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Comparison of the Performance of Electrostatic Field meter & Electrostatic Voltmeter used to measure electrostatic surface potentials on materials and ESDS

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Background

- Electrostatic Field Meters (EFM's) are widely used in electronic production to measure electrostatic fields and surface potentials
- These EFM's are used many times not only for evaluation of large materials, they are often used as well to check PCB's and IC's
- ESD coordinators are often not aware how accurate these measurements are, because the technical limits of an EFM is not clear for them.

This study shows the differences between different instruments available on the market.

Objectives

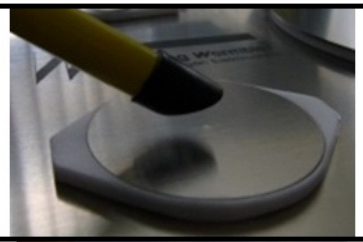
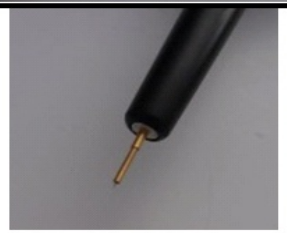
- Discussion of the different test methods of Electrostatic Field Meters (EFM's) and Electrostatic Voltmeters (ESVM's)
- Highlighting the advantages & disadvantages of EFM's and ESVM
- Giving a guideline for users which instrument is adequate for the specific task of testing

Outline

- Background
  - Brief explanation of the different test methods of the instruments used in this study
  - Problems and impact on planned testing
- IEC 61340-5-1
  - Only for evaluation of process relevant insulators a testing of the electrostatic field and/or surface potential is defined
- Importance of testing surface potential
  - To detect CDM like problems in Electrostatic Protected Areas (EPA's) a reliable measurement of the surface potential is needed

