

PRE-SLHY

Electrostatic measurements around a cryo-jet

KIT, 2018-04-19

Pre-normative REsearch for Safe use of Liquid HYdrogen

223
1966



Content

- I. Intro
- II. Main
- III. Conclusions

Motivation

- S.J. Hawkworth “Spontaneous ignition of hydrogen leaks”, 2007
 - 81 incidents involving hydrogen releases and spontaneous ignition
 - 86,3% of ignition sources are not identified

- Possible mechanisms of spontaneous ignition
 - Open fire
 - Spark (hot particle)
 - (Reverse Joules Thomson effect)
 - Hot surface
 - Diffusion ignition
 - Sudden adiabatic compression
 - **Electrostatic discharge**
 - Spark discharge
 - Brush discharge
 - Corona discharge

Introduction



Wanted: Measurement of electric charges generated by a cold (100K) hydrogen jet.

Needed: A reliable method to detect and measure the electric field of charges generated by several unknown processes.

Aim: Identify those processes.

Work was done by Paul Coupé for his master thesis with a little help from some other people.

Typical field strengths

Area	Field Strength
Normal weather conditions	100 – 300 V/m
Thunderstorm	several kV/m up to ~ 30kV/m
Breakdown in air	3 MV/m

How people do it.



Measurement of static electric field, units is V/m.

Just measure the voltage between 2 points in space! Really? Why not?

- To measure a voltage you need at least a small current. To avoid measurement errors an extremely high input impedance is needed.
- High input impedance means high sensitivity to stray fields and all kinds of electromagnetic interference.
- But you can do it, if you invest a lot into a good shielding: see Chem. Eng. Technol. 2015, 38, No. 7, 1261–1268. They still see some hum from the AC supplies. See next page for the device they used.
- We can not always shield the object of our measurement from the rest of the world.

Alternative equipment



Keithley Electrometer 610C, extremely simple but cleverly built. New models aren't cheap (US \$5,650 - US \$16,100).

Using modern ICs, it should be possible to built high input impedance devices. But the best circuit layout is a real challenge.



Field Mill Principle I

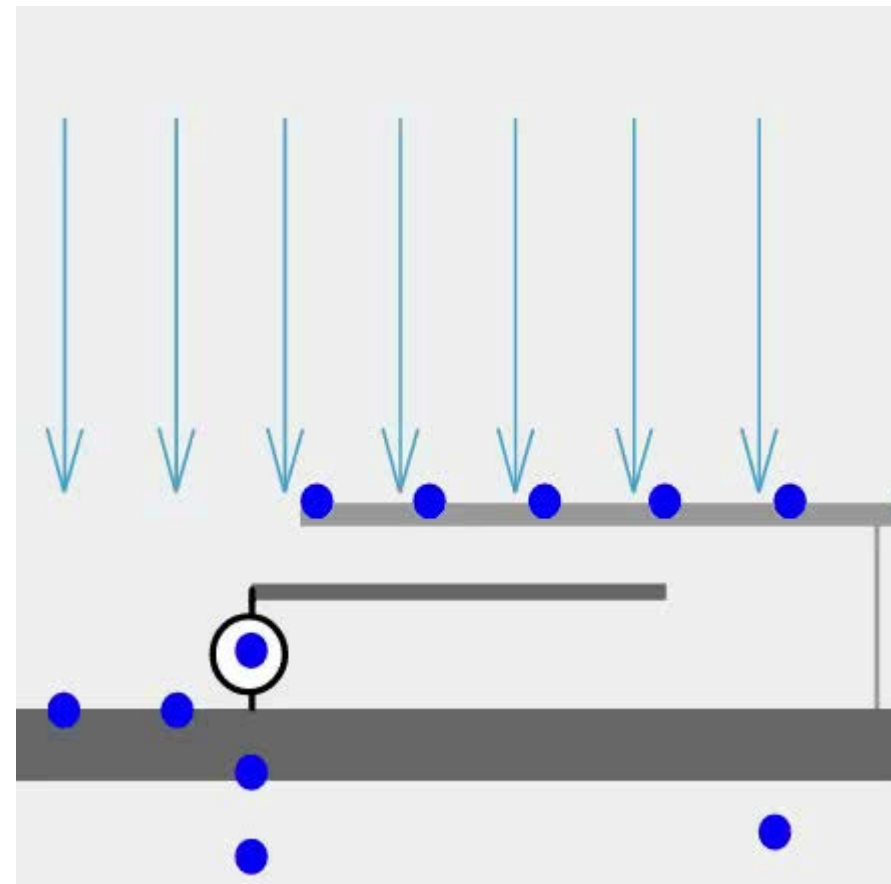
Disadvantage of all “normal” electronic devices:

Finite input impedance.

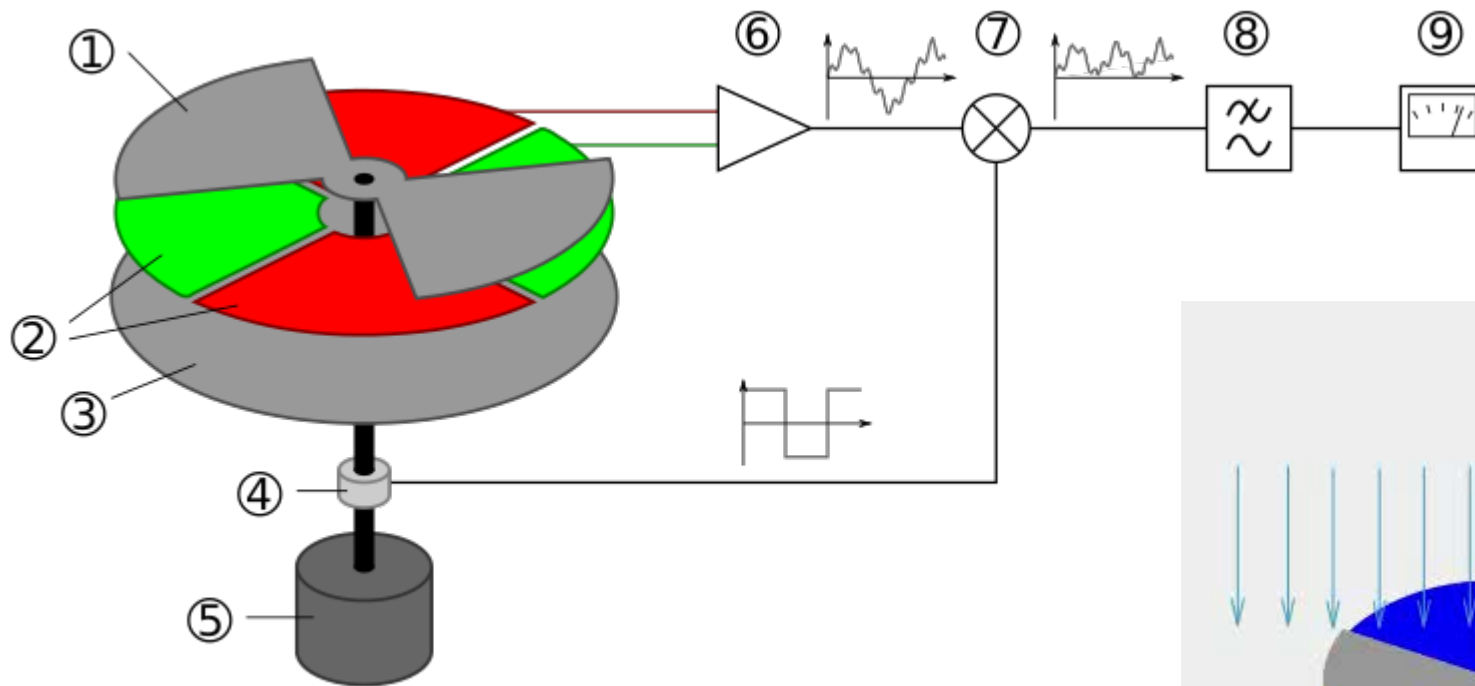
What can be used instead?

Electric induction. An electric field will cause moving charges.

