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Research article

Charging by contact as the primary source hazard from static electricity.

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Abstract

In this article, attention was paid on charging by contact of materials that should be considered as the primary source hazard from static electricity. Here explains the causes of interference that caused by the charged material and describes the distortions caused charging by contact of a material. In addition, it also devoted attention to the hazard from static electricity caused by the adverse effects of electric field by the man, the technological system, or the surrounding atmosphere potentially explosive. Furthermore, based on historical records can be traced silhouettes of a scholar who have made further discoveries accidental phenomena caused by random charged material happened after charging by contact.

The presence charge induced on the material same character is manifested in that the material is charged. Described the principle charging by contact through material non-metallic, which appears to be a primary causative agent of charging material. The presence of charges induced on the charged material is detected by an electroscope.

In the final part of this paper presents the result of research charging by contact in the form of dissipative brush discharge. For comparison, an example of the risk of explosion from static electricity caused by continuous charging by contact during pneumatic transport of dust by a flexible hose with grounded metal braid.

Keywords: static electricity, charge, charging by contact, hazards.

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1. Introduction

Team of the appearance phenomena excess electrical charge on the material with low electrical conductivity (non-conductive material) or insulated from the ground conductive material (e.g. the human body, conductive devices) is called static electricity. Protection against static electricity requires special knowledge, which is usually not readily available. Experts in the fields protection against static electricity should be familiar with the theory electric field, building materials, and high-voltage technology. It is important in assessing hazard from static electricity discharge rate should have charge on the surface charged material [6]. Experts ask themselves fundamental questions about the hazard from electrostatic in industrial processes (industrial electrostatics) and lightning protection (atmospheric electrostatics).

2. Hazard from static electricity

The issue protection against static electricity can be divided into two distinct areas namely protection against static electricity in industry and lightning protection in the weathering processes. Comprehensive assessment the effects and the choice of materials testing methods require knowledge of a static electricity charging by contact and neutralization of the charge in the course local discharge on the charged material

. Understanding the process charging of a non-conductive material can facilitate the proper monitoring hazard and become one the key security tasks.

"Poisoning" environmental hazards which are released from the static electricity due to the presence of a strong electric field in the human environment

Despite the specific requirements for the protection against static electricity contained in the regulations, standards and procedures, there is still the world and the country to explosions and fires caused by spark ESD in which the victims are men.

Charging by contact the material contributes occurrence to the hazard from static electricity. In any case, the origin and the nature hazard from static electricity should be considered individually. The term "hazard" should be specific expression indicating its origin (e.g. as a result of continuous charged human due to charging by contact) or expected the nature damage (e.g. hazard shock electrostatic spark discharge ESD as an effective source ignition, fire hazard). Therefore, the hazard from electrostatic and static should be treated as exogenous (caused by external factors).

Hazard from static electricity is created when:

- At the location where the material can’t be ruled out the possibility charging by contact. There are two types of charging by contact:

a) ad-hoc in the course of cleaning maintenance, non-metallic elements such as cleaning goggle lenses, wipe the helmet shell and the raising man with a chair, walking on the non-conductive floor, removal of clothing.

Research charging by contact of a human was carried out in the laboratory room under controlled conditions of temperature and humidity. After the electrification potential measurement was performed on isolated electrified body. Then were determined a charge transfer. The charge transfer during the discharge out of charged isolated human shown in Table 1.

Table 1: The charge transfer during the discharge out of charged ad-hoc human isolation.

Or.	Charging by contact	Charge transfer Q (nC)
1	Raising the chair	265
2	The transition to the non-conductive floor	700
3	Removal of clothing	900

b) Continued in use of an elements non-metallic (e.g. protective clothing worn by a man in motion, the conveyor belt moved along grounded conductive parts, pneumatic transport dust through the pipe),

- The material that is capable of static electricity ("chargeability") [8]. The material charge carriers can be electrons and ions. Charge produces an electric field around them. The materials in which the phenomenon associated with the accumulation electric charge characterized by particularly hard materials are non-conductive electrostatic properties. Non-conductive products are used in all industries,

- The charged material impact on the surrounding environment. Galvanized material produced in a finite period

time inhomogeneous electric fields which, by the local discharge can be enhanced by short pulse superimposed on the field already exist [3].
The presence electric field around the charged material produces two types hazard from static electricity:

1.1. Interface technological system,
1.2. Adverse effects electric field.

2.1. Interface technological system

The electric field around the charged material may cause harmful interference to normal operation technology. The distortion created by the charged material hamper the proper functioning of industrial processes:

1. the shock electrostatic when touching the charged material with properties electrostatic of non-conductive,
2. the aggregation or the repulsion charged preventing thin film non-metallic rewinding or fast (difficulty in processing, cutting, arranging and sorting),
3. the pollution surface as a result of non-attracting particles,
4. sparking at development duct tape,
5. the mutual bonding charged clothing and to the human body,
6. the damage (damaging or deteriorating performance) as a result electronic component breakdown thin insulating layers (metal oxides) in the structure of transistors and integrated circuits. Damage may occur during their production, packaging, transport, sale, installation and operation of the complete equipment, service and support,
7. influence electric field on integrated circuits:

a) degradation insulation gaps. Damage to the structure of the insulating material as a result strong oxidative action of reactive oxygen species "in statu nascendi" ("in the course formation") spark ESD. Penetration the material can result in erosion paths in the formation path insulating circuits (order nanometers and micrometers), which due to the small thickness have a low dielectric strength (several tens to hundreds Volt);
b) degradation paths conductive. The heat capacity paths conductive on a chip is not sufficient to withstand the rising stroke heat. Short current pulses can reach the intensity few to several amperes. Devastating melt and break the thin conductive path in the structures integrated circuits.

