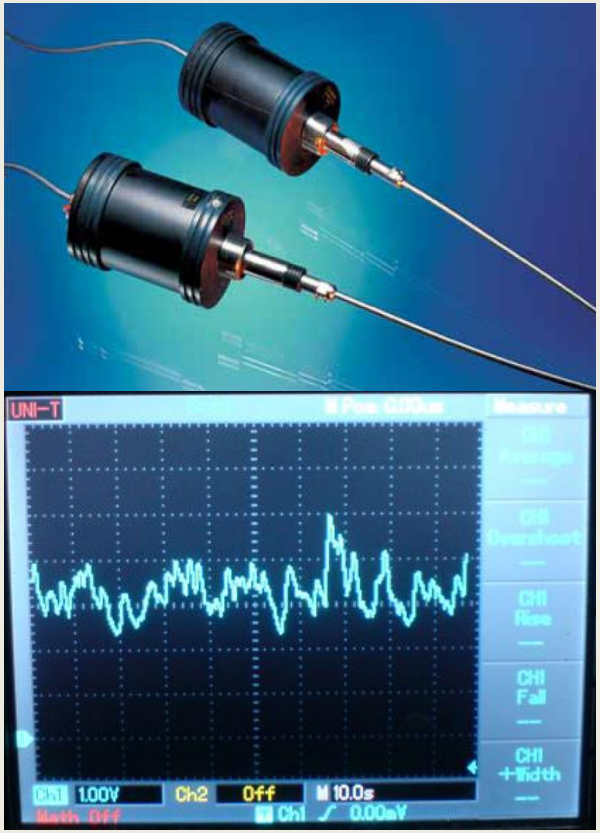
Some Experiences in the Exploitation of Triboelectric Sensors for Measuring Concentration of Particulate Matter on Thermal Power Plants

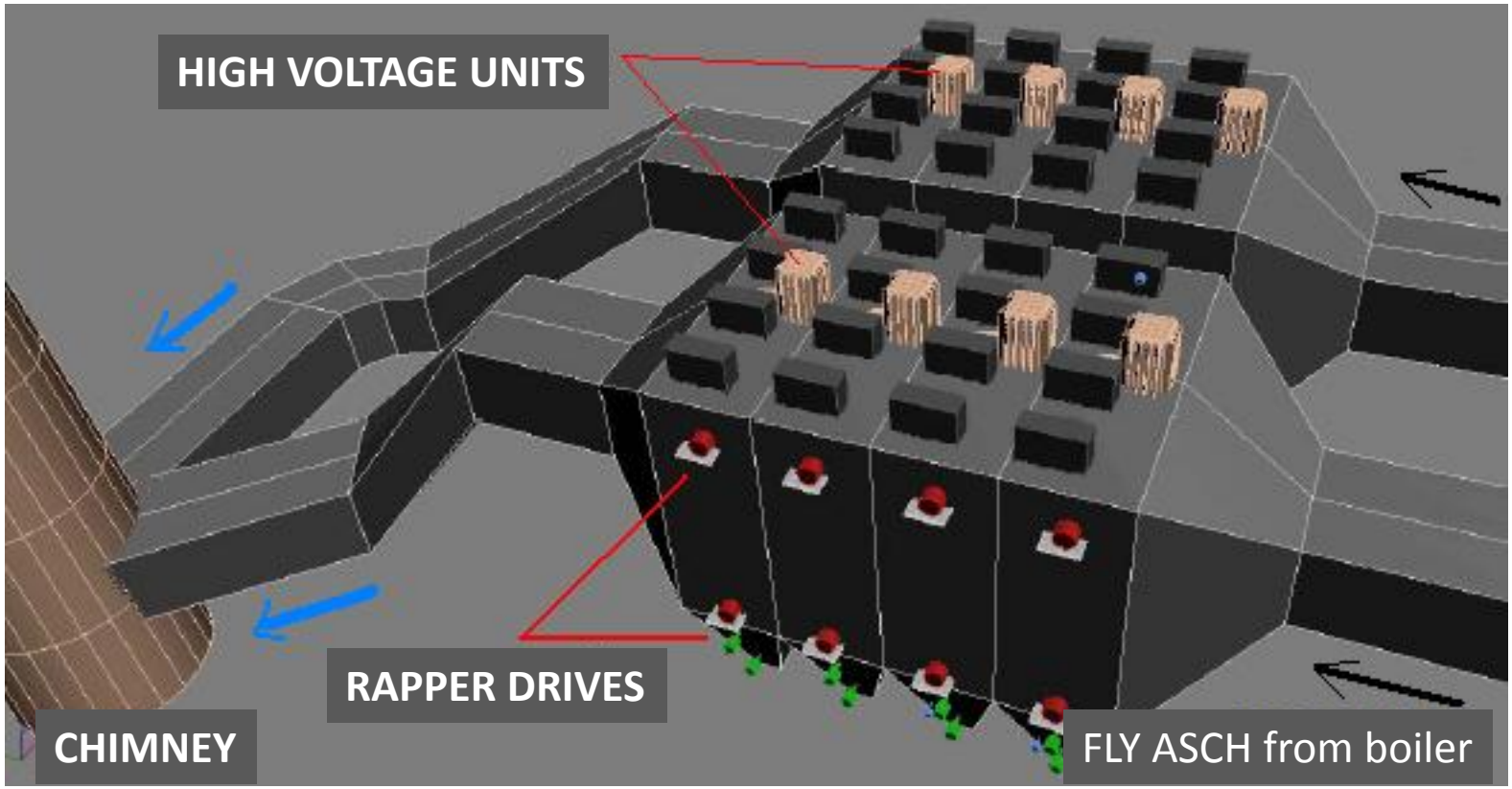


Dr Zeljko V. Despotovic, dipl.el.ing ,
zeljko.despotovic@pupin.rs
Mihajlo Pupin Institute, University of Belgrade