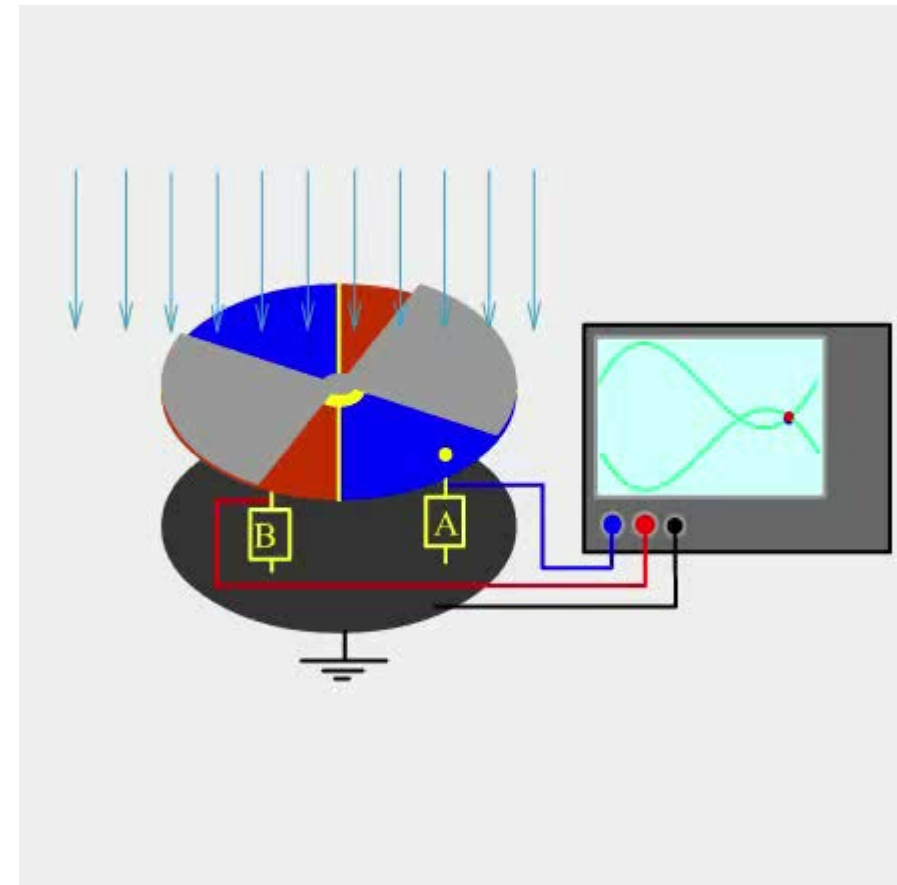
The short movie shows the principle:



Field Mill Principle II



- ① Chopper wheel
- ② sensor plates ③ base plate
- ④ rotary encoder
- ⑤ drive ⑥ amplifier
- ⑦ multiplier ⑧ low-pass ⑨ display