Discharge out of charged man who touches the grounded conductive element, accompanied by a spark ESD. In recent years there has been a steady increase in interest in the issues deal with the hazard from static electricity which disrupt production in factories, cause damage to the chip, causing a system crash or hard to detect the random noise.

2.2. Adverse effects electric field

Threats from static electricity caused by the adverse influence electric field:

2.2.1 Adverse effects electric field on the man

Effect of an electric field being in the isolated man is his charging. The isolated man in the operating equipment for processing materials non-metallic capable of static electricity, and when you deal with them (e.g. developing the roll of film) is exposed to a constant electric field. The isolated charged man in the course discharge due to accidental touching the grounded piece conductive feel its effects in the form light bites until a strong shock.

Grounded due to accidental contact man will discharge charged local material non-metallic. If as a result discharging out of the charged material the value charge transfer will be for 1000 nC, the energy spark ESD will be W = 2.5 mJ.

The impact electric field to the man is not indifferent to the body. It can have a negative impact on the health and well-being as a result staying for a long time in the electric field. Strong shocks can cause by man violent, uncontrollable reflex, and ultimately lead to the accident. If a man supports the device with moving or sharp objects (e.g. fight, gears, blades, etc.), or working at height, this hazard effect shock can be rapid, involuntary dodge, which could lead to the collapse, serious injury, or damage to the man, shock in extreme cases, death.

The isolated man operating machinery and equipment with components non-metallic exposed to the conditions use for continuous charging by contact could be a multiple of unpleasant shocks electrostatic (see Table 2). Long term the effects electric field on the man can cause changes in the man circulatory system and nervous system, as well as the morphological structure the blood. Harmful biological effects may be enhanced during spark ESD. Exceptions are situations where shocks are felt by man continuously and interact constantly in one place. In extreme cases, these situations can cause muscle contraction, cardiac arrhythmia or arrest. However, these situations are very rare.

Since there are currently no regulations defining the permissible value charge transfer during in the discharge out of isolated charged man in Table 2 are the typical levels of perception according to [15].

Table 2: Typical levels of perception and physical reactions of a man with a capacity of 200 pF to spark ESD.

Energy discharge W (mJ)	Charge transfer Q (nC)	The level of perception
0,1	200	perceptible
0,9	600	impression felt
6,4	1600	unpleasant shock

Unpleasant shocks are dangerous to health and should seek to eliminate.

2.2.2 Adverse effects electric field on a technological system (damage to electronic components)

The adverse effects electric field will hinder the operation technological system. It should be taken into account at the design stage technological systems. When designing the technological system must be provided the presence charging by contact and consider the effects it may have on a charged.

Pressures electric field may reduce the efficiency production process. Long-term effects electric field due to the accidental spark ESD may cause harmful interference to the proper functioning equipment. The induction additional voltage and current in a circuit may lead to a state emergency in the use of equipment such as:

- reduction in the functioning computer,
- false indications in the receipt and processing signals in control systems,
- damage to electronic components supervising the safe running technological system in measuring and control apparatus,
- identify adverse medical diagnostic equipment.

2.2.3 Adverse effects electric field on a potentially explosive atmosphere

A man suffers accidental sometimes unpleasant or painful shock, but do not realize that even a barely perceptible tremors are spark ESD. Each shock accompanies the many can cause a potentially explosive atmosphere, with a probability greater than zero. Explosion hazard arises when the energy spark ESD achieves greater than or equal to the minimum ignition energy (MIE) gas explosive atmosphere [1].

The discharge out of isolated charged conductive elements to the ground e.g. charged man, accompanied by the production extremely high energy W. In the course discharge out of charged man spark ESD can ignite an explosive atmosphere. If the result discharge spark ESD is felt by man, is the energy W discharge is at least 0,9 mJ (threshold physiological response man positioned in Table 2). This energy is at least several times higher than the minimum ignition energy MIE most gas explosive atmospheres. For example, the minimum ignition energy methane is 0.28 mJ.

Local discharge through the charged element non-conductive accidentally touched by a man grounded may result in perceptible shock electrostatic about energy 0,2 mJ. In this case, the charge transfer during the discharge will be ca 300 nC.

3 Definitions

To clarify the content article, the following definitions apply:

Bottle (Leyden) Kleist - unit (original capacitor) for the collection electric charge. **Dielectric, an electrical insulator** – a material in which electric current is very poorly conducted. This may be as a result low concentration electric charges, low motility, or both simultaneously. **Electret** – a dielectric, in which a permanent dipole polarization persists or charged. Electret generates external electric field, and in this sense it is an electrostatic equivalent permanent magnet. **Electrostatics** - branch of physics dealing with the electric field produced by a stationary electric charge does not require the constant input energy.

Electric dipole moment p - vector physical quantity characterizing electric dipole. Dipole is a system two charges same absolute value but the opposite signs. The importance dipole by the fact that atoms are in the electric field dipoles (polarity material). The electrical properties of a material associated with the properties electric dipole in a field.

Charging by contact (tribo charging) - the phenomenon movement electric charge (electrons, which have greater flexibility in the structure of a materials) within the material under the influence different material. The result is the generation electric charge on the two materials rubbed with each other.

Spark ESD (electrostatic discharge) - spark (electrostatic discharge) - transport charge transfer (sudden flow of electrical current) flowing between two materials with different electrical potentials (IEC 61340-1-2) due to the contact or induced by a field electric.