INTRODUCTION

- **Environmental pollution problems are the outcome of the worldwide increase in energy consumption and industrial growth.**
- **The overall concentrations of waste gasses, including the particulate matter emission has increased.**
- **The fine 1–100 µm, particles particularly harmful and being a well-known health risk.**
- **Large industrial plants (cement plants, thermal power plants, etc...) require dust cleaning equipment, advanced particulate monitoring, measuring of their emissions and on-line pollution control.**
- **Control goals include the need to meet the environmental regulations, keeping at the same time the power losses and the overall energy consumption under control, in order to reach the energy efficiency goals.**
- **These regulations impose very stringent levels for upper concentration limits 50mg/m^3 of emitted particulate matter.**
- **The tendency is to reduce these levels to the values less than 20mg/m^3.**
- **A very important factor in satisfying these requirements is a reliable and accurate particulate monitoring and measurement.**

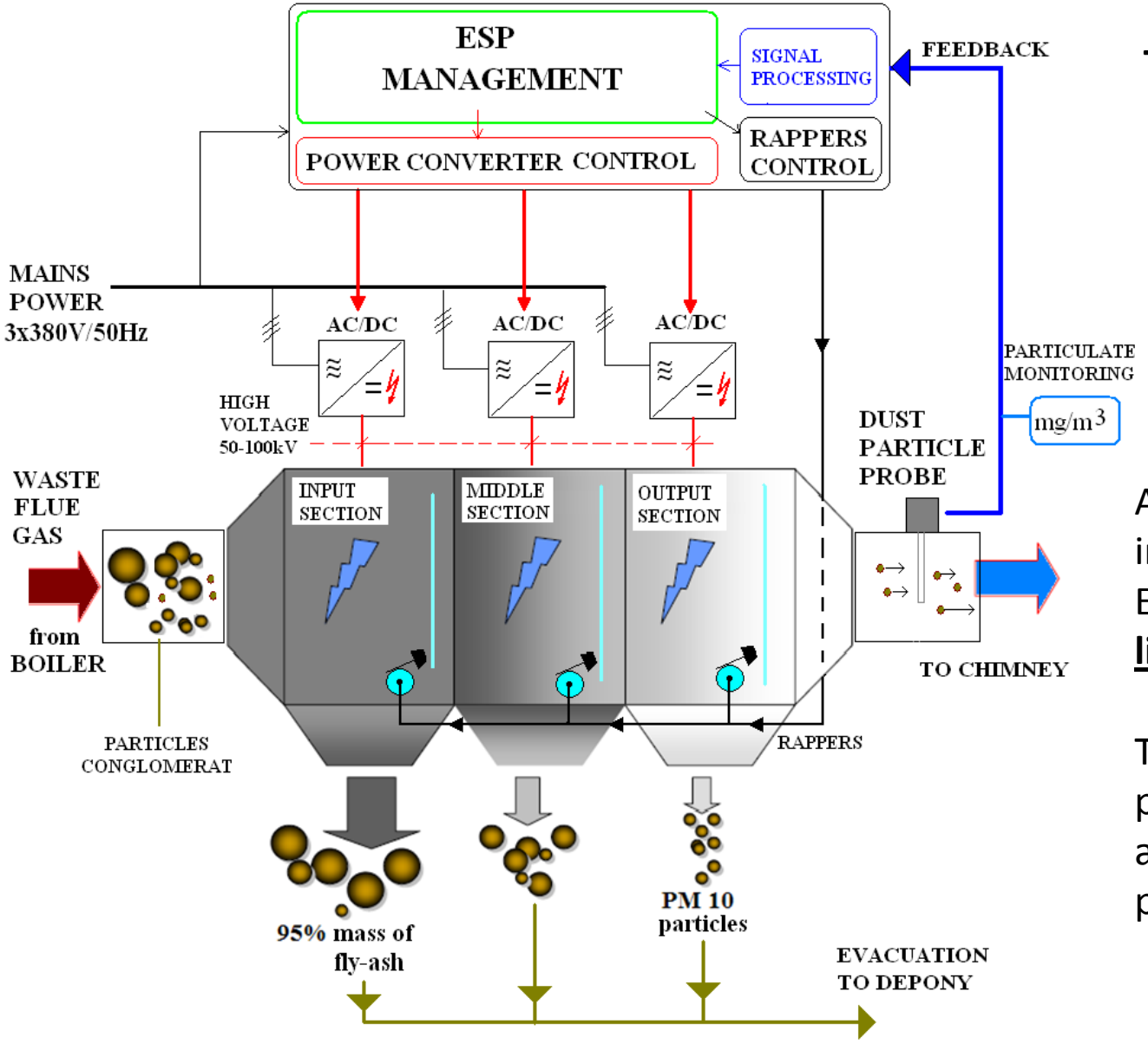
DISPOSITION OF PLANT for REMOVAL DUST PARTICLE



Typical electrostatic precipitation and dust removal systems on thermal power plants (TPP)

HIGH VOLTAGE UNITS- 100kV DC, 1A (ELECTRICAL SYSTEM)

RAPPING OF COLLECTING AND EMISSION ELECTRODES (MACHANICAL SYSTEM)