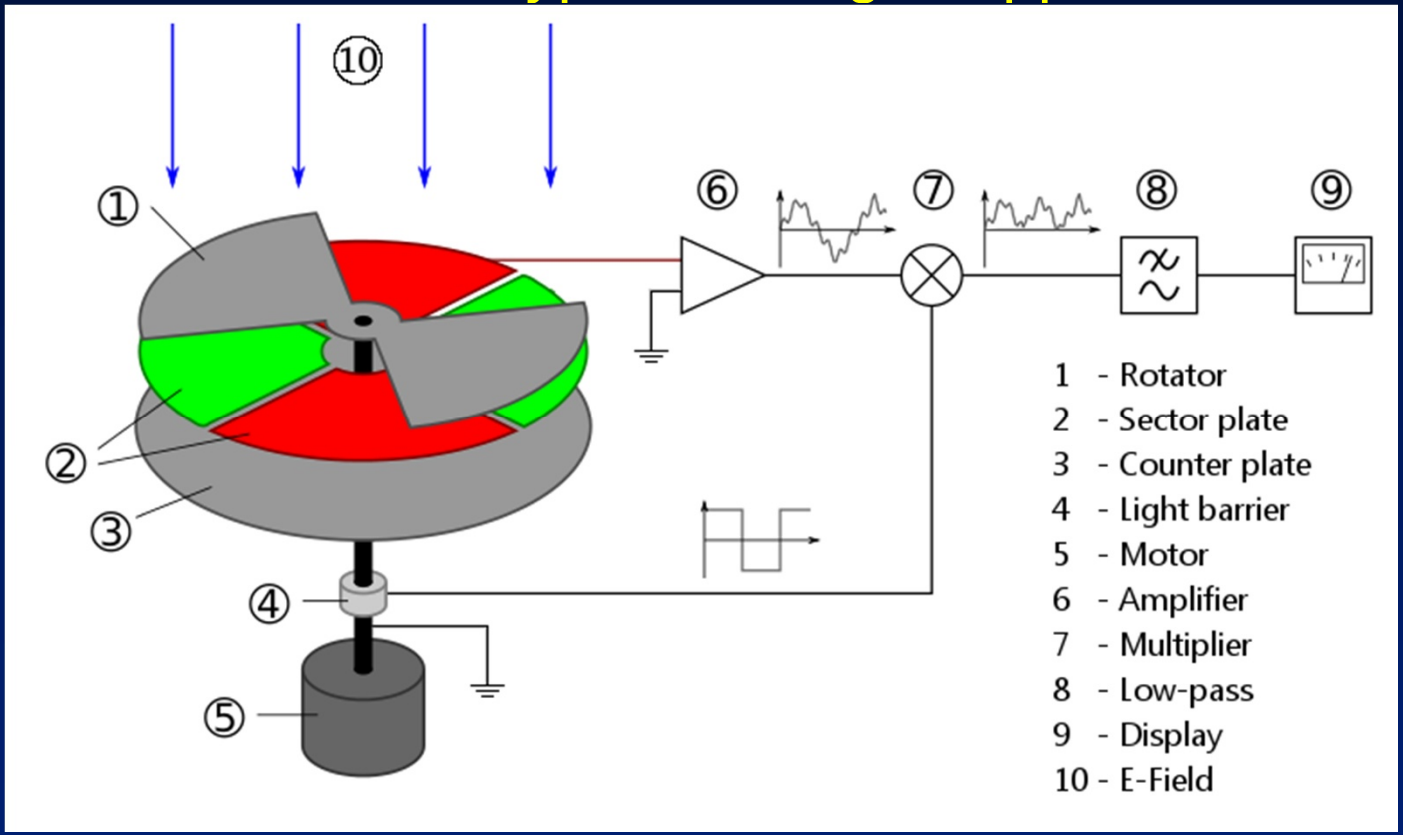
Background

- Four different instruments were used in this study

Instruments	Range	Sensor	Calibration
Electrostatic Field meter "rotating chopper" type	**0 to ± 16 kV** distance 20 mm to test surface		in homogeneous field (plate capacitor) **Tested voltage levels:** ± 400 V tolerance EFM ≤ 5% ± 1.600 V tolerance EFM ≤ 5% ± 4.000 V tolerance EFM ≤ 5% ± 8.000 V tolerance EFM ≤ 5%
ESVM – type 01 "non-contacting" type	**0 to ± 2 kV** distance probe to test surface 5 to 50 mm		with large metal plate **Tested voltage levels:** ± 500 V tolerance ESVM ≤ 20% ± 1.000 V tolerance EFM ≤ 10% ± 2.000 V tolerance EFM ≤ 5%
ESVM – type 02 "non-contacting" type	**0 to ± 1 kV** distance probe to test surface 1 to 15 mm		with large metal plate **Tested voltage levels:** ± 500 V tolerance ESVM ≤ 2% ± 1.000 V tolerance ESVM ≤ 1%
ESVM – type 03 "contacting" type	**0 to ± 2 kV** (input impedance >1x10^14 ohm) = contacting probe		with large metal plate **Tested voltage levels:** ± 500 V tolerance ESVM ≤ 4% ± 1.000 V tolerance ESVM ≤ 2% ± 2.000 V tolerance ESVM ≤ 1%

Background

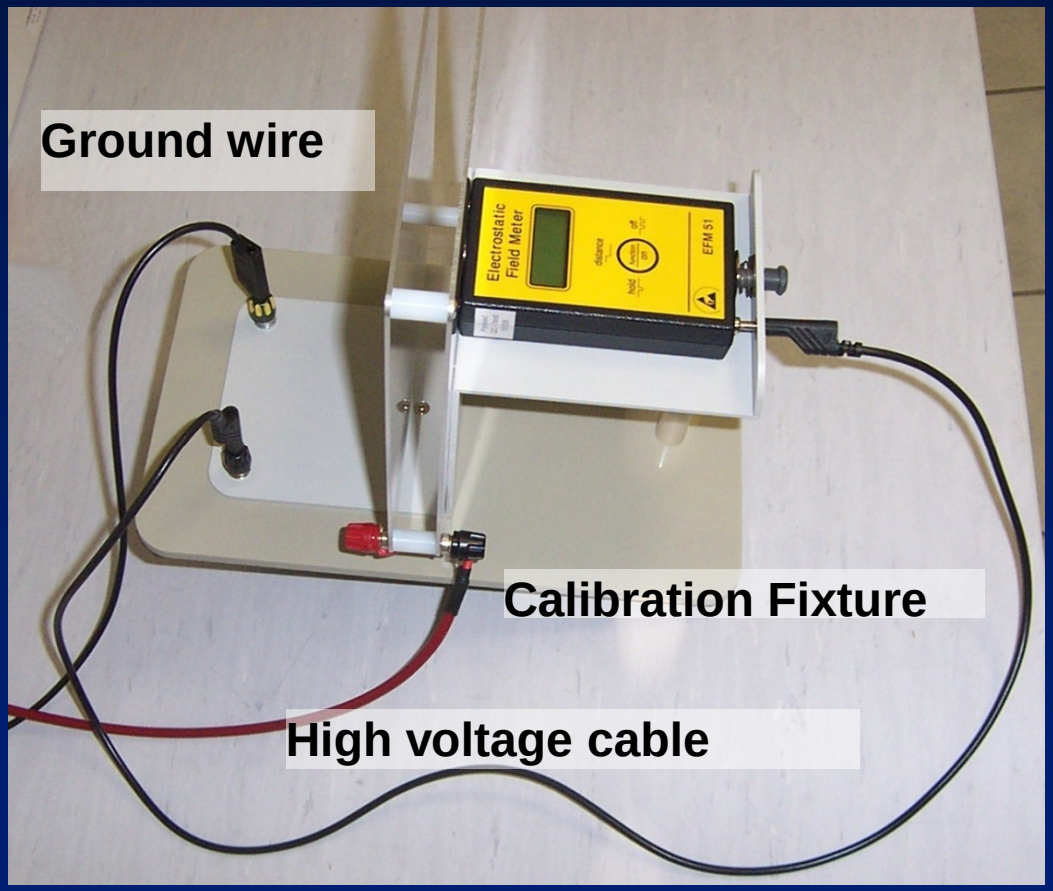
- Test method EFM – type “rotating chopper”



The electrostatic field (DC) is chopped into an AC field which is then amplified. A sector plate checks the polarity of the field and the AC signal will be rectified to a DC signal then.

Background

- An electrostatic field meter (EFM) is calibrated in an homogenous field at a distance i.e. of 20 mm.



Size of this metal plate capacitor:

200 x 200 x 20 mm

Applied voltages:

+/- 400 V

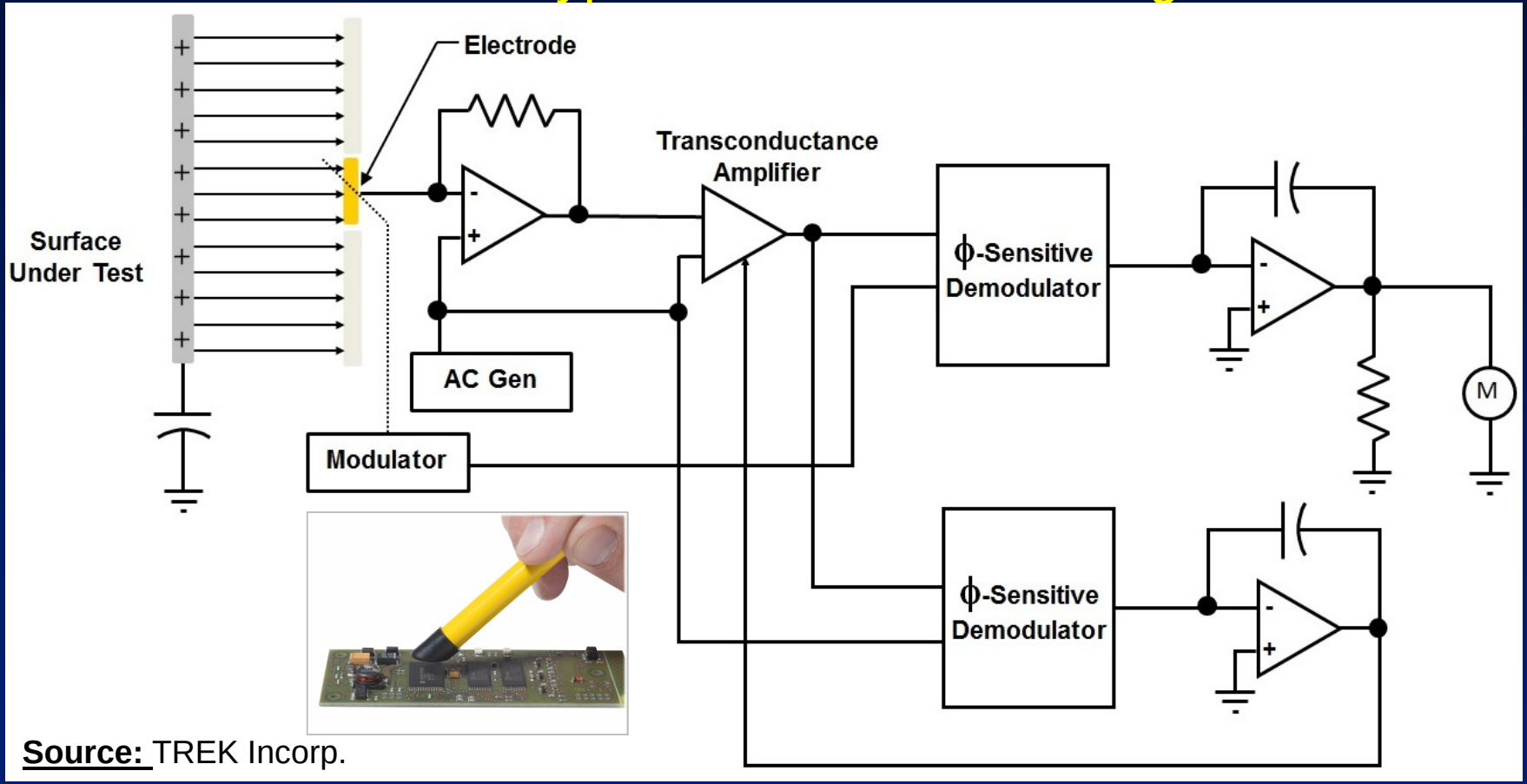
+/- 1.600 V

+/- 4.000 V

+/- 8.000 V

Background

- Test method ESVM type #01 – non-contacting voltmeter

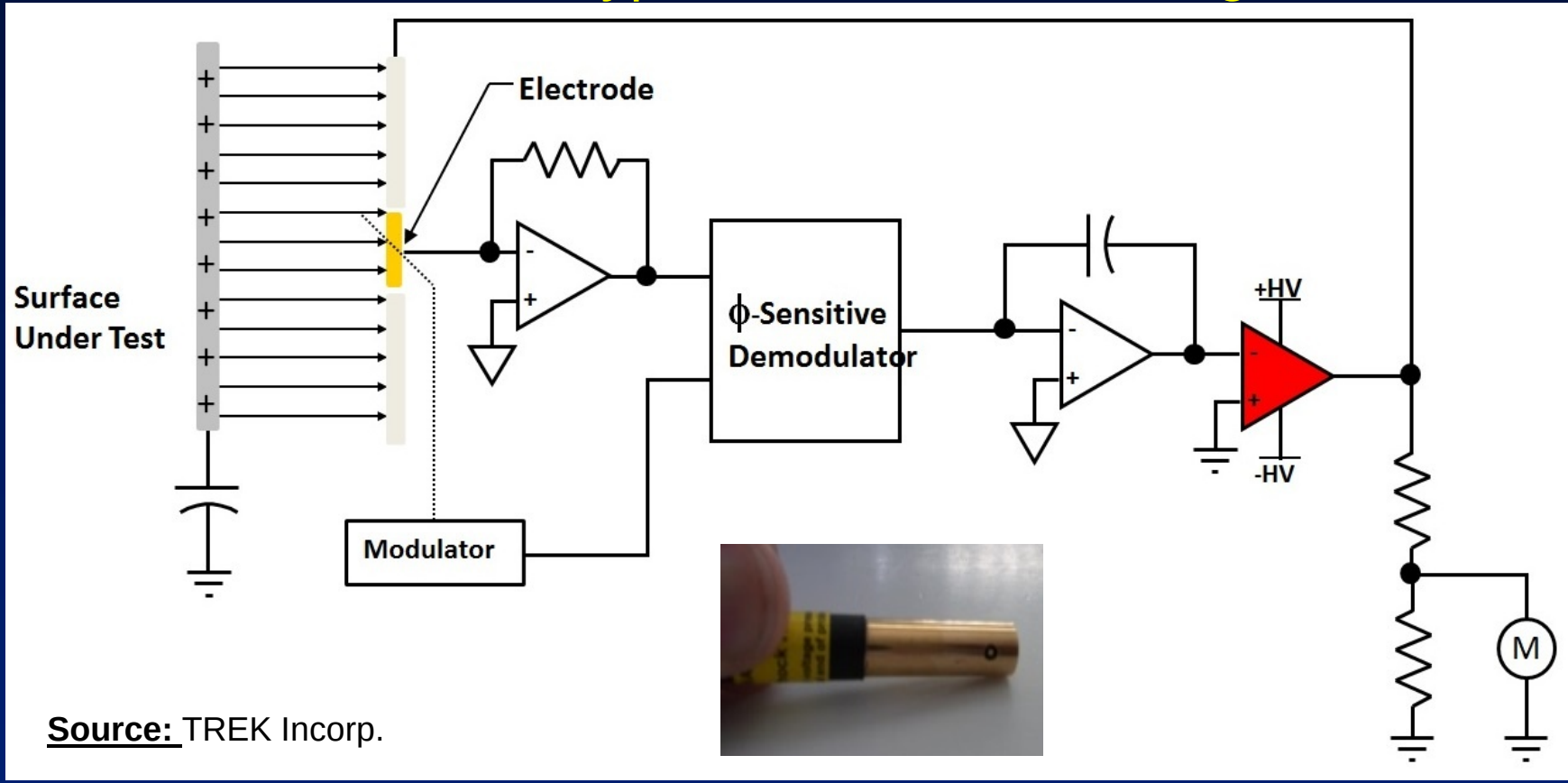


Source: TREK Incorp.