Areal density σ [C/m^2] electric charge - the amount charge Q per unit area S charged material. **Capacitor** - electrical component (electronic), consists two conductors (cover) separated by a dielectric. The capacitor capacitance C is characterized by determining the ability charge storage capacitor Q (1):

$$C = \frac{Q}{U} \tag{1}$$

where:
C [F] - capacitance of the capacitor,
Q [C] - charge induced on one cover,
U [V] - an electric voltage between the covers.

Supply voltage to the capacitor electrodes causes the assembly to their electrical charge. After disconnecting from the power supply, charges remain on the cover electrical forces attraction. Capacity determines the ability charge storage capacitor. If the specific electrode (capacitor cover) accumulates electric charge Q, then moves on to the second capacitor cover unit SI (unit derived SI) is expressed in farads [F]. Capacitance electric isolated conductor sackcloth one of F (2), it is the ratio charge Q accumulated on the conductor to induced by this charge voltage U.

$$1F = \frac{1C}{1V} = \frac{1A \cdot 1s}{1V} = 1\frac{A^2 s^4}{kg \cdot m^2} \tag{2}$$

One farad is a very large unit, so in practice meets capacitors with a capacity of pico-(10^{-12} F), nano-(10^{-9} F), micro- (10^{-6} F) and a mile-(10^{-3}) Farad. The inverse capacitance is expressed in daraf is elastance (this is not an unit SI).

Electrical charge (elementary) Q [C] - one of the primary physical quantities. In the SI system is expressed in coulombs and has an approximate value. The value electron charge (equivalently, the positive charge of proton) is e = 1.6021764 (40) × 10^{-19} C. The unit SI electric charge is called Charles-Augustin de Coulomb. The value charge 1C is defined as:

- transported by current 1 A ad the time 1 s (3):

$$1C = 1A \times 1s \tag{3}$$

or equivalently:

- on the cover of the positively polarized capacitor with a capacity of 1 F and potential difference between the capacitor plates 1 volt (4)

$$1C = 1F \times 1V \tag{4}$$

Charge induced - if the charge generated by surrounding a closed surface area (according to Gauss law), the total charge induced on the surface is equal to the charge closed in this area. **Charge transfer Q (nC)** - local drainage charge Q out of a charged material. If the value charge transfer Q out of charged material does not exceed 10 nC, it does not present the hazard explosion in potentially explosive atmospheres.

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Non-metallic material - material plastic (synthetic or plastic materials structurally modified) or natural (ceramics, wood).
Non-conductive material (electrostatic) – the parameter resistive material (surface resistance R_S, volume resistance R_V) is in excess of 1.0 x 10^9 Ω (eg. plastics). Collected on a charge induced is not dissipated even when it is provided with contact with the ground.
Conductive material (electrostatic) - material is unable to accumulate electric charge in the event contact with the ground, and having a surface resistance R_S and the volume resistance R_V than less or equal to 1.0 x 10^6 Ω (resistance below the distraction allowing currents and avoid electric shock).
Dissipative material (electrostatic) - material unable to accumulate electric charge in the event contact with the ground, and having a surface resistance R_S and volume resistance R_V in the range of (1.0 x 10^6 Ω, 1.0 x 10^9 Ω).
Antistatic material - material conductive or dissipative, that does not accumulate static electricity when it is in contact with the ground.
NOTE: The word is commonly used to describe the type shoes or composition antistatic liquid.
Polarization of a dielectric - phenomenon electric dipoles create or change the settings existing dipoles in the material. The atoms and the molecules material is polarized in an electric field, i.e. induced the dipole electric. As a result, the dielectric polarization is formed in the internal electric field. Macroscopically polarization manifested by the fact that increases the capacitance capacitor filled with dielectric.
Field electric - as the space surrounding electric charges. The electric field acts on the electric charge electrostatic force.
Permittivity ε - physical quantity characterizing the electrical properties material. In the unit SI electric permittivity is F • m^{-1} (farads per meter).
Surface resistance R_S (Ω) - surface resistance of a material between two parallel electrodes equal length of contact.
Volume resistance R_V (Ω) - resistance on the two opposite surfaces material between two electrodes placed through.
Shock electrostatic - pathophysiological effect, resulting from the flow electrical current through the man.
Dielectric strength E (V/m) - the highest value electric field that exists in the dielectric (insulator) without causing a discharge spark.
Hazard - a potential source of damage caused by external forces such as electricity or human, that makes sense security decreases or completely disappears.

4. Historical overview

The phenomenon charging by contact materials is known from antiquity. To explain the phenomena occurring during the process charging continues, however to this day. The ability to charging materials [9], it can be either random, usually malicious or intentionally be the result ongoing process.

4.1 VI century BC

The existence electrostatic interactions was already known in antiquity. Name electricity comes from the Greek word meaning amber electron. In ancient times, the electrostatic effect was known as "amber effect", as it was primarily concerned with rubbing amber material.

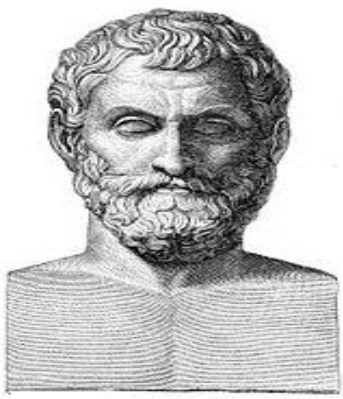

Figure 1: Thales of Miletus gr. Θαλῆς ὁ Μιλήσιος Thales ho Milesios.

