CHEMICAL ENGINEERING TRANSACTIONS
VOL. 31, 2013
Guest Editors: Eddy De Rademaeker, Bruno Fabiano, Simberto Senni Buratti

ISBN 978-88-95608-22-8; ISSN 1974-9791
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet
DOI: 10.3303/CET1331157

Electrostatic Discharges from Non-Conductive Materials

Ulrika Nilsson[a], Ingvar Karlsson[b], Ken Nessvi[a*]

[a]Process Safety Group

[b]SP Technical Research Institute of Sweden

ken.nessvi@psgroup.se

1. Introduction

In recent years insulating solid materials has been more commonly used in the industry. This is due to a variety of commercial reasons. As insulating materials tend to become electrostatically charged, handling of flammable materials in combination with plastics therefor is a potential ignition hazard.
Industries handling flammable materials and / or combustible dusts should be risk assessed; a classification plan for explosive atmospheres as well as an explosion protection document shall be drawn up. Among other things sources of ignition in explosive atmospheres must be identified and assessed.
Static electricity is an ignition source that is causing much concern as it is not easy to predict. Electrostatic brush discharges arise from charged insulating materials. Charge that build up can arise from contact charge when handling insulating solid material as well as when transporting bulk material (gases, liquids, solids) in insulating pipes, containers and other process equipment.
With regard to electrostatic brush discharges, it is flammable gases and vapours from flammable liquids that can be ignited. So far, no one has been able to demonstrate that combustible dust can be ignited by brush discharges in normal atmospheres.

The purpose of the project presented in this paper is to clarify when hazardous electrostatic brush discharges occurs in non-conductive materials in the industry.

- How does contact between different materials interact to build up charges able to ignite flammable gases and vapors?
- How does charge that build up in real industrial situations appear when handling flammable liquids in insulating containers and pipes?

Measurements have been conducted in real process situations, when handling flammable liquids. Experiments have been carried out at a laboratory on SP Technical Research Institute of Sweden. Specifically, the effect of surface area, type of material and the loading mechanism was further investigated.

The project has been part-funded by the Swedish Fire Research Board, Tyréns AB and the Association for process safety (IPS). Performers and authors of the report has been Ulrika Nilsson and Ken Nessvi, Process Safety Group Sweden AB. Ingvar Karlson, SP Technical Research Institute of Sweden, has contributed as an expert during the industrial measurements, as well as leading the experiments in the laboratory at SP. The project is based the CENELEC Technical Report 50404: 2003.

Literature study, field measurements, laboratory tests, and a draft report were conducted by Tyréns. The completion of the report and a seminar was conducted in the fall of 2011, through commissions from Tyréns, by Process Safety Group Sweden AB.

Please cite this article as: Nilsson U., Karlson I. and Nessvi K., 2013, Electrostatic discharges from non-conductive materials, Chemical Engineering Transactions, 31, 937-942 DOI: 10.3303/CET1331157

2. Measurements

2.1 Method

The initial measurements were carried out at Trioplast in Landskrona(SWE), Akzo Nobel in Malmö(SWE) and FeF Chemicals in Køge(DK). At each occasion the temperature and humidity in the air was measured. The measurements were carried out to get a feeling for how to use the instruments in different kinds of process equipment.

2.2 Poly Peptide Laboratories, Malmö(SWE)

Measurement of electrostatic charge when filling ethanol (99%) into insulating plastic drums was conducted by Ingvar Karlson, SP, and Ulrika Nilsson, PS Group. The air humidity was at the time 37% RH and the temperature 19°C. Four scenarios were simulated;

1. Filling with manual pump of plastic material from 200 l metal drum to 120 l plastic container (Figure 1)
2. Filling with electric pump from 200 l metal drum to 25 l plastic container
3. Filling with manual pump of plastic material from 25 l plastic container to 25 l plastic container
4. Filling from RIBC to 25 l plastic container

Figure 1, Filling with manual plastic pump from 200 l metal drum to 120 l plastic container

Before each measurement the plastic container was deionized with a fan. Potential measurements were made with an electrostatic voltmeter on the outside of the plastic container. The potential on the outside of the plastic container was continuously monitored throughout the filling.