The AC feedback type does have a small AC signal applied to the probe body and the small AC signal is used to identify different capacitance due to spacing variations

Background

- Test method ESVM type #02 – non-contacting voltmeter



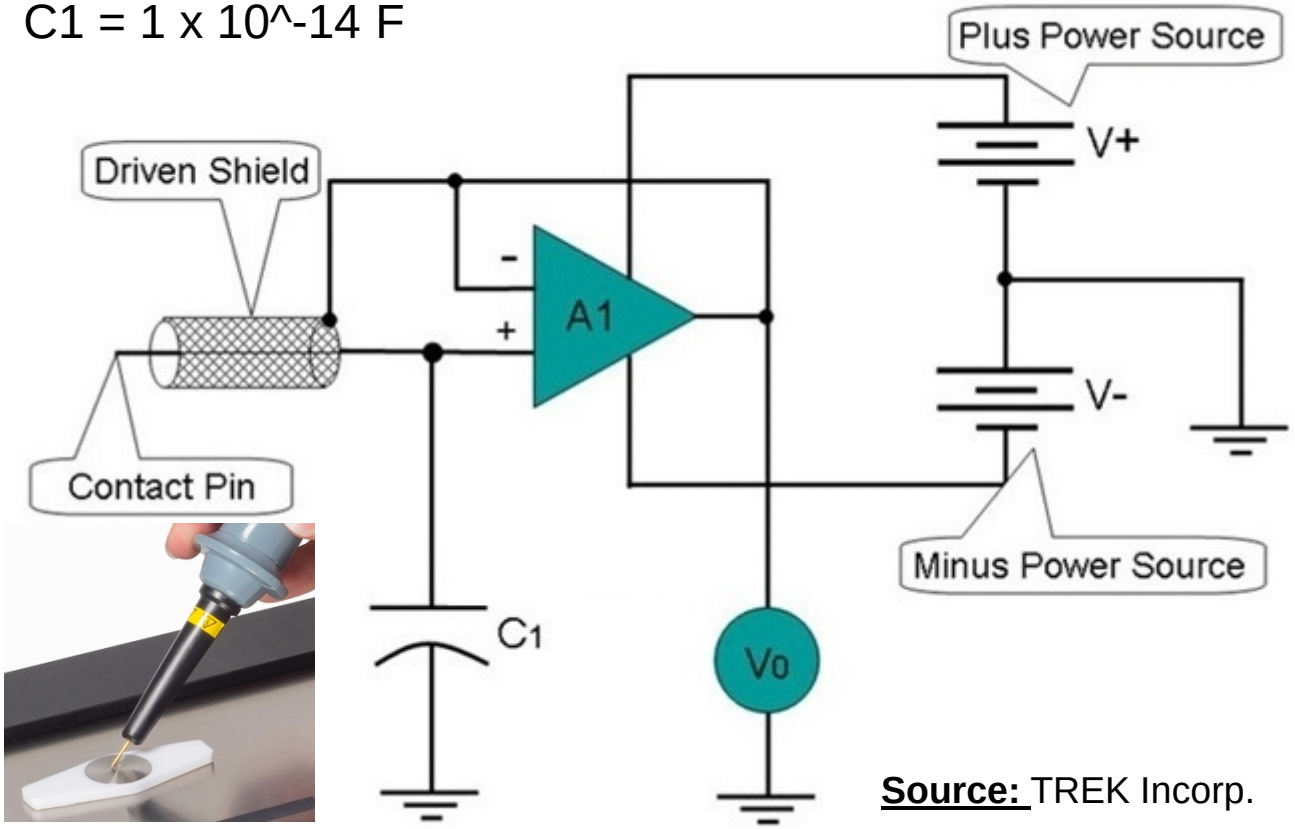
Source: TREK Incorp.

This type has a DC feedback to the probe (field nulling technique) and so the probe housing is driven to the voltage being measured.

Background

- Test method ESVM type #03 – contacting voltmeter

C1 = 1 x 10^-14 F



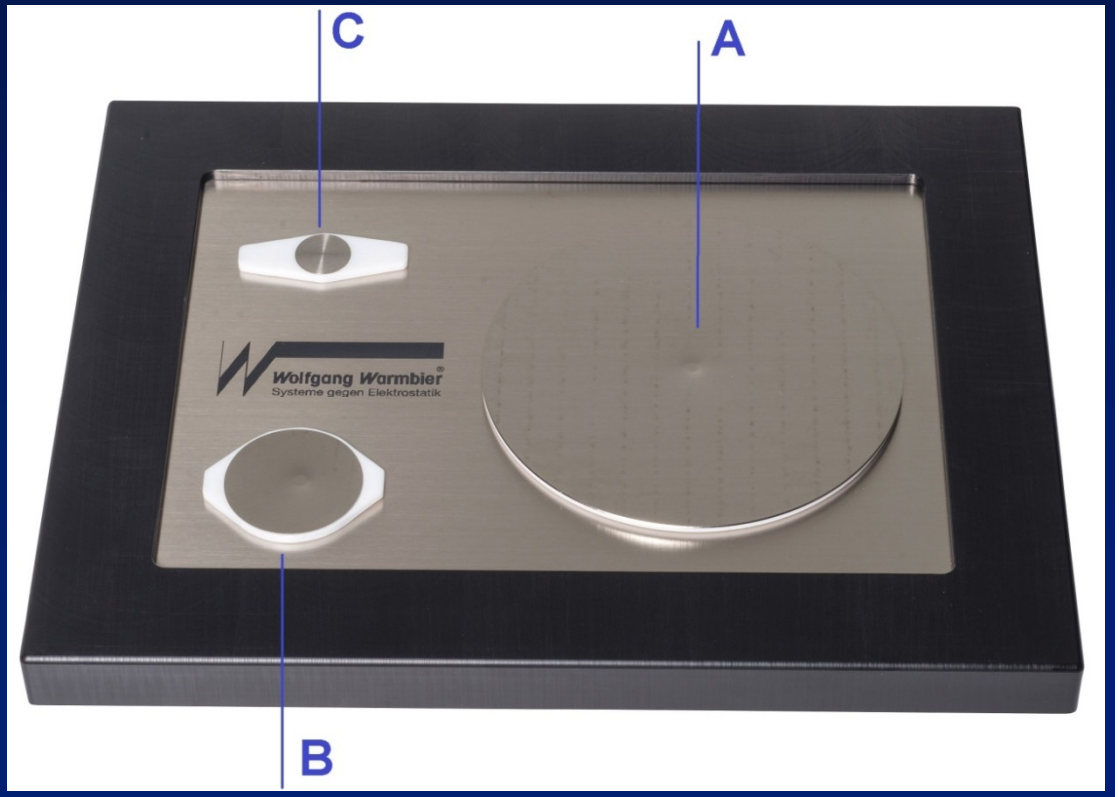
Source: TREK Incorp.