Static electricity in the charging were known almost 2600 years ago. The Greek philosopher and mathematician Thales of Miletus (*620 -+540 BC) was one seven sages belonging to the Presocratic [9]. He attributed the discovery of electricity. He noted that the wool rubbed amber attracts small, lightweight materials such as wood chips. He described some experiments on charging by contact with amber, cat fur etc. He also described the motion of particles, which can be invoked in the immediate vicinity "filled" materials [9].

4.2 Seventeenth century

William Gilbert (Fig. 2) (* 24 05 1544 Colchester - + 10 12 1603 London). He was an English physicist and physician, the discoverer magnetic induction and charging by contact. As the first carried out around 1600 detailed studies and showed that the addition of amber can charged other materials [5]. He said that other materials when they are rubbed behave like a charged amber. He showed that as a result charging by contact (friction) can charged many material.

Figure 2: William Gilbert.

Gilbert's major work entitled “De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure” was published in 1600. Gilbert first popularized in English, the term "electricity". In his honor, the unit magnetomotive force (magnetic tension) called gilbert (Gb).

Electrostatic machine

Otto von Guericke (Fig. 3) (* 20 11 1602 Magdeburg, + 11 05 1686 Hamburg). He was a German physicist and inventor. In 1663 he constructed an electrostatic machine. This is a device for generating and storing electric charge (for a positive electrode, and the other negative).

Figure 3: Otto von Guericke and stamped stamp to commemorate the 250th anniversary of his death.

Electrostatic machine built by Otto von Guericke (Fig. 4) in 1663 has been described as a large ball of sulfur mounted on vertical supports. Sulfur ball was turned crank. Charging by contact (friction) was called a ball by hand position on a rotating ball. Rotating sulfur ball touching a grounded liner produced static electricity spark. However, Otto von Guericke had no idea what they are for spark ESD.

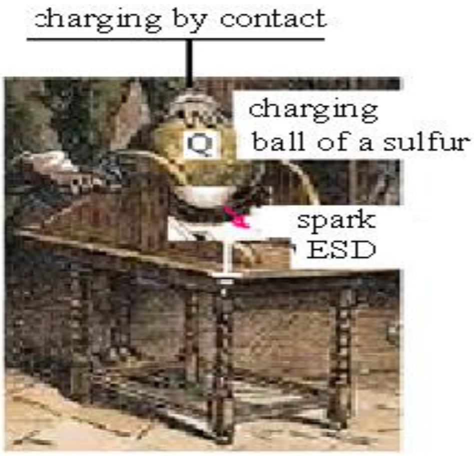

Figure 4: Prototype electrostatic machine Otto von Guericke.

Electrostatic machine can produce very high voltage, however, is completely unsuitable for the continuous delivery large currents.

4.3 Eighteenth century

Stephen Gray (* in December 1666 in Canterbury, Kent, + 07 07 1736 London). He was an English scientist and amateur astronomer. Be the first systematic experiments conducted on electrical conductivity. In 1719, he began to experiment with static electricity using charged glass tube. One night in his room at Charterhouse, said that the cap on the end out of charged tube produces the force attraction small scraps paper.

Figure 5: Stephen Gray.

In 1730 an important experimental work carried out, which led to understand the difference between conductors and insulators.

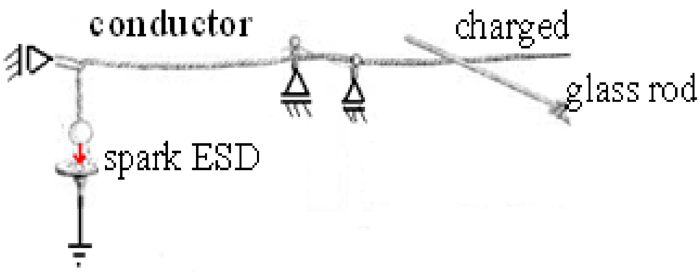

Figure 6: Moving "electric power" at a distance.

These observations later became the basis for the claim that "electric power" can be transferred at a distance from the material to the material, using metal or damp fibers. He is considered one with fathers electricity. Further experiments and observations research have contributed to the breakdown materials for guides and insulators.

The idea that there are two types of electricity introduced by [2] **Charles François de Cisternay du Fay** (Fig. 7) (* 14 09 1698 - + 16 07 1739). He was a French chemist, superintendent and curator at the Jardin du Roi in Paris. He has made an important discovery that there are two kinds electricity, the first produced by the glass (glassy materials), the second produced by the resin (resin material).

Figure 7: Charles François de Cisternay du Fay.

In 1734 he presented his famous theory of electrostatics. Tested a number of materials treated charging by contact. On the basis of the results identified a group of glassy materials (on electricity vitreous), and a group of resin materials (on electricity resin). To the group glassy materials he scored rocks, crystals, precious stones, animal hair, wool, etc., and to the group resin materials he scored amber, rubber, silk, paper, etc.

Ewald Jürgen Georg von Kleist (Fig. 8) (* 10 06 1700 Wicewo (Vietzow) near Białogardu (Belgard), + 10 12 1748 Koszalin (Poland))

Figure 8: Plaque in Kamień Pomorski (Poland), reads as follows: "Jurgen Ewald Georg von Kleist - from 1722 to 1747 the dean of Kamień - the 300th anniversary of birth of people cut Kamień Pomorski 10 VI. 2000 " He was dean of a cathedral chapter in Kamień.

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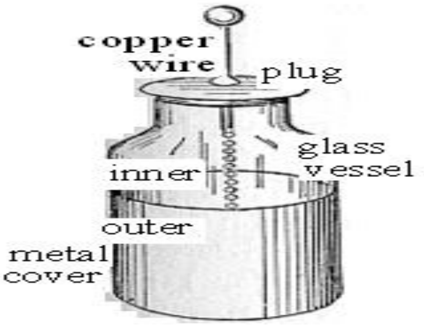

Figure 9: Bottle (Leyden) Kleist.