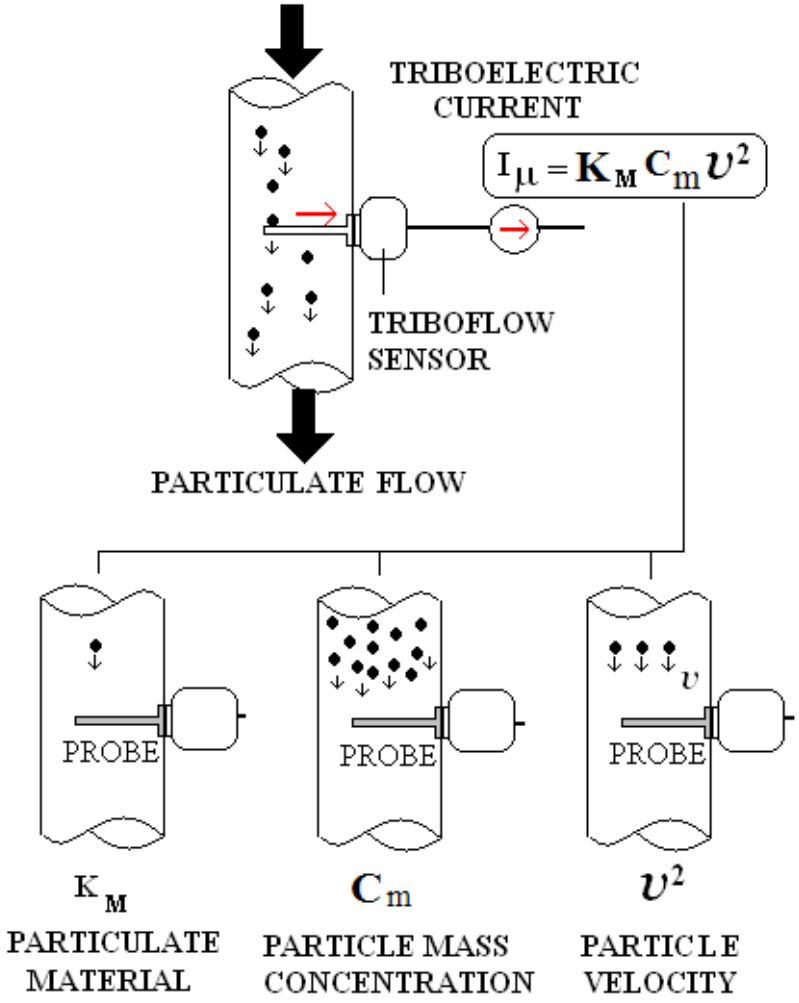
Typical disposition of ESP plant having particulate matter pollution control

A very important element in the best performance ESP management is **<u>on-line</u>** pollution control.

These require advanced particulate monitoring and measuring of pollutants emission.

One possible way of reliable measuring the concentration of particles is to use **<u>DC or AC coupled triboelectric effects.</u>**

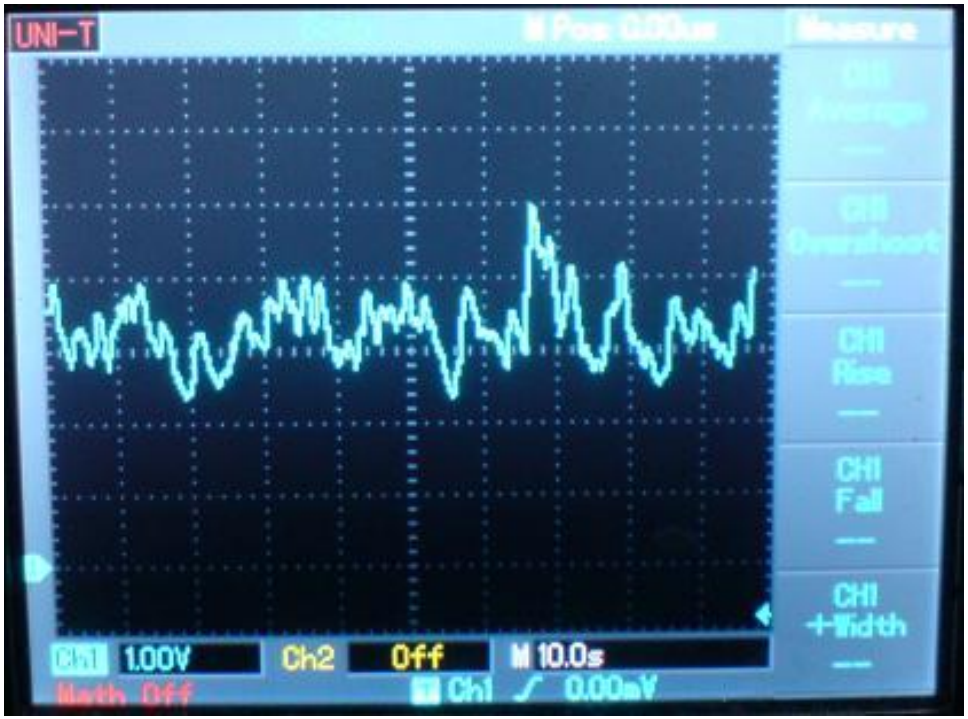
TRIBOELECTRIC EFFECT



- The small particles of fly ash suspended in a flue gas stream will carry an element of electrical charge that is generated from friction with other particles and metal surfaces.
- This phenomenon is referred to as the triboelectric effect.
- The charge carried is proportional to the surface area of the particle, size particles and mass of the particle.
- If a conducting probe is inserted into the gas stream, particles in the stream will collide with the probe and charge will be transferred to the probe as a result of the collisions.
- A triboelectric particulate monitoring device (conducting probe and transmitter) measures the direct current produced by the charge transfer when particles strike the probe.