Equipment

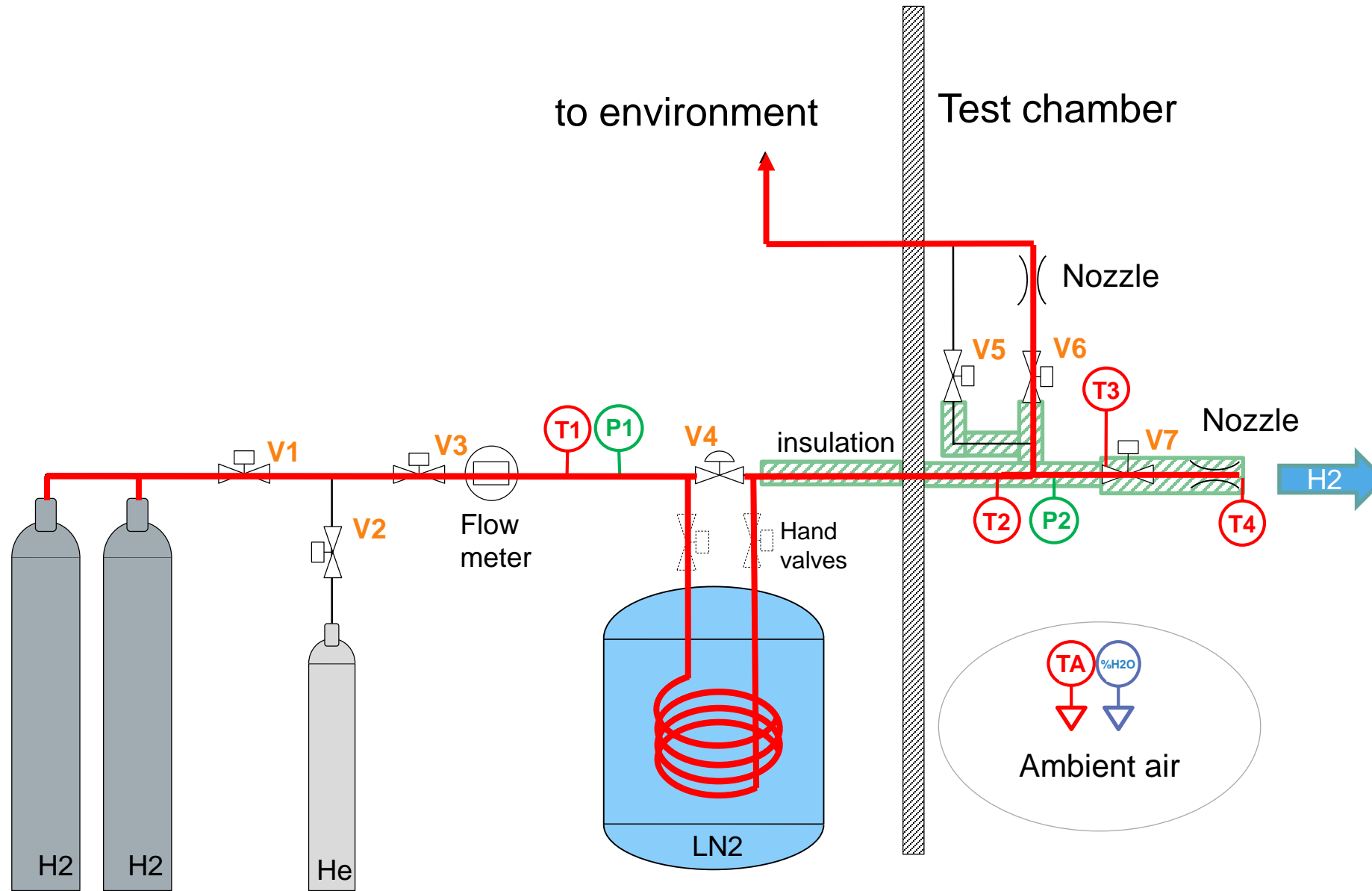


Kleinwächter	EFM 251
Dimension (L x B x H)	180mm x 73mm x 73mm
Weight	820g
Ranges	200V/m, 2kV/m, 20kV/m
Error	< 2%
Power supply	7 -10V DC
Interface	$\pm 1V$ ($R_i > 1k$)