He constructed a simple electric capacitor (Fig. 9), which is a device that would collect energy. The device consisted of a glass vessel (dielectric), two metal layers acting as capacitor electrodes and cork pierced through copper wire. Glass vessel was filled with water. The device is called a bottle (Leyden) Kleist (originally "Kleistche Bottle").

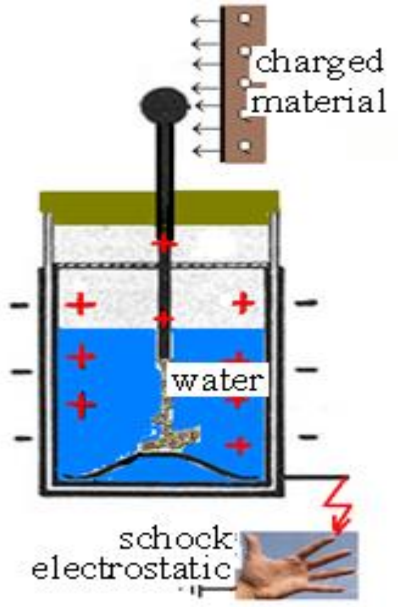

Figure 10: Discharge charged bottle (Leyden) Kleist.

11 October 1745, in Kamień Pomorski, Ewald von Kleist, after many attempts, made a great discovery that revolutionized the study electricity. During his research he noticed that electricity can be stored in the "bottle" when he was approached charged material to a copper rod. By wire and water charge is sent to the center of the vessel and the inner layer charged metal. Consequently, a "bottle" was charged.

Approaching hand to the charged outer layer metal body experimenter was experiencing shock due to the jump spark ESD (Fig. 10).

French priest **Jean-Antoine Nollet** (1700 - 1770), an avid experimenter, completed in 1746, the successful experience of "Bottle (Leyden) Kleist". In the courtyard of the royal palace at Versailles, in the presence king and the whole court, he discharged charged "capacitor bottle" having used the chain holding hands 240 Royal Guards (a schematic representation is shown in Fig. 10). To the admiration and delight spectators, stunned by the shock guards jumped up at the same time. Another time, the same experimenter uncharged "the bottle" chain almost three kilometers in length formed by the monks abbey in Chartreux, connected by a wire segments. And in this experiment, participants clearly felt the shock.

Supply voltage to the capacitor electrodes causes the assembly to their electric charge (Fig. 11). After disconnecting from the power supply, charges remain on the cover capacitor electrical attractive forces. If the capacitor is charged, the charge is stored on both covers is the same as the value but opposite sign. Convincing

argument in favor of assigning the stored energy in the capacitor electric field is an attempt to move away from a covers charged capacitor.

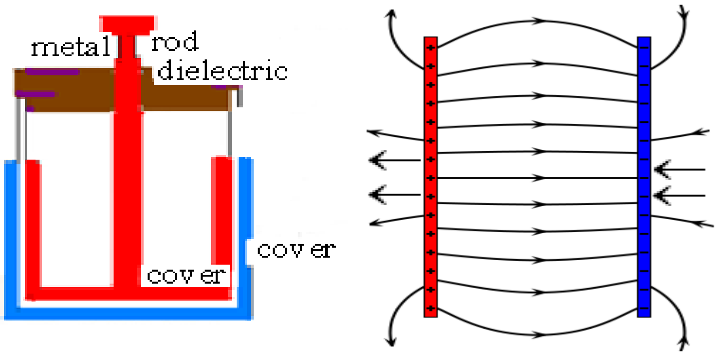

Figure 11: Charged the "bottled of capacitor".

While distancing covers the work is done, because the cover attracted by static electricity charges different character. Produced between capacitor plates electric field is dependent on the distance between them (Fig. 11).

Daniel Gralath (Fig. 12) (*30 May 1708 in Danzing, + 23 July 1767 in Danzing (Poland)) - Danzig, Mayor, margrave, scholar.

Figure 12: Daniel Gralath

Figure 12: Stone plinth in Danzing commemorating the scientific Daniel Gralath.

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He was interested in electricity. Since 1747 he researched on the "bottled capacitor". The idea was to combine several Gralath " bottled capacitors ", which marked the beginning electric battery.

With the help electric battery performed pioneering experiments involving arson wine spirit spark ESD (1744). The results his research has included in "The History of Electricity", which discusses the history research on these issues from the ancient Greeks after its time.

Benjamin Franklin (fig. 13) (* 17 01 1706 Boston, + 17 04 1790 Philadelphia). He was an American politician, scientist, philosopher, freemason. In the years 1747 - 1753 performed the experiments, including the Kite Runner and "Bottle Kleist" - using these devices collect electricity imported from lightning. His experiments described in the book "Experiments and Observations on Electricity".

Figure 13: Benjamin Franklin and the hundred-dollar bill.

In physics, led among others studies on electricity. The achievements of Franklin's theory electricity include electrical phenomena, in which the assumed positive and the negative charging materials. As the first to introduce the concept polarization positive or negative, as evidenced by the example bottle (Leyden) Kleist. He said that the materials one character charged repel, and charged opposite sign - attract with a force F. He discovered and formulated the principle attraction in and out material, depending on the sign electric charge. He patented several inventions including invented the lightning rod, rocking chair, bifocal glasses and glasses authorities.

Charles-Augustin de Coulomb (Fig. 14) (* 14 06 1736 - +23 08 1806).