Result when filling with manual plastic pump from 200 l metal drum to 120 l plastic container: maximum voltage 50 V.
Result when filling with electric pump from 200 l metal drum to 25 l plastic container: maximum voltage 20 V.
Result when filling with manual plastic pump from 25 l plastic container to 25 l plastic container: maximum charge 200 V.
Result when filling from RIBC to 25 l plastic container: maximum voltage 170 V.

<u>Conclusion</u>

There was no high charge when filling Ethanol to insulating plastic drums. Due to the high conductivity of ethanol there was an even charge distribution in the fluid and as expected, no high charge of the fluid. Nor were there high charge on the insulating material when filling. In this particular case the conclusion is that the filling of ethanol in insulating plastic drums is no electrostatic risk.
This does not exclude that the plastic drums can be charged on the outside due to friction when handling the drums. This means that there may be a risk of electrostatic discharge from plastic drums when drums have been exposed to excessive charging on the outside.

2.3 Bona, Malmö(SWE)

The humidity was at the time of the test 26% RH and the temperature 20°C. The liquid had a conductivity <0.05 µS/cm.
The measurements were carried out at BONA AB, Malmö 2010-11-18 by Ingvar Karlson SP and Ulrika Nilsson PS Group. The purpose with the measurements was to check if charging will occur when filling insulating plastic containers. Three scenarios were simulated:

1. Filling with pipe ending in the bottom of the container.
2. Filling with pipe ending about 50 cm down in the container.
3. Filling without pipe (splash filling)

The volume of the container was 1000 litre and the time to fill the container was about 7 minutes. Before each measurement the plastic drums was deionized with a fan. Potential measurements were carried out with an electrostatic voltmeter on the outside of the plastic drum. The potential on the outside of the plastic drum was checked continuously during the filling.

1. *Result when filling with pipe ending in the bottom of the container: Maximum voltage 400 V.*
2. *Result when filling with pipe ending about 50 cm down in the container: Maximum voltage 150 V.*
3. *Result when filling without pipe (splash filling): Maximum voltage 20 V.*

<u>Conclusion</u>
When measuring, no high charging occurred during filling. Despite the low conductivity of the liquid, there were no signs of charge neither on the container nor in the liquid itself. The method of filling had no impact on the ability of the liquid to be charged. When filling from the bottom the charge were higher than when filling from the top.

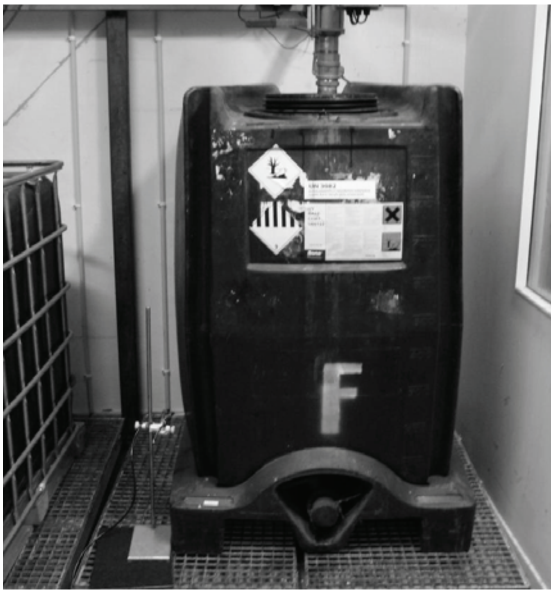

Figure 2 Filling with pipe ending about 50 cm down in the container.

2.4 Akzo Nobel Functional Chemicals, Stenungsund(SWE)
Measurement was made of electrostatic charging during filling of fluid in insulating plastic drums (200 l) at Akzo Nobel's premises in Stenungsund 2011-01-26.
The air humidity was at the time 18% RH and the temperature was 20^{o}C.