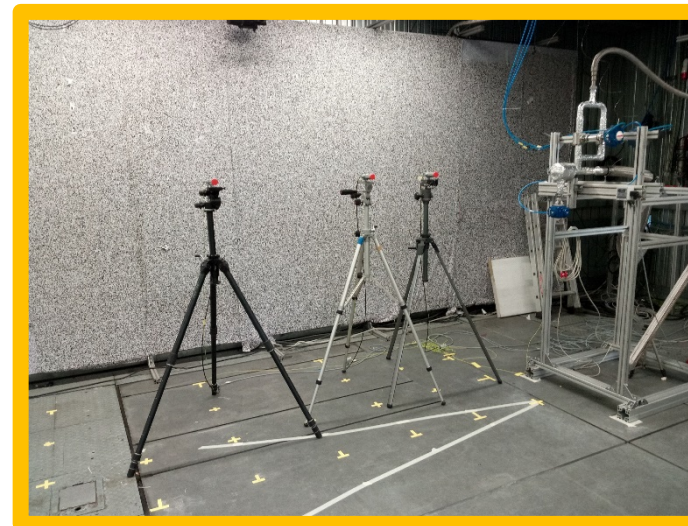
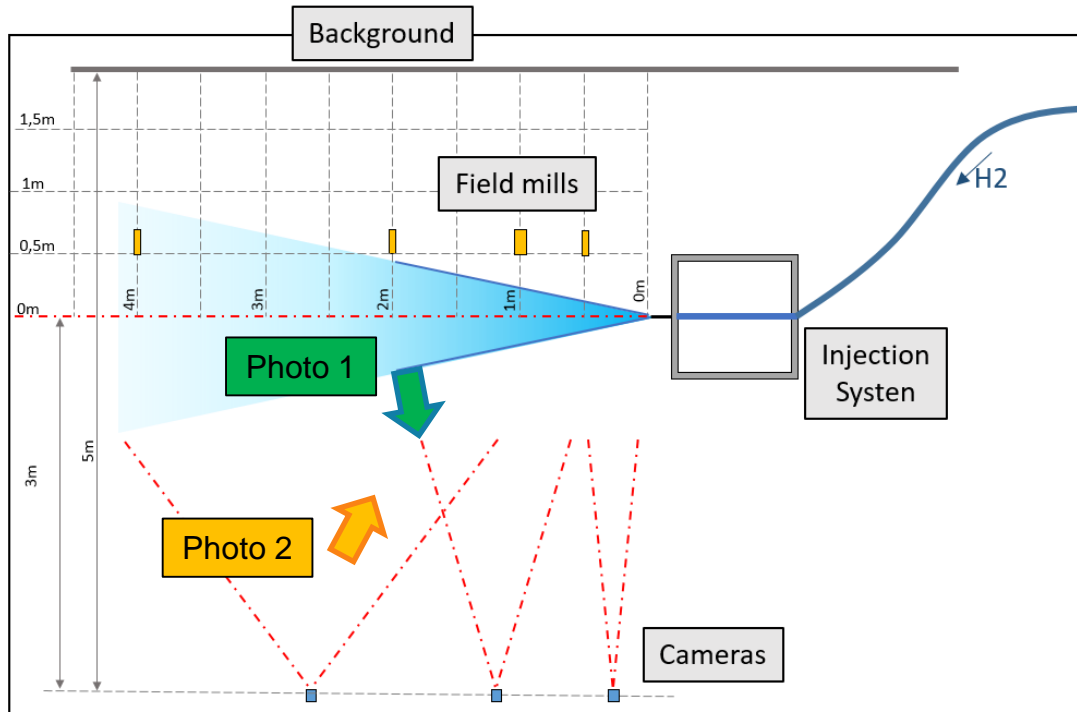


Kleinwächter	EFM 113B
Dimension (L x B x H)	36mm x 120mm
Weight	180g
Ranges	5kV/m, 20kV/m, 50kV/m, 200kV/m
Error	< 5%
Power supply	9 -15V DC / ca. 60mA
Interface	$\pm 1mA$ ($R_i < 2k$)