K_M-calibration factor that consider the type of particulate material, in [$A \cdot m/s^2 \cdot mg$]

Real triboelectric signal consist of several components

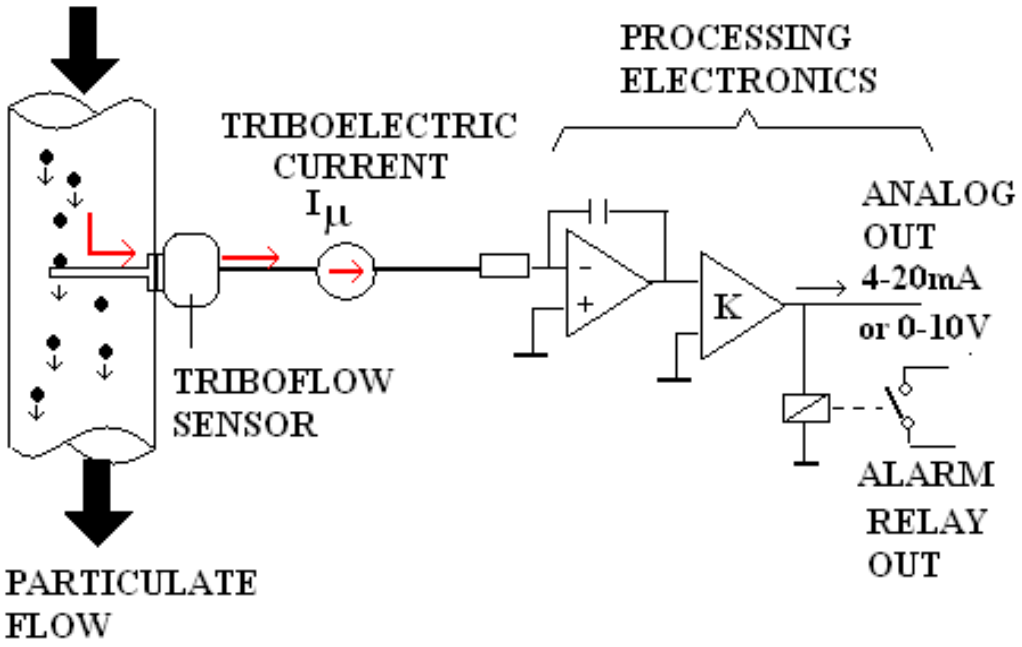


The high-frequency AC component is unusual and must be filtered.

Only the DC component and the low-frequency AC component are useful!!!!

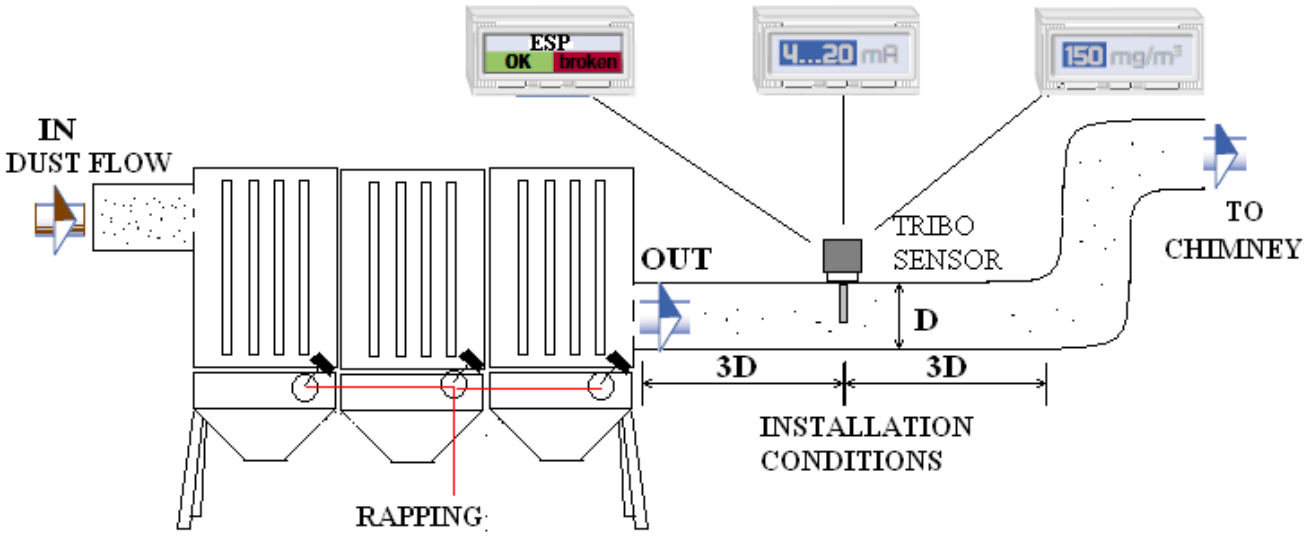
- In really industrial conditions triboelectric signal is made up of several components
- DC component generated by the particulate striking the sensor (It is proportional to the mass flow and varies with the actual flow rate).
- The low frequency AC component generated by short-term intermittent variations of fluctuations in the mass flow rate of particulate, and by particulate passing near the probe, but not impacting the probe.
- The high-frequency AC component. (high-frequency modulation resulting from equipment, vibration and other factors).