He was a French physicist. He published in 1785 a law known as the Coulomb law (5) describing the relationship between the strength of the F_e, charges q_1, q_2 and the distance r

$$F_e = k_e \frac{q_1 \cdot q_2}{r^2} \tag{5}$$

where:
F_e [N] - the electric force,
k_e [Nm^2/C^2] - Coulomb's constant,
q_i [C] - charge on the material,
r [m] - the distance between the charges.

Figure 14: Charles-Augustin de Coulomb.

It says that the electric force F_e between two charges q_1 and q_2 is proportional to the product charges and inversely proportional to the square distance. Coulomb explained the law attraction and repulsion between electric charges same and opposite signs. Divided the materials to guide dielectrics. One of the conclusions of a study was that there is no perfect dielectric, and each has the limited value resistance.

5 Charging

5.1 Triggering charge

Charging is the primary source causing excitation charge induced on the surface [7]. Charging (electrification) is a physical phenomenon, involving the production material, initially electrically neutral, the excess univariate charge induced. It usually occurs in conditions of contact between the approximation and subsequent separation on the two not charged materials, which can be: solid materials, solid material and liquid, solid material and gas, liquid and gas or liquid. Charging can be ad hoc (batch) or continuous.

Charging materials present in greater or lesser degree with all solid materials. Is particularly evident in the non-conductive material, in which the disclosed whether the accumulated charge relatively long time may affect the environment. His accompanied always by a rise surrounded by charges of opposite sign, the same absolute value. The charges create an electric field around him with an intensity the greater, them greater is their value. Putting in the electric field on structure material produce atomic particle excess one character and the material is charged. In the twentieth century a knowledge of a materials electrostatic properties [4]. Research charging apply to non-conductive materials (surface resistance R_S and/or volume resistance R_V in excess of 1.0×10^9 Ω). Use non-conductive materials in industrial processes is quite common and should be taken into account when assessing the hazard from static electricity [8]. In any non-conductive material charging sometimes spontaneous and varied [5]. The occurrence of adverse symptoms charging materials usually combined so-called charging by contact.

5.2 Charging by contact

Charging by contact is the most common in practice, the process of causing accidental or intentional charged material. So far, there is no single and comprehensive theory about charging by contact. Phenomena causing charging by contact are not fully understood. Perhaps the mechanism charging will be fixed in the twenty-first century. Access to sophisticated instruments can help to know the structure materials at the atomic level and the enable closer explanation phenomenon charging.

The investigation charging material as a result friction and contact issues are a group that has long been considered one most confusing and inaccurate. For this situation corresponds to a significant number the phenomena occurring in micro space between two materials in the course of charging by contact. These phenomena are difficult to control even under laboratory conditions. In the course charging by contact, the surface material is rubbed charged by friction with another material [1]. It includes a group complex issues not fully explained the phenomenon boundary between two materials, which are difficult to control even under experimental conditions. To understand the effects charging by contact is important to know the chemical composition and the structure surface contact. The molecules in the material are static systems. Charges on a material after the charging by contact and the associated electric field induces, in many cases, the effect electret materials [1]. Real surfaces are usually rough and the charging is potentiated if contact and separation caused by friction and/or pressure, the real contact area is enlarged by the action [14]. In the present article, the author focuses on the role asymmetric friction during charging by contact between the fabric and the construction material of different molecules. In the course charging by contact are particularly important dielectric materials in contact with each other. In certain sections standards [12 Annex D] as well as [13 c. 26.14] charging by contact materials are described for two types fabric rubbing causing this type of charging (Figure 16). For hand rubbing the material used fabric cotton or nylon (the causative agent charging).

The consequence contact (friction), and then separate the two materials, regardless of their electrical conductivity is the accumulation electric charges. Charging by contact material (Fig. 15), the electrostatic properties material with a non-conductive. The size and sign electrical charge produced on the material at the moment charging, depends among other things on their chemical structure, composition (mainly the nature and amount of impurities contained therein structural), physical properties materials which are in contact [14]. The friction between surfaces that are usually mutually charging material impact on increasing the number points of contact, which is tantamount to a better adhesion surface and in turn leads to an increase in the degree static electricity.

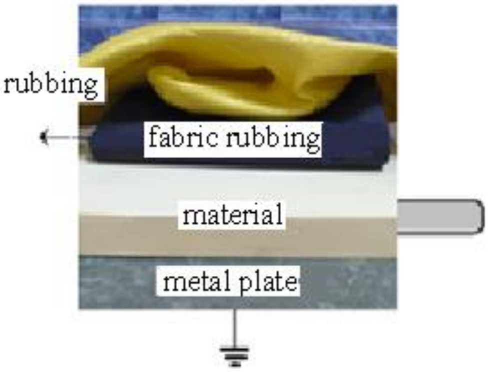

Figure 15: A set of elements necessary to carry out charging by contact.

The size of a charge induced in the specific conditions of contact the two materials is constant. It was found that charging the two materials is generally directly proportional to the difference electrical constants.
The methodology for charging by contact, the surface the material is fixed asymmetrically rubbed with a cloth (fig. 15). Is an example rubbing friction occurring between the surfaces rubbing cloth and material. Rubbing the surface fabric, it is a sliding friction which requires the action movement quasi constant force.

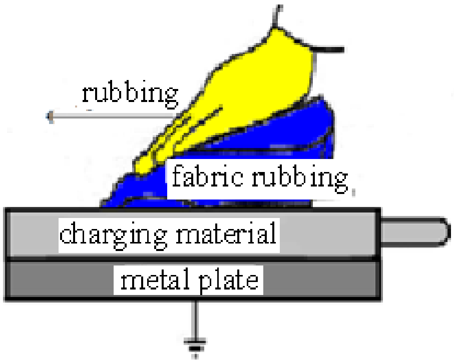

Figure 16: Charging by contact.