Experimental Setup – Injection System



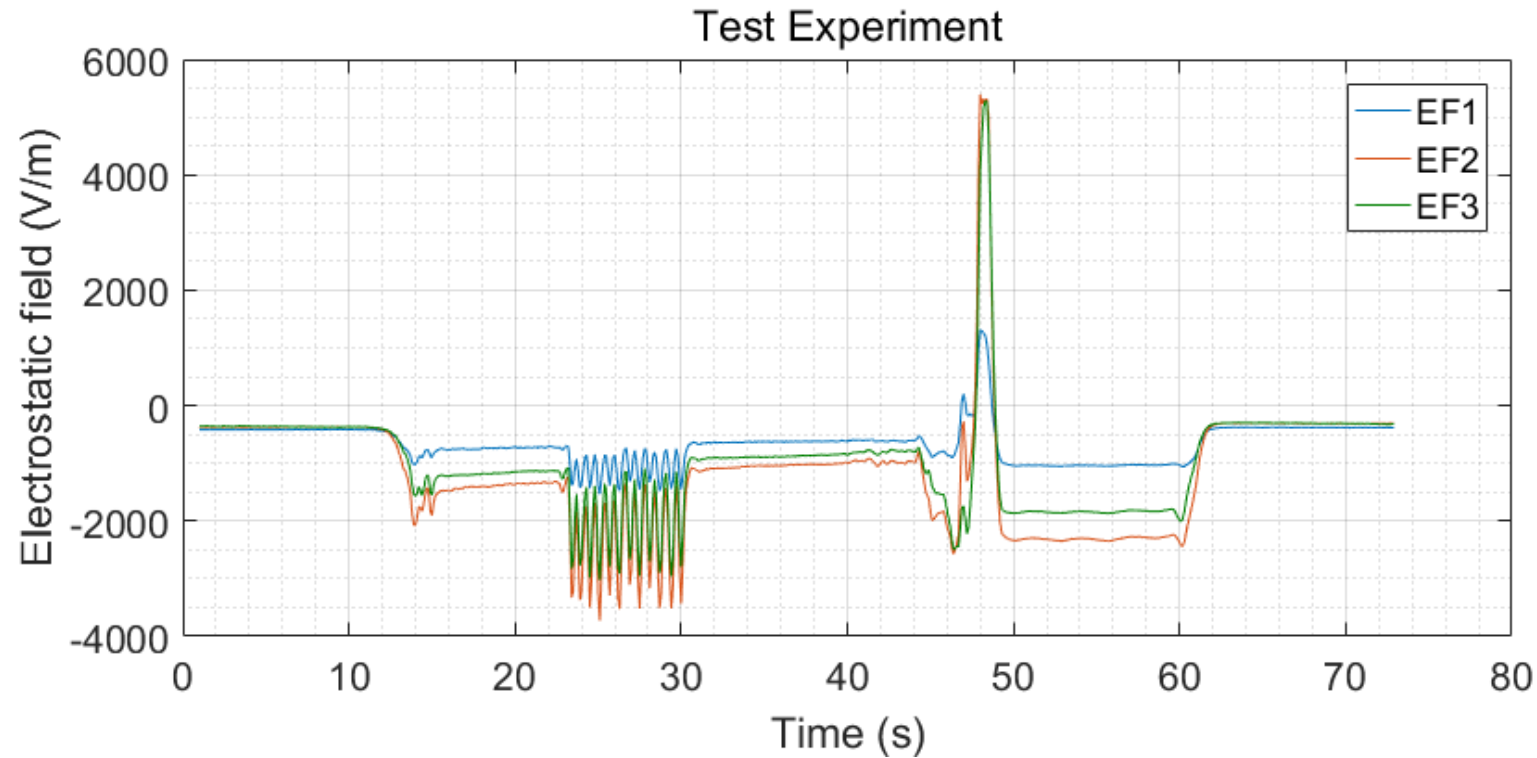
Experimental Setup – Measurement system



LN2 Pool



Tests –Electrostatic field signal