AC coupled triboelectric measuring

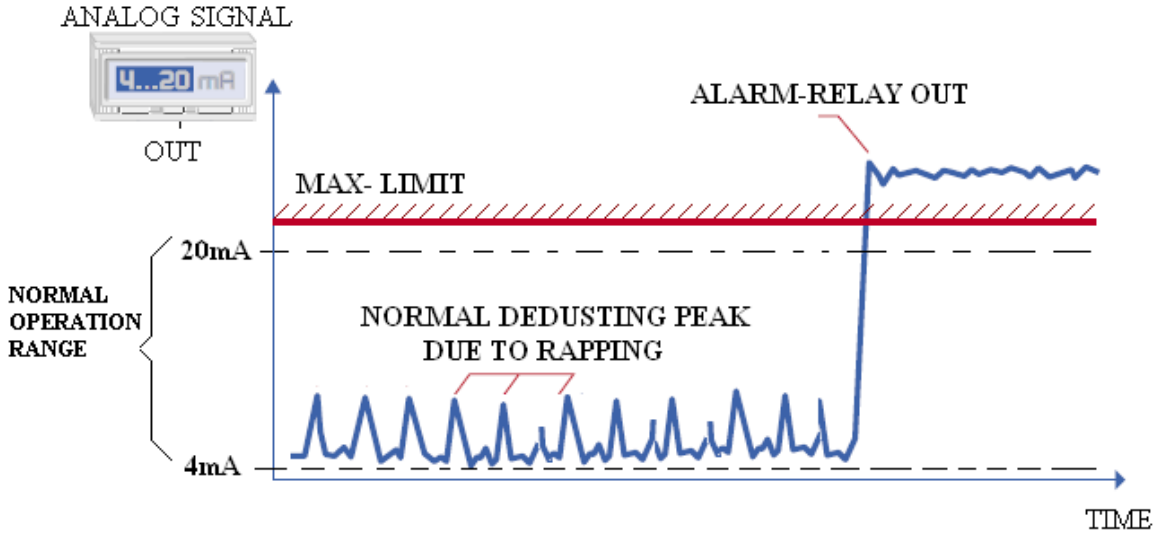


The resulting current is amplified, filtered, rectified and further filtered looking only at the AC component, giving a linear representation of the concentration or mass flow rate of the particles in the gas stream. Amplification electronics convert the current to an instrument output signal (voltage 0-10V or current 4-20mA).

- AC-coupled circuits utilizing only the AC components are completely dependent on fluctuations in the dust flow signal to function.
- If the degree of fluctuation varies to any extent, the dust flow will be detected as significantly lower or higher amounts than actually are present.
- Significant changes take a long time to settle down.


ESP
OK broken
4...20 mA
150 mg/m³
IN
DUST FLOW
OUT
TRIBO
SENSOR
TO
CHIMNEY
D
3D
3D
INSTALLATION
CONDITIONS
RAPPING

(a)

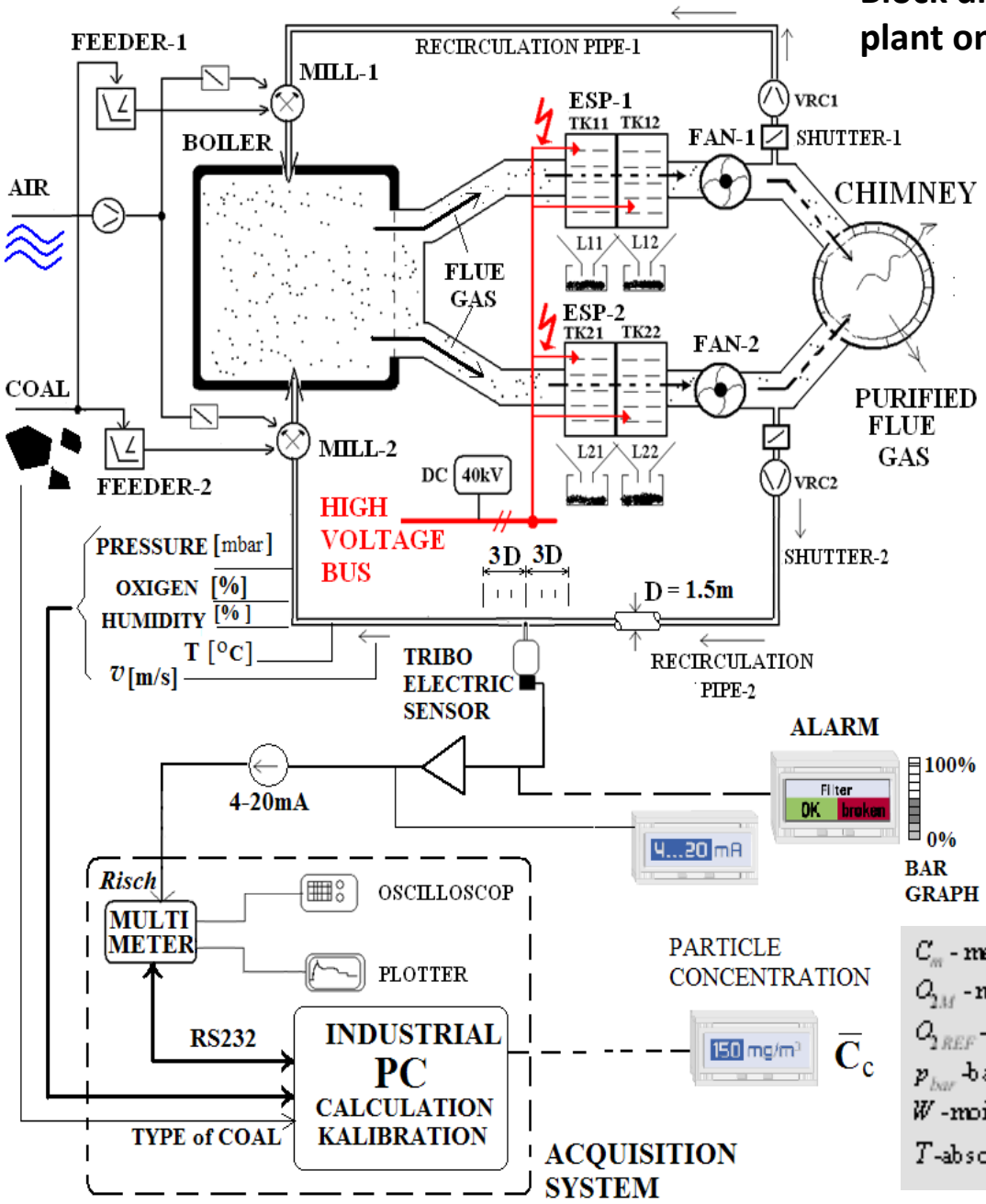

ANALOG SIGNAL
4...20 mA
OUT
ALARM-RELAY OUT
MAX- LIMIT
20mA
NORMAL
OPERATION
RANGE
NORMAL DEDUSTING PEAK
DUE TO RAPPING
4mA
TIME