Test set-up

- A special metal plate test set-up was used to compare the 4 different instruments. The 3 metal plates are highly insulated from ground.

Plate type:

- #A – diameter 150 mm
- #B – diameter 48 mm
- #C – diameter 22,5 mm



- Applied test voltages
- ± 100 to ± 2.000 VDC (in 100 V steps)

Test set-up

- With each instrument and the relevant probe the surface potential on all 3 insulated metal plates had been tested

ESVM#01:

EFM:

ESVM#02:

ESVM#03:

Results

Plate A = 150 mm

Plate B = 48 mm

Plate C = 22,5 mm

Electrostatic Field meter (rotating chopper)						
applied voltage [V]	plate A [V]	difference	plate B [V]	difference	plate C [V]	difference
2.000	2.000	0,00%	1.580	-21,00%	815	-59,25%
1.900	1.900	0,00%	1.520	-20,00%	790	-58,42%
1.800	1.800	0,00%	1.430	-20,56%	740	-58,89%
1.700	1.700	0,00%	1.340	-21,18%	655	-61,47%
1.600	1.600	0,00%	1.270	-20,63%	630	-60,63%
1.500	1.500	0,00%	1.170	-22,00%	590	-60,67%
1.400	1.400	0,00%	1.100	-21,43%	560	-60,00%
1.300	1.300	0,00%	1.020	-21,54%	510	-60,77%
1.200	1.200	0,00%	940	-21,67%	470	-60,83%
1.100	1.100	0,00%	850	-22,73%	420	-61,82%
1.000	1.000	0,00%	760	-24,00%	417	-58,30%
900	895	-0,56%	700	-22,22%	385	-57,22%
800	800	0,00%	610	-23,75%	341	-57,38%
700	695	-0,71%	530	-24,29%	301	-57,00%
600	595	-0,83%	455	-24,17%	259	-56,83%
500	495	-1,00%	388	-22,40%	216	-56,80%
400	400	0,00%	308	-23,00%	174	-56,50%
300	304	1,33%	234	-22,00%	134	-55,33%
200	204	2,00%	158	-21,00%	93	-53,50%
100	107	7,00%	84	-16,00%	51	-49,00%

Results

Plate A = 150 mm
Plate B = 48 mm
Plate C = 22,5 mm

Electrostatic Voltmeter (type 01 - non contacting)						
applied voltage [V]	plate A [V]	difference	plate B [V]	difference	plate C [V]	difference
2.000	1.965	-1,75%	1.894	-5,30%	1.818	-9,10%
1.900	1.865	-1,84%	1.806	-4,95%	1.707	-10,16%
1.800	1.767	-1,83%	1.711	-4,94%	1.615	-10,28%
1.700	1.668	-1,88%	1.616	-4,94%	1.520	-10,59%
1.600	1.570	-1,88%	1.520	-5,00%	1.430	-10,63%
1.500	1.473	-1,80%	1.425	-5,00%	1.336	-10,93%
1.400	1.373	-1,93%	1.330	-5,00%	1.245	-11,07%
1.300	1.275	-1,92%	1.235	-5,00%	1.154	-11,23%
1.200	1.176	-2,00%	1.139	-5,08%	1.063	-11,42%
1.100	1.077	-2,09%	1.043	-5,18%	973	-11,55%
1.000	979	-2,10%	947	-5,30%	884	-11,60%
900	880	-2,22%	851	-5,44%	793	-11,89%
800	782	-2,25%	755	-5,63%	703	-12,13%
700	683	-2,43%	659	-5,86%	612	-12,57%
600	584	-2,67%	564	-6,00%	523	-12,83%
500	485	-3,00%	467	-6,60%	433	-13,40%
400	386	-3,50%	371	-7,25%	344	-14,00%
300	288	-4,00%	275	-8,33%	255	-15,00%
200	188	-6,00%	178	-11,00%	165	-17,50%
100	90	-10,00%	82	-18,00%	76	-24,00%

Results

Electrostatic Voltmeter (type 02 - non-contacting)						
applied voltage [V]	plate A [V]	difference	plate B [V]	difference	plate C [V]	difference
1.000	1.005	0,50%	1.005	0,50%	1.005	0,50%
900	904	0,44%	904	0,44%	904	0,44%
800	803	0,38%	804	0,50%	803	0,38%
700	703	0,43%	703	0,43%	703	0,43%
600	601	0,17%	603	0,50%	601	0,17%
500	502	0,40%	502	0,40%	502	0,40%
400	401	0,25%	402	0,50%	402	0,50%
300	301	0,33%	301	0,33%	301	0,33%
200	200	0,00%	201	0,50%	201	0,50%
100	100	0,00%	100	0,00%	100	0,00%