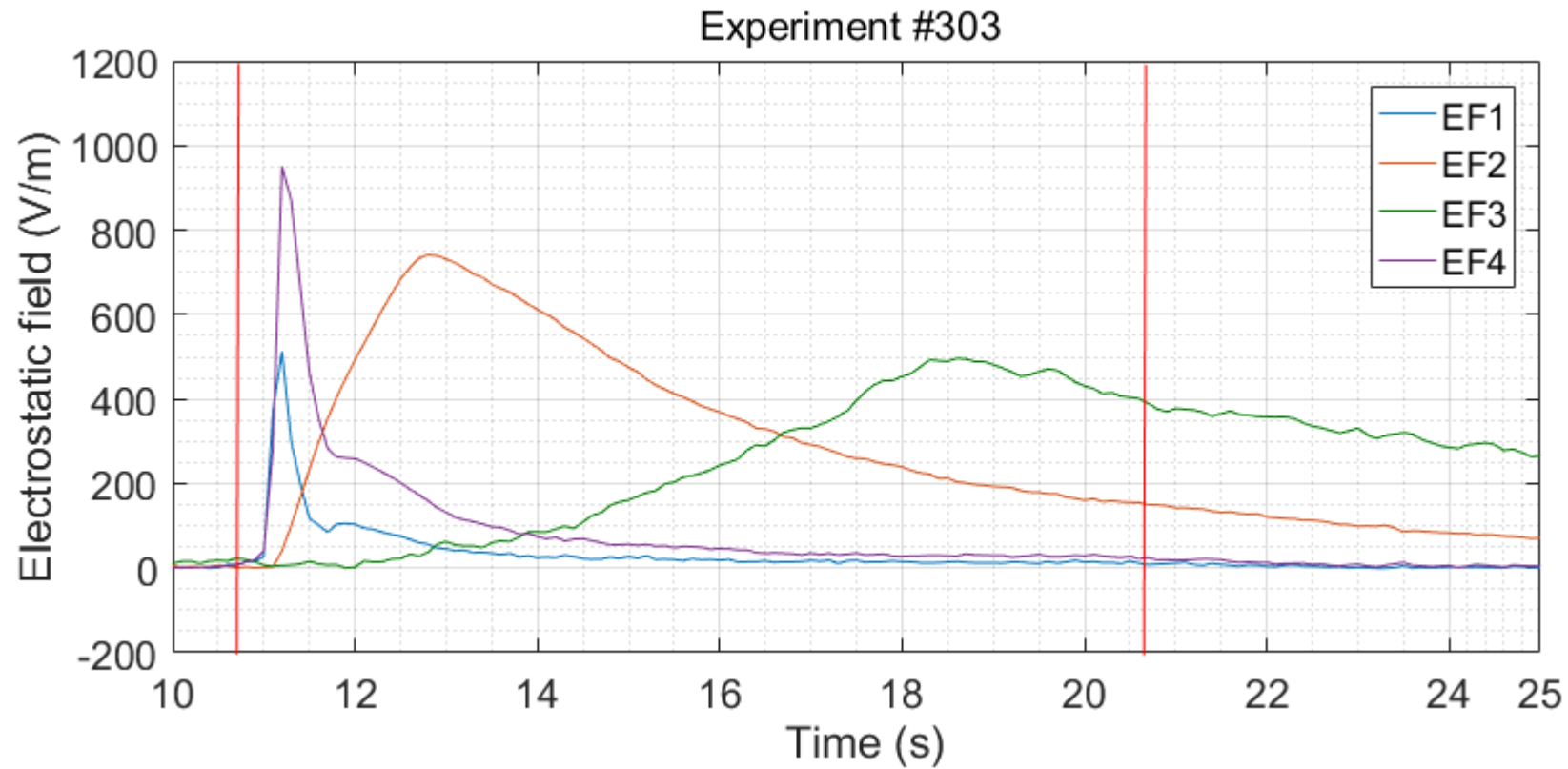


Cloud Weather	Standing 1m away	Taking off jacket	Dielectric strength air
~ 0.1 kV/m	~ 1 kV/m	> 5 kV/m	3 000 kV/m