Charging by contact (Fig. 16) occurs at the "elementary interaction zone friction" [1]. Charging the two materials in the system does not depend on which materials is grater and which rubbing. The richness and diversity of a materials makes it difficult putting a thesis about the reasons and the ability to static electricity ("chargeability"). The consequence interaction molecular surface rubbing cloth during the forced movement after the surface is charged material. At the point contact and separation fabric rubbing the outer surface material is rubbed manufacture electrical double layers [8].

Even once the contact with each two different materials causes univariate electrical charges opposite polarity on their surfaces. Loss of contact between the fabric and the material causes the separation dissimilar electrical charges, as a result which the both materials are charged.

5.3 Electroscope

After the charging by contact material is charged. Polarization material is caused by the orientation dipole existing in its interior. The measure material's charging dipole moment. The net dipole moment charged material is different from zero. Polarization may be different in the different areas material, if the field is not uniform or the atomic structure material. The effect charging by contact occurs between the fabric and is the charged material (Fig. 17).

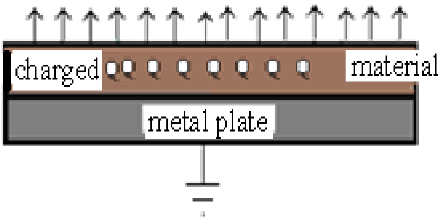

Figure 17: Non-uniform electric field perpendicular to the surface charged non-homogeneous material.

Surface charged material attributed to the charges induced on the surface density σ. The lines electric field on the charged material (Fig. 18) are abstract lines which, in any point of the field is tangent to the force in the field.

The electric field environment each charged material. Each the charge induced Q is a source electric field acting on the other charge, but also subjected to the same fields produced by other charges. Through the electric field it is possible to effect a non-conductive material between charged conductive element spaced apart, the impact of distance [14].

To detect the presence charge on the charged material is electroscope. The principle operation is used electroscope phenomenon induced repulsion of charges one sign (Fig. 19)

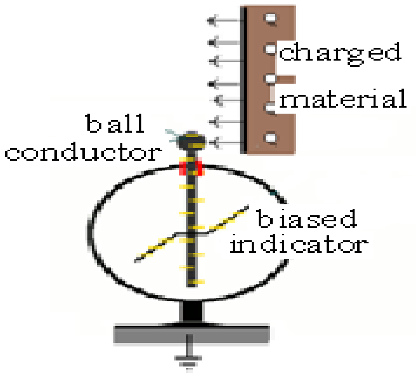

Figure 19: Verification electroscope leafs to the charged material.

The components electroscope leafs (fig. 19) are:
- Grounded metal shield on both sides closed panes,
- Vertically through the guard passes, isolated from the rod ended metal ball,
- At the end rod are pivotally attached two rectangular sheets of thin and light conductive film. On contact with the charged metal ball material part charge flows from the material to the electroscope, and the film leaves repel. The amount of deviation depends on the blades accumulated charge transfer to them.

5.4 Polarization of selected materials as a result the charging by contact

- Amber rubbed with a silk cloth negatively charged.
- Staff of woolen cloth rubbed ebonite negatively charged.
- Staff glass rubbed with silk cloth positively charged.

6 Example hazard from static electricity

During the test charging by contact on the test bench shown in figure 16 in supervised conditions of temperature and humidity test sample is placed on the grounded metal plate repeatedly rubbed with a fabric. As a result of charging by contact is charged by the sample material (Fig. 20). Approaching the sample surface charged prod registered grounded electrode (Fig. 20) discharge ESD. This discharge is characterized by a large number of discharge channels and is called propagating brush discharge. Propagating brush discharge is highly energetic type spark ESD that can occur with charged non-conductive material, located on a grounded metal plate.

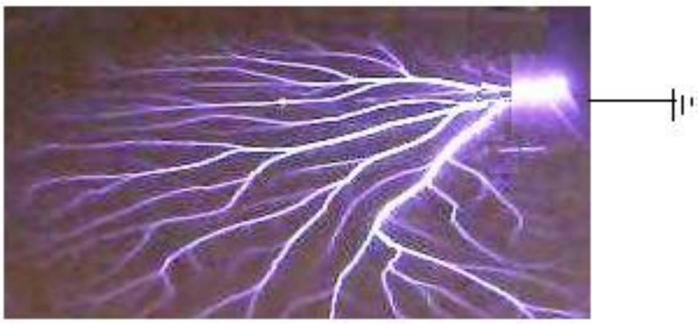

Figure 20: Propagating brush discharge as a result spontaneous local discharge charged material sample about a length 295 mm and a width of 240 mm.

Discharge collects most charge with the charged material in the form of channels to the point where the touch occurs [8].
Flexible hose with integrated metal spiral [10] is often used for the pneumatic transport dust. Air transport is an example continuous dust charging by contact inner coating non-conductive hose.

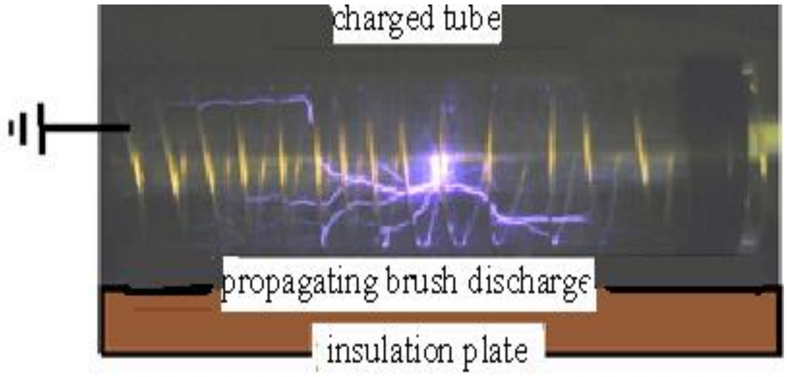

Figure 21: Propagating brush discharge between the grounded metal coils spiral non-metallic filler hose [10 page photo section 253].