(b)

Application and Testing Triboelectric Sensors on TPP "Morava"

- Since June 13th 2008 until July 21st 2010, the testing took place at TPP "Morava"-Svilajnac, equipped with conventional SCR-50Hz (4 pieces) and high voltage high frequency (HVHF) ESP power supply units (4 pieces).
- The measurements were organized in order to the comparison HVHF power units with conventional SCR units; examine the effects of HVHF power supply on the precipitation efficiency and to establish the expected reduction in dust emission.
- In addition to these tests are obtained and some experience in the use of AC coupled triboelectric sensors type EM5, Tyco-GOYEN production

Block diagram of measuring equipment in ESP plant on TPP “Morava”



In the exploitation testing and examination is used the formula (in accordance with the legislative regulations) for calculate corrected concentrations of particulate matter compared to normal condition (temperature 0° C, pressure 1013mbar, dry gas and concentration of reference oxygen 6%):

$$C_c[mg/m^3] = C_m[mg/m^3] \cdot \frac{21 - O_{2REF}[\%]}{21 - O_{2M}[\%]} \cdot \frac{1013.25}{p_{bar}[mbar]} \cdot \frac{100}{100 - W[\%]} \cdot \frac{T}{273.15[K]}$$

C_m - measured particle mass concentration $[mg/m^3]$

O_{2M} - measured concentration of oxygen [%]

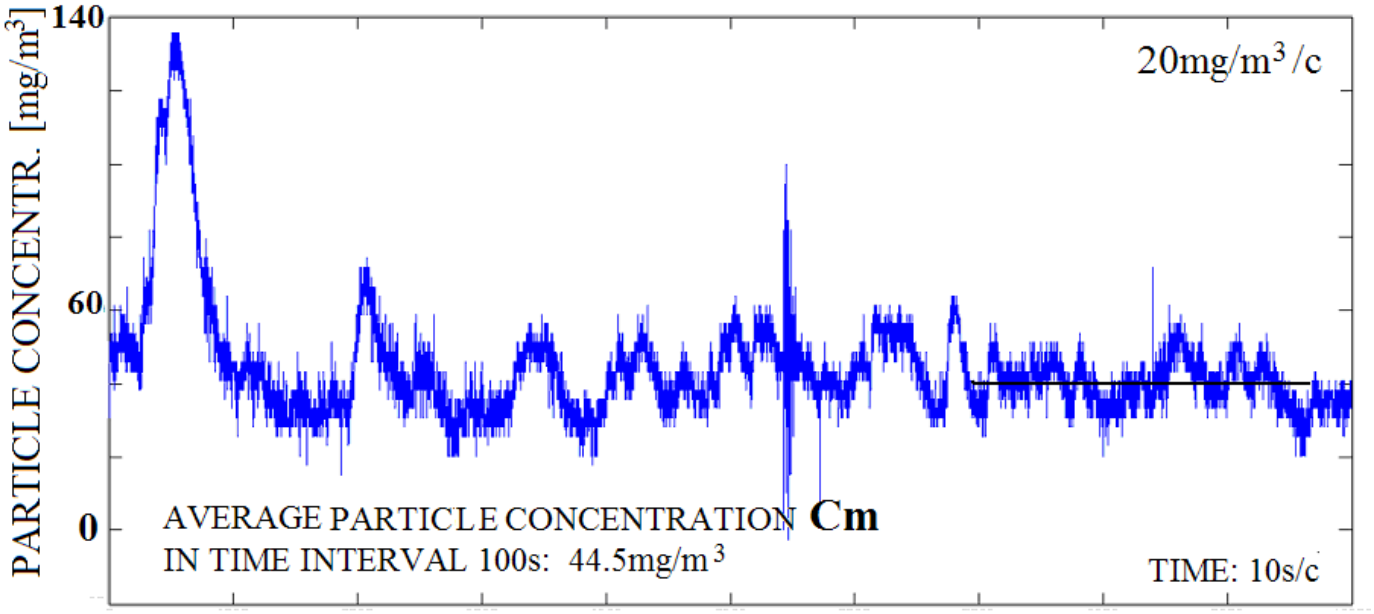
O_{2REF} - reference value of oxygen concentration (for coal combustion 6%) [%]