Results – #200 and #300 Series – 120K

#200 & #300 Series
 H₂ – He
 T₂ = 120~130 K
 P₁ = 9,5 bar
 Ø1mm nozzle

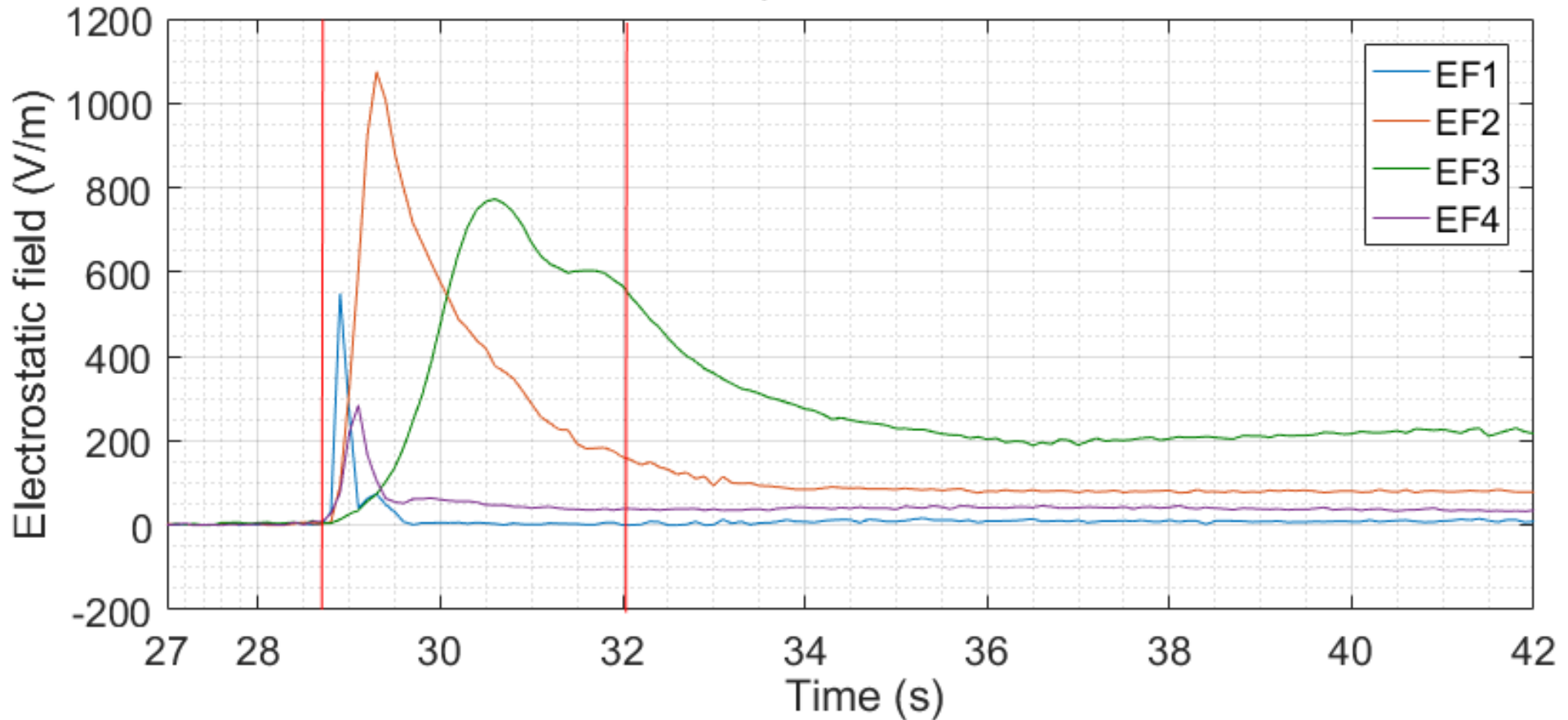
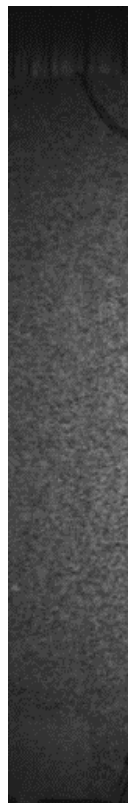
Boiling point:
 Water - 273K
 CO₂ - 194K
 O₂ - 90K
 N₂ - 77K



Results – #400 Series – 120K - ø3mm Nozzle

#400 Series
 H₂ – He
 T₂ = 110~130 K
 P₁ = 9,5 bar
 Ø3mm nozzle

Experiment #424



Conclusion

- Static electric fields can be easily measured using the right equipment.
- Devices are not robust. They have to be shielded from dust, humidity, etc.
- Field mills are good for slowly varying fields. Cut off frequency is a few Hz.

Paul's conclusions

- Deduction from the results:
 - The jet is carrying charges
 - Mainly the front wave of the jet
 - At cold temperature only
 - Minimum level of humidity required

- Hypothesis:
 - Charges are carried by ice particles
 - Ice forming on the cold nozzle before the experiment
 - Teared away by the hydrogen flow