Plate A = 150 mm

Plate B = 48 mm

Plate C = 22,5 mm

Results

Plate A = 150 mm

Plate B = 48 mm

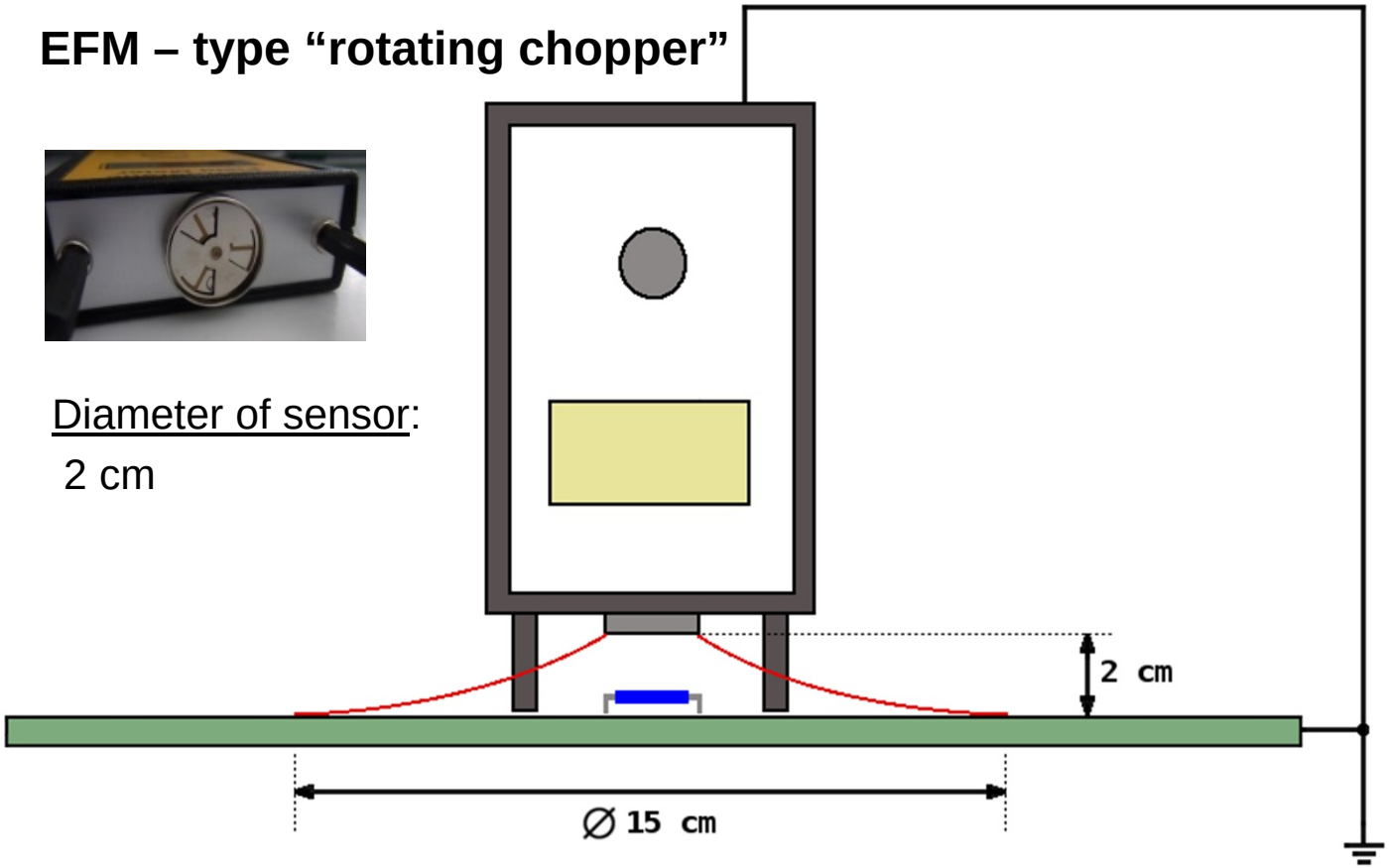
Plate C = 22,5 mm

Electrostatic Voltmeter (type 03 - contacting)						
applied voltage [V]	plate A [V]	difference	plate B [V]	difference	plate C [V]	difference
2.000	1.999	-0,05%	1.999	-0,05%	1.999	-0,05%
1.900	1.899	-0,05%	1.899	-0,05%	1.899	-0,05%
1.800	1.798	-0,11%	1.798	-0,11%	1.798	-0,11%
1.700	1.697	-0,18%	1.697	-0,18%	1.697	-0,18%
1.600	1.597	-0,19%	1.597	-0,19%	1.597	-0,19%
1.500	1.496	-0,27%	1.496	-0,27%	1.496	-0,27%
1.400	1.396	-0,29%	1.396	-0,29%	1.396	-0,29%
1.300	1.296	-0,31%	1.296	-0,31%	1.295	-0,38%
1.200	1.195	-0,42%	1.195	-0,42%	1.195	-0,42%
1.100	1.095	-0,45%	1.095	-0,45%	1.095	-0,45%
1.000	995	-0,50%	995	-0,50%	995	-0,50%
900	895	-0,56%	895	-0,56%	895	-0,56%
800	795	-0,63%	795	-0,63%	795	-0,63%
700	695	-0,71%	695	-0,71%	695	-0,71%
600	596	-0,67%	596	-0,67%	596	-0,67%
500	496	-0,80%	496	-0,80%	496	-0,80%
400	396	-1,00%	396	-1,00%	396	-1,00%
300	297	-1,00%	297	-1,00%	297	-1,00%
200	197	-1,50%	197	-1,50%	197	-1,50%
100	98	-2,00%	98	-2,00%	98	-2,00%

Discussion of results

EFM – type “rotating chopper”