p_{bar} - barometric pressure $[mbar]$

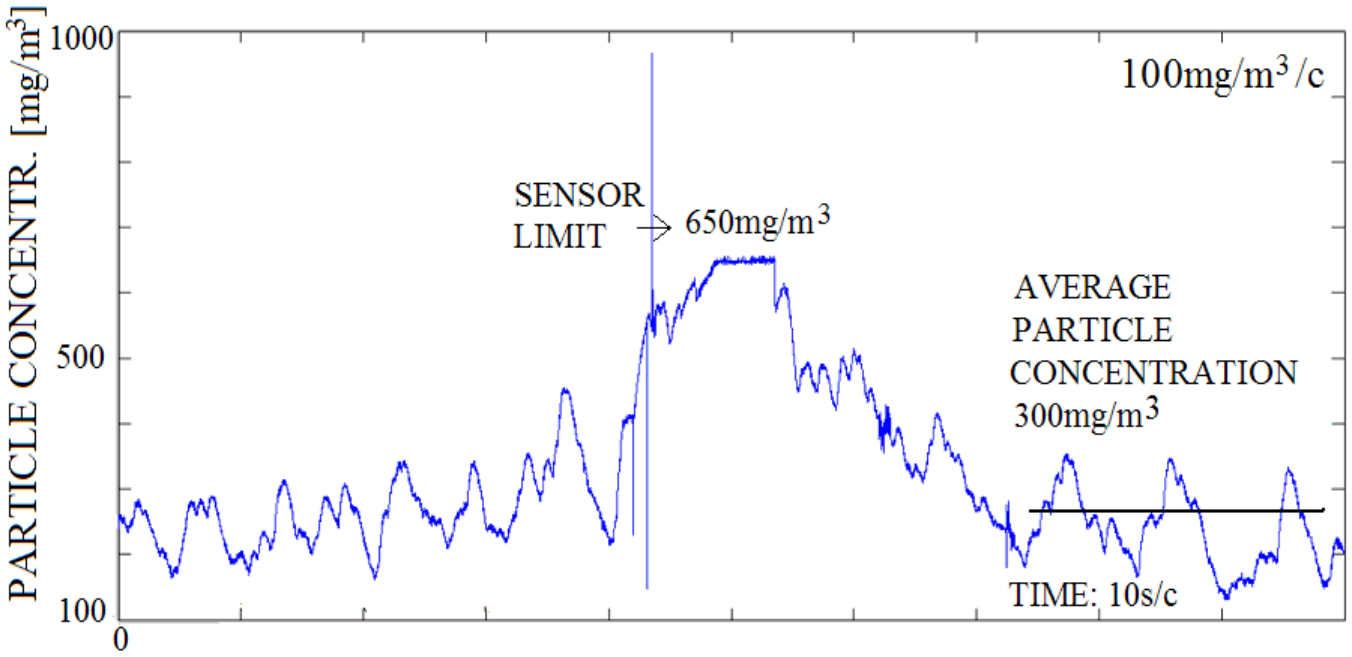
W - moisture content in the flue gas [%]

