh STANDARD	PREVIEW
Polyurethane (standards it	eh ai)
PTFE (Standar US.IU	11.a 1 <i>j</i>

Table 1 – Example of triboelectric series

IEC TR 61340-1:2012

The two materials are oppositely charged and consequently there is an electric field between them. If the materials are then separated, measures shall be taken to overcome the attraction between the opposing charges and the potential difference between them increases linearly with distance. This higher potential difference tends to drive charge back to any point of residual contact. In the case of two conductors, the recombination of charges is virtually complete and no significant amount of charge remains on either material after separation. If one material, or both, is a non-conductor, the recombination cannot take place completely and the separating materials retain part of their charge. There may only be a small amount of charge involved but, because the distance between the charges when the surfaces are in contact is extremely small, the potential generated on separation can easily reach many kilovolts. Realistic surfaces are usually rough and so the charging is enhanced if the contact and separation involves rubbing and/or pressure, since the area of real contact is increased by these actions. Note that the real area of contact can be quite different in size from the appearing area of contact. They can differ by a magnitude or more.

Contact electrification in liquids is essentially the same process but it can depend on the presence of ions or sub-microscopic charged particles (the latter are usually less important). lons (or particles) of one polarity may be absorbed at the interface and they then attract ions of opposite polarity which form a diffuse layer of charge in the liquid, close to the surface. If the liquid is then moved relative to the interface, it carries away some of this diffuse layer, thereby bringing about separation of the opposing charges. As in the case of solids, a high voltage is generated because of the work done to bring about separation, provided that the liquid is sufficiently non conducting to prevent recombination. Such processes can occur at both solid/liquid and liquid/liquid interfaces.

4.3 Charging by induction

There is an electric field around any charged object. A conductor or dissipative material introduced into this field changes the distribution of electric field in its vicinity and at the same time there is a redistribution of charges in the material under the influence of the field (see