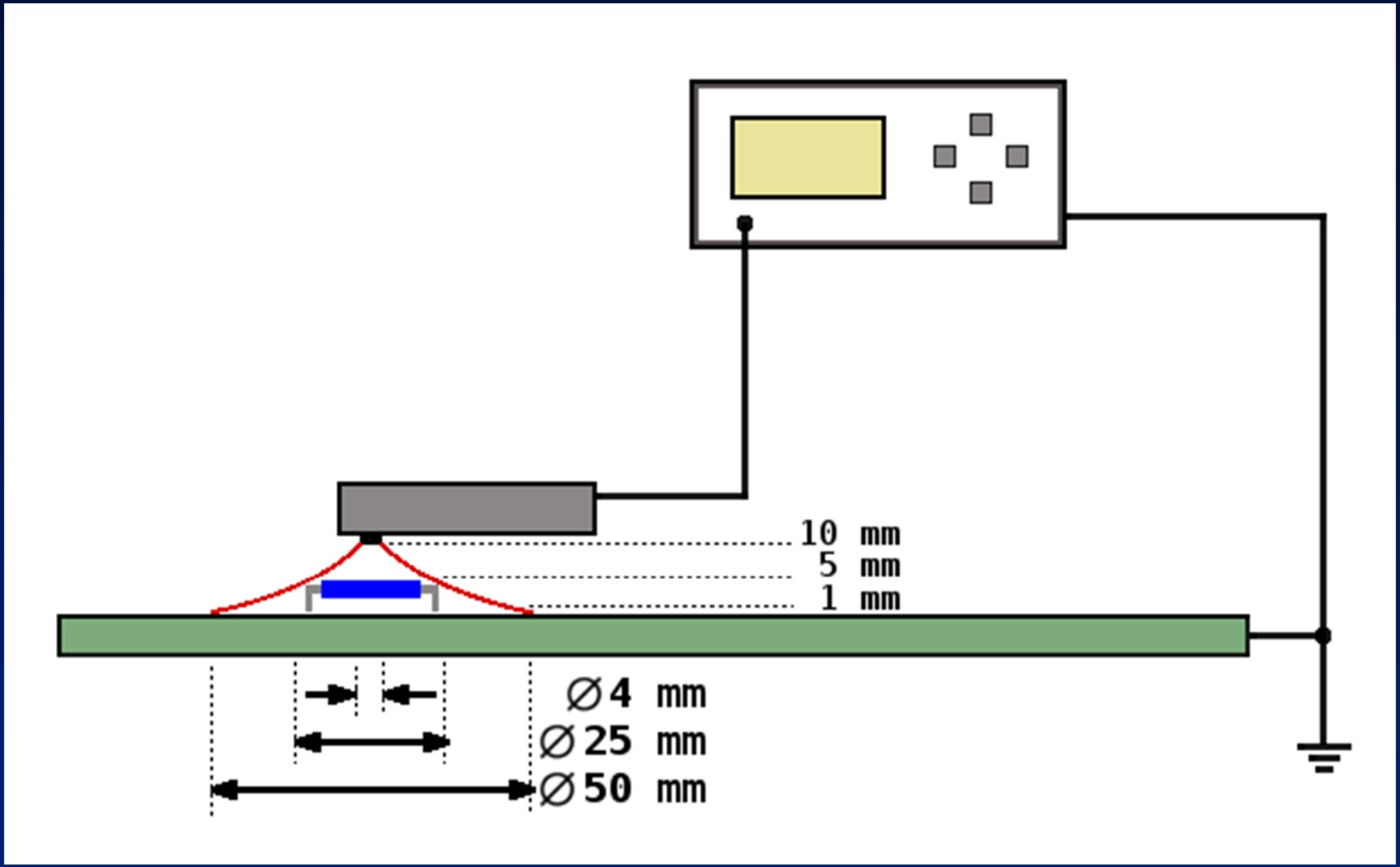
Diameter of sensor:
2 cm



The tested EFM detects an area of a diameter of around 15 cm.

When the tested materials or items are smaller than these 15 cm the accuracy will go significantly down

Discussion of results



The tested ESVM#02 detects an area of a diameter of around only 4 mm when the distance of the probe to the measured surface is 1 mm. At a distance of 10 mm the area is around 50 mm.

Test on pogo pins

Pogo pin #01:

Diameter 3.95 mm

Pogo pin #02:

Diameter 2.35 mm

A voltage of U = 500 V had been applied to two pogo pins type #01 and #02 in order to see the test results with the 4 different instruments on a very small conductive surface area

Test results on Pogo Pins

Electrostatic Fieldmeter (rotating chopper)				
applied voltage [V]	Pogo pin #01 [V]	difference	Pogo pin #02 [V]	difference
500	115	-77,00%	110	-78,00%
400	83	-79,25%	75	-81,25%
300	60	-80,00%	55	-81,67%
200	30	-85,00%	25	-87,50%
100	17	-83,00%	13	-87,00%

Difference -77 to -87 %

Electrostatic Voltmeter (type 01 - non-contacting)				
applied voltage [V]	Pogo pin #01 [V]	difference	Pogo pin #02 [V]	difference
500	360	-28,00%	361	-27,80%
400	280	-30,00%	254	-36,50%
300	230	-23,33%	178	-40,67%
200	140	-30,00%	132	-34,00%
100	60	-40,00%	60	-40,00%