Measuring electrostatic charge when filling fluid

The purpose was to determine if the plastic drums are charged when filled.
The drums were filled from the bottom with a stainless steel lance that followed the liquid to the top. The lance was always below the liquid level in the plastic drum. The velocity of filling was at the time about 0,7 kg/s. The product filled was a viscous liquid.
Before each measurement the plastic drums was deionized with a fan. Measurements of the voltage was carried out with an electrostatic voltmeter on the outside of the plastic drum. The potential on the outside of the plastic drum was checked continuously during the filling.

Result when filling plastic drum 1: Maximum voltage 160 V.
Result when filling plastic drum 2: Maximum voltage 120 V.
Result when filling plastic drum 3: Maximum voltage 85 V.

<u>Conclusion</u>
The measurement showed no high charging of the insulating plastic container during filling in this particular case. This indicates that the filling of liquid in insulating plastic containers is no electrostatic risk. Higher flow rates may change the results and these conditions should be checked further.

Another electrostatic risk is plastic containers charged to high potentials on the outside through friction when handling. This means that there may be a risk of electrostatic discharge from plastic containers.

A third electrostatic risk to be taken into consideration is the discharge of a person. The staff had at the time protective shoes with dissipative properties. They stood and worked on a galvanized metal floor. This is a very good way to ensure that the staff can not cause ignitions of flammable gases when filling plastic drums.

3. Laboratory measurements

3.1 **Purpose**

The purpose was to quantify the risks regarding brush discharges from plastic drums during use in explosive atmospheres. When handling drums in a production line the drums will be exposed to separation between surfaces either by contact between each other or by contact between the drum and the operator. This separation will build up charge on the drums surface and a potential risk will occur regarding brush discharges. The built up charge on the surface will be different depending on which material the drum will be rubbed with, and it will also depend on the material in the drum.
The results of the measurements was then compared with the permissible charge build up limits for equipment placed in explosive atmosphere, expressed by the representative groups I, IIA, IIB and IIC (IEC 60079-12) and the classification of the hazardous area (IEC 60079-10-1 and IEC 60079-10-2):

60 nC for group I or IIA equipment;
30 nC for group IIB equipment
10 nC for group IIC equipment;

The risk for brush discharge will also depend on if the drum is empty or if it is filled with a liquid. The conductivity of the liquid will also affect the ability to accumulate charge on the surface of the drum. In this study the purpose was to emulate three possible scenarios:

Scenario 1: The drum is empty and exposed to rubbing on the outside of the drum.
Scenario 2: The drum is filled with a conductive liquid and exposed to rubbing on the outside of the drum.
Scenario 3: The drum is filled with a conductive liquid and exposed to rubbing on the outside of the drum. After that the liquid is poured out.

The humidity in the facility where the drums are handled is another utterly important parameter. If they are handled in a dry humidity, the ability to charge and accumulate the charge will be much higher. The purpose was to simulate a winter climate which will also be a worst case scenario and therefor the measurements were performed in a dry climate.
Test object 1: 25 litres drum made of insulating Polyethylene High Density (surface resistance $<10^{12}\ \Omega$ according to IEC 61340-5-1). Before test the top of the drum was removed and the thickness was measured. The thickness of the plastic was between 1.8 mm to 2.3 mm. (see Figure 3)
Test object 2: 200 litres drum made of insulating Polyethylene High Density (surface resistance $<10^{12}\ \Omega$ according to IEC 61340-5-1). Before test the top of the drum was removed and the thickness was measured. The thickness of the plastic was between 4.2 mm to 6.0 mm. (see Figure 4)

Figure 3 drum 25 litres

Figure 4 drum 200 litres.