Continuous charging by contact under the transport by air of combustible dust by hose causes the charged non-conductive layer. Local discharge charged liner would produce between grounded metal coils propagating brush discharge fig. 21. At the fig. 21 shows a case of continuous charging by contact inner tube due to the transport dust through a hose. To reduce the hazard from static electricity coated non-conductive hose and a built-in spiral metal should not be used for pneumatic transport combustible dusts. Because the inner wall continuous charging by contact can produce a propagating brush discharge and ignite an explosive dust atmosphere. In practice, this means that the flexible hoses with metal spiral in order to rule out any hazard explosion by static electricity used for pneumatic transport combustible dust should be made of a material dissipative, or conductive.

Both at the design stage and also during operation must be based on the optimization control and elimination a hazards [11]. Due to the fact that many features influences the measurement uncertainty for the limited human perception, for assessing the hazard from static electricity should be used such as risk analysis fault tree analysis FTA. To assess the hazard from static electricity that could occur in process systems would be beneficial probabilistic logic. Before placing a non-metallic into operation should be carried out to assess the ability to static electricity ("chargeability") under conditions simulating use, in order to determine the safety and handling. These tests enable to answer the question: Do charged material could pose the hazard from static electricity in the conditions of use?At the same time you should be provided with a system ongoing monitoring electrostatic properties non-metallic device to ensure safety. Each installation is equipped with a flexible hose with metal spiral should be considered individually, and each time the discharge out of a charging hose determine the charge transfer.

7. Conclusions

1 The presence of static electricity in everyday life creates many unexpected phenomena distort the correct operation of the equipment as a result of damage to sensitive electronic components.

2 The charged non-conductive material reveals appearance on the homonymous electrical charges. The richness and diversity of the atomic structure of a materials difficult putting a thesis about the causes of a static electricity. Conceptually, it is difficult to interpret because little is known about the structure.

3 Isolated the human body is exposed to very often charged is caused charging by contact and then any incidental contact with grounded metal component can cause an discharge ESD.

4 Static electricity at the turn of a century aroused great interest among scientists only because of a mystery observed phenomena.

5 The level of a charge and its schedule for macroscopic surface charged material raises concerns, that technological systems can't be ruled discharge ESD. Therefore, should attempt to answer on the question: Is it possible to effectively prevent the risk of static electricity if it can't be ruled out discharge ESD?

6 The main question to be clarified in electrostatics:

Is it on the charged material, charges induced are generated by the transfer of an electrons, ions, or both [3]?

References

[1] V. Babrauskas, Ph.D. "Ignition handbook" Fire Science Publishers 2003.

[2] A. G. Bailey: "The charging of insulator surfaces" Journal of Electrostatics Volumes 51–52, May 2001, Pages 82–90 Electrostatics 2001: 9th International Conference on Electrostatics.

[3] I. Berta: „Static control" Journal of Electrostatics, Volume 63, Issues 6–10, June 2005, Pages 679-685.

[4] G. S. P. Castle: "Contact Charging Between Insulators" Journal of Electrostatics 40&41 (1997) pages 13-20.

[5] J. N. Chubb: "A Standard proposed for assessing the electrostatic suitability of materials" Journal of Electrostatics, Volume 65, Issue 9, August 2007, Pages 607-610.

[6] J. N. Chubb: "Comments on methods for charge decay measurement" Journal of Electrostatics Volume 62, Issue 1, September 2004, Pages 73–80.

[7] K. Cybulski, B. Wiechuła: „Charging non-conductive material non-metallic intended for use in potentially explosive atmospheres" quarterly journal of GIG 3/2010 p. 15…29.

[8] K. Cybulski, B. Wiechuła: „Charging as a source of hazard" quarterly journal of GIG 3/2011 p. 5…25.

[9] P. Iversen, D. J. Lacks: "A life of its own: The tenuous connection between Thales of Miletus and the study of electrostatic charging" Journal of Electrostatics, Volume 70, Issue 3, June 2012, Pages 309-311.

[10] I. D. Pavey: "Propagating brush discharges in flexible hoses" Journal of Electrostatics Volume 67, Issues 2–3, May 2009, Pages 251–255, 11th International Conference on Electrostatics.

[11] U. von Pidoll: "An overview of standards concerning unwanted electrostatic discharges" Journal of Electrostatics, Volume 67, Issues 2–3, May 2009, Pages 445–452 11th International Conference on Electrostatics.

[12] EN 13463-1: 2009 „Non-electrical equipment for use in potentially explosive atmospheres– Part 1: Basic method and requirements".

[13] EN 60079-0: 2009 „Explosive atmospheres - Part 0: Equipment - General requirements".

[14] IEC / TR 61340-1: 2012 "Electrostatics - Part 1: Electrostatic phenomena - Principles and measurements".

[14] B. M. Wiechuła: „Charging materials non-metallic used in underground mining explosive methane and/or coal dust" Mining News (in Poland: Wiadomości Górnicze) 3/2013 p. 146-155.

[15] IEC/TR 61340-1: 2012 Electrostatics phenomena – Principles and measurements