Difference -28 to -40 %

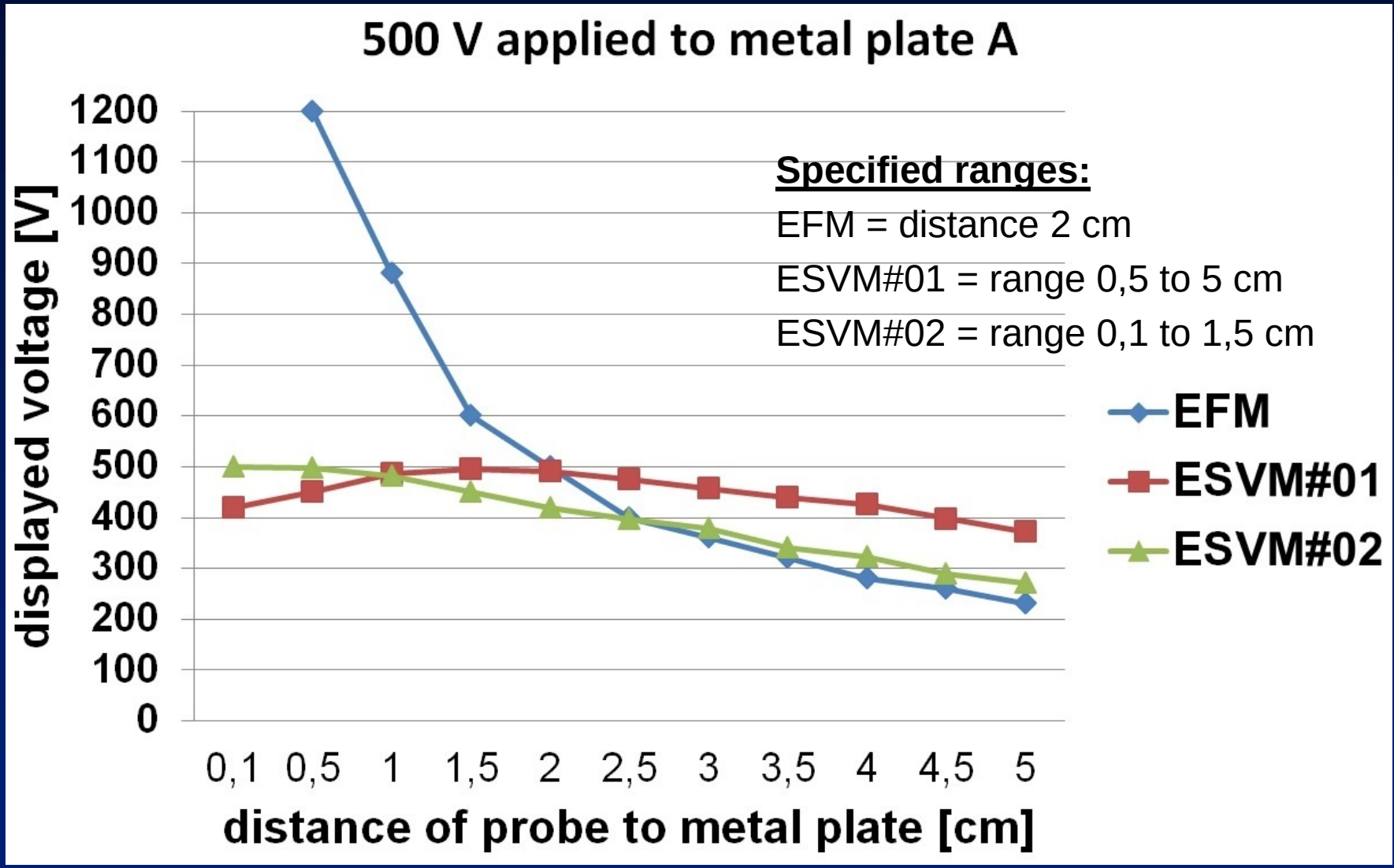
Electrostatic Voltmeter (type 02 - non-contacting)				
applied voltage [V]	Pogo pin #01 [V]	difference	Pogo pin #02 [V]	difference
500	480	-4,00%	480	-4,00%
400	384	-4,00%	384	-4,00%
300	288	-4,00%	288	-4,00%
200	191	-4,50%	191	-4,50%
100	95	-5,00%	95	-5,00%

Difference -4 to -5 %

Electrostatic Voltmeter (type 03 - contacting)				
applied voltage [V]	Pogo pin #01 [V]	difference	Pogo pin #02 [V]	difference
500	496	-0,80%	496	-0,80%
400	396	-1,00%	396	-1,00%
300	297	-1,00%	297	-1,00%
200	197	-1,50%	197	-1,50%
100	98	-2,00%	98	-2,00%

Difference -0,8 to -2 %

Influence distance of probe to test item



Influence of distance of probe to test item

Electrostatic Field Meter:

- Calibrated with a distance of 2,0 cm to a metal plate in a parallel plate capacitor. When the distance to the test item is changed the displayed value on instrument varies significantly

Electrostatic Voltmeter:

- In the defined distance range on each type of ESVM the influence on the displayed value is minimal

Summary

Instruments	Test on metal plate setup (A, B and C)	Test on metal Pogo pins (#01 and #02)	Influence of distance probe to test surface
Electrostatic Field meter "rotating chopper" type	suitable only for homogeneous surface areas with a diameter ≥ 15 cm	**not** suitable	accurate only at specified distance of 20 mm
ESVM – type 01 "non-contacting" type	suitable for homogeneous surface areas ≥ 48 mm	**not** suitable	accurate in the distance range 10 to 25 mm (in the specified range 5 to 50 mm still acceptable results)
ESVM – type 02 "non-contacting" type	suitable for all plates sizes	suitable for both types	accurate in specified range 1 to 15 mm
ESVM – type 03 "contacting" type	suitable for all plates sizes	suitable for both types	**no** influence, probe is always in contact with test surface

Conclusions

- Electrostatic Field Meters (rotating chopper type) are suitable to measure surface potential of materials with larger areas
- To measure surface potential on small areas and objects a suitable Electrostatic Voltmeter (ESVM) is recommended and the following points should be considered
  - voltage range & the specified tolerances
  - type of probe
  - specified distance range for the measurement
  - contacting or non-contacting type ESVM

Conclusions

- The most accurate results we got when a ESVM as a contact voltmeter version was used. Here it is important that the input resistance is > 1 x 10^14 ohm and that the input capacitance is very low because the probe will be in contact with a conductive surface for example.
- Because of the very small contact probe an exact measurements on component pins can be performed.