Test equipment

Handheld coulombmeter, Schnier, type HMG 11/02.(see Figure 5)
Corona charger , Schnier, type HER 26/01.(see Figure 5)
Cloths made of polyamide, cotton and PVC. The cloths were big enough to avoid contact between the operators hand and the test object.

3.2 Performance and results

Measurements were performed according to EN 13463-1, Non-electrical equipment for potentially explosive atmospheres – part 1: basic method and requirements.
Test objects were conditioned during more than 72 h in 23°C ± 2°C and 12% RH ±3% RH. The measurements were performed in the same climate.

Charging by rubbing was performed with three different materials, cotton, polyamide and PVC. The test objects were also charged with corona.

Tests to simulate scenario 1.
The first scenario was to simulate an empty drum exposed to rubbing on the outside of the drum.
Test setup is really simple in this case and it can be seen in Figure 5.

Tests to simulate scenario 2.
The second scenario was to simulate a drum filled with a conductive liquid and exposed to rubbing on the outside of the drum.
To simulate this scenario an aluminium foil was attached to the inside of the drum. The aluminium foil was connected to protective earth during the test. (see Figure 6)

Tests to simulate scenario 3.
The third scenario was to simulate a drum filled with a conductive liquid and exposed to rubbing on the outside of the drum. After that the liquid is poured out.
To simulate this scenario an aluminium foil was attached to the inside of the drum. The aluminium foil was connected to protective earth during the test. After the drum had been charged, the aluminium foil was removed and the discharge was taken. (see Figure 7)

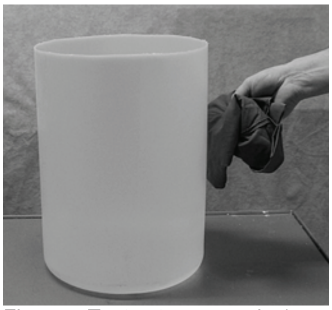
Figure 5 Test setup scenario 1


Figure 6 Test setup scenario 2

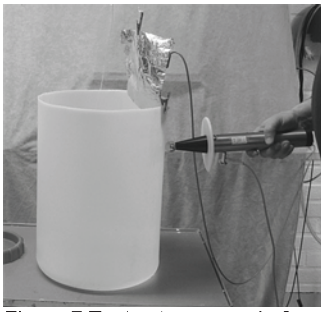
Figure 7 Test setup scenario 3

The drums were rubbed with three different cloths and they were also charged by corona. The results can be seen in table 1, table 2 and table 3.

Table 1: Test results scenario 1.

25 litres drum				200 litres drum			
Polyamide	**Cotton**	**PVC**	**Corona**	**Polyamide**	**Cotton**	**PVC**	**Corona**
No disch.	No disch.	26 nC	No disch.	32 nC	46 nC	44 nC	No disch.
No disch.	No disch.	28 nC	No disch.	29 nC	17 nC	34 nC	No disch.
No disch.	No disch.	33 nC	No disch.	59 nC	18 nC	47 nC	12 nC
No disch.	No disch.	15 nC	No disch.	26 nC	42 nC	35 nC	20 nC
No disch.	No disch.	15 nC	No disch.	32 nC	42 nC	70 nC	No disch.
No disch.	No disch.	21 nC	No disch.	18 nC	41 nC	78 nC	No disch.
No disch.	No disch.	26 nC	No disch.	32 nC	12 nC	39 nC	No disch.
No disch.	No disch.	28 nC	No disch.	21 nC	27 nC	48 nC	12 nC
No disch.	No disch.	24 nC	No disch.	22 nC	21 nC	88 nC	No disch.
No disch.	No disch.	24 nC	No disch.	27 nC	30 nC	81 nC	No disch.

Table 2: Test results scenario 2.