T - absolute temperature of flue gas, $T[K] = t[^0C] + 273\,K$

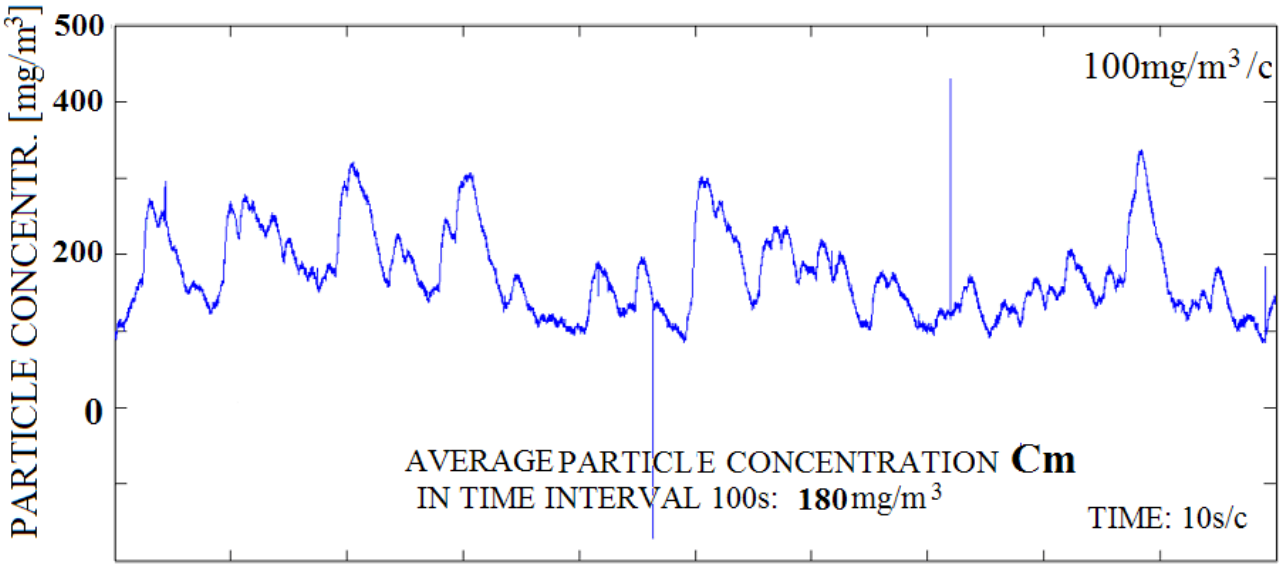
EXPERIMENTAL RESULTS



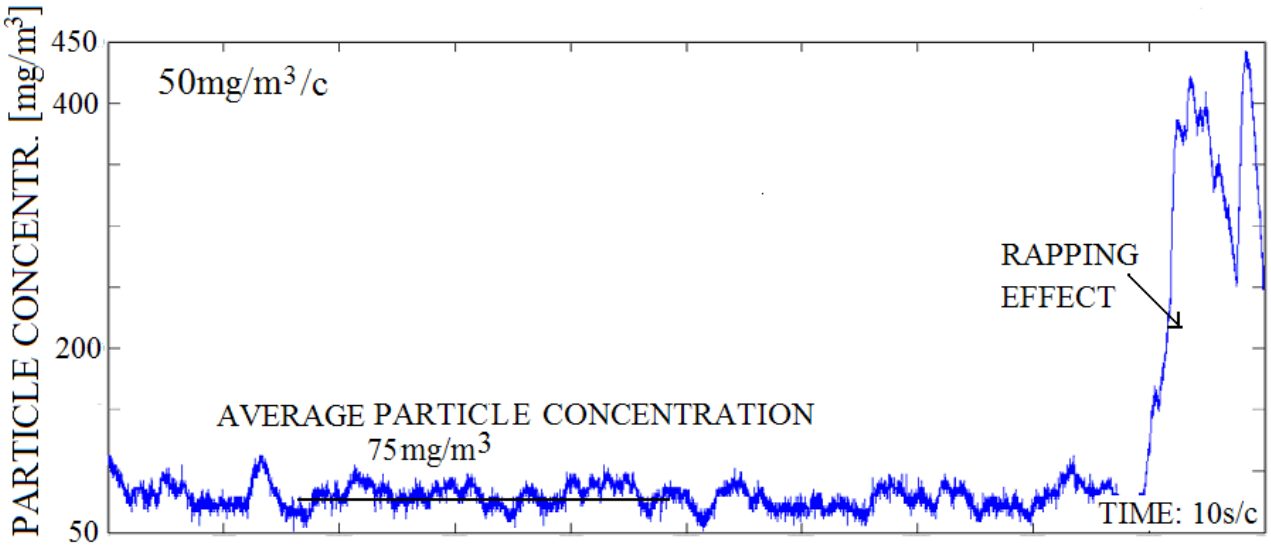
Measuring particle concentration in recirculation pipe channel at 2xHVHF power



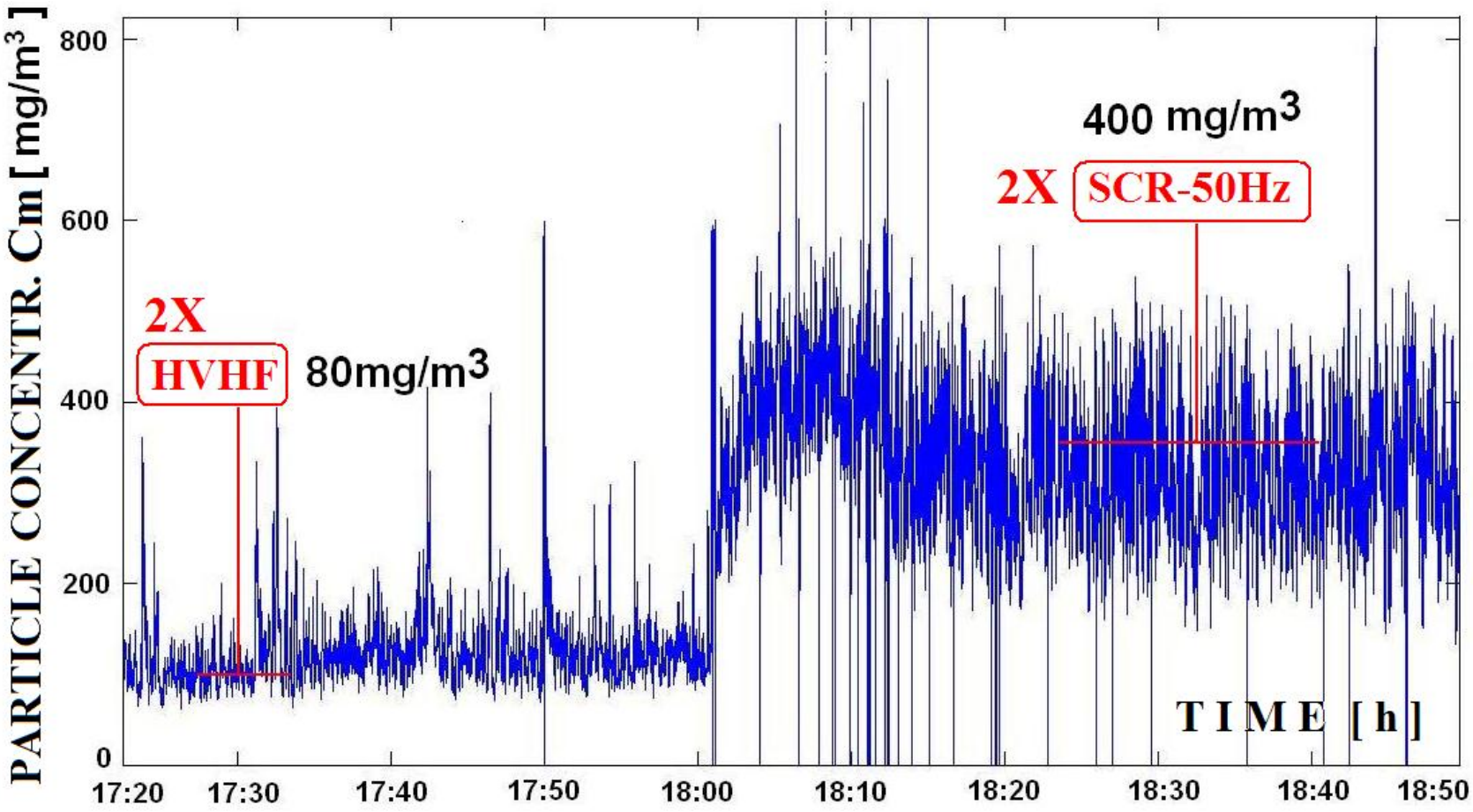
Measuring particle concentration in recirculation pipe channel at transient regime of power changing: 2xHVHF power to 2xSCR-50Hz power.



Measuring particle concentration in recirculation pipe channel at 2xSCR-50Hz power.



Measuring particle concentration in recirculation pipe channel at transient regime of turning on rapping mechanisms; 2xHVHF power