25 litres drum				200 litres drum			
Polyamide	**Cotton**	**PVC**	**Corona**	**Polyamide**	**Cotton**	**PVC**	**Corona**
60 nC	17 nC	No disch.	76 nC	No disch.	11 nC	No disch.	24 nC
54 nC	14 nC	No disch.	71 nC	No disch.	44 nC	No disch.	36 nC
38 nC	17 nC	No disch.	111 nC	No disch.	35 nC	No disch.	68 nC

25 litres drum				200 litres drum			
44 nC	19 nC	No disch.	97 nC	No disch.	39 nC	No disch.	12 nC
56 nC	18 nC	No disch.	72 nC	No disch.	42 nC	No disch.	22 nC
33 nC	24 nC	No disch.	82 nC	No disch.	26 nC	No disch.	24 nC
34 nC	11 nC	No disch.	89 nC	No disch.	83 nC	No disch.	16 nC
32 nC	23 nC	No disch.	78 nC	No disch.	38 nC	No disch.	17 nC
23 nC	12 nC	No disch.	61 nC	No disch.	14 nC	No disch.	63 nC
46 nC	14nC	No disch.	75nC	No disch.	45 nC	No disch.	35 nC

Table 3: Test results scenario 3.

25 litres drum				200 litres drum			
Polyamide	**Cotton**	**PVC**	**Corona**	**Polyamide**	**Cotton**	**PVC**	**Corona**
40 nC	40 nC	39 nC	No disch.	21 nC	36 nC	17 nC	21 nC
36 nC	24 nC	28 nC	28 nC	28 nC	22 nC	23 nC	32 nC
31 nC	44 nC	37 nC	No disch.	27 nC	31 nC	33 nC	30 nC
23 nC	40 nC	38 nC	20 nC	23 nC	31 nC	44 nC	29 nC
41 nC	51 nC	31 nC	14 nC	29 nC	26 nC	20 nC	38 nC
36 nC	33 nC	36 nC	10 nC	29 nC	36 nC	29 nC	23 nC
31 nC	32 nC	24 nC	18 nC	34 nC	22 nC	20 nC	38 nC
34 nC	32 nC	30 nC	No disch.	29 nC	34 nC	17 nC	22 nC
28 nC	28 nC	36 nC	28 nC	33 nC	29 nC	18 nC	21 nC
22 nC	37 nC	28 nC	10 nC	22 nC	36 nC	24 nC	19 nC

3.3 Summary

The test results show that it is possible to create brush discharges exceeding the permissible limits for group IIA, IIB and IIC from both of the tested drums.
Corona charging gave the highest levels of charge for the smaller drum and rubbing gave the highest levels of charge for the 200 litres drum.

4. Conclusions

The results of the study show that the contact charge may give rise to much higher energy levels than those measured in relation to the filling of liquids in plastic containers.
Results show that the contact charging in connection with the handling of insulating materials in explosive atmospheres constitutes an ignition source. It was also verified that the build-up of electrical charge in various areas is well consistent with the maximum allowed surface areas in the draft technical report IEC TR 60079-32. The conclusion from measurements on filling of different types of vessels indicates that this does not pose any problems with the fluids tested in the study. This is despite the fact that most people that handle flammable liquids are mainly focused on the build-up of electrical charge of fluids and vessels associated with handling in pipelines and filling/emptying of containers.
The presence of insulating materials in the industry is growing and since industry does not comply with the standards today the problem will exceed. Regarding managing the explosion risk, a greater focus should be placed on charging of insulating surfaces in hazardous areas. In general, the knowledge in this area is low among industries, and therefore, it is also difficult to reach out with the message.

References

IEC 60079-0, Explosive atmospheres - Part 0: Equipment - General requirements
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 TR 60079-32, draft for comments (31/952/NP) Explosive atmospheres – part 32:1 Electrostatic hazards - Guidance
IEC TR 60079-32, draft for comments (31/953/NP) Explosive atmospheres – part 32:2 Electrostatic hazards – Tests
IEC 61340-5-1, Electrostatics - Part 5-1: Protection of electronic devices from electrostatic phenomena - General requirements
CENELEC TR 50404:2003, Electrostatics – Code of practice for avoidance of hazards due to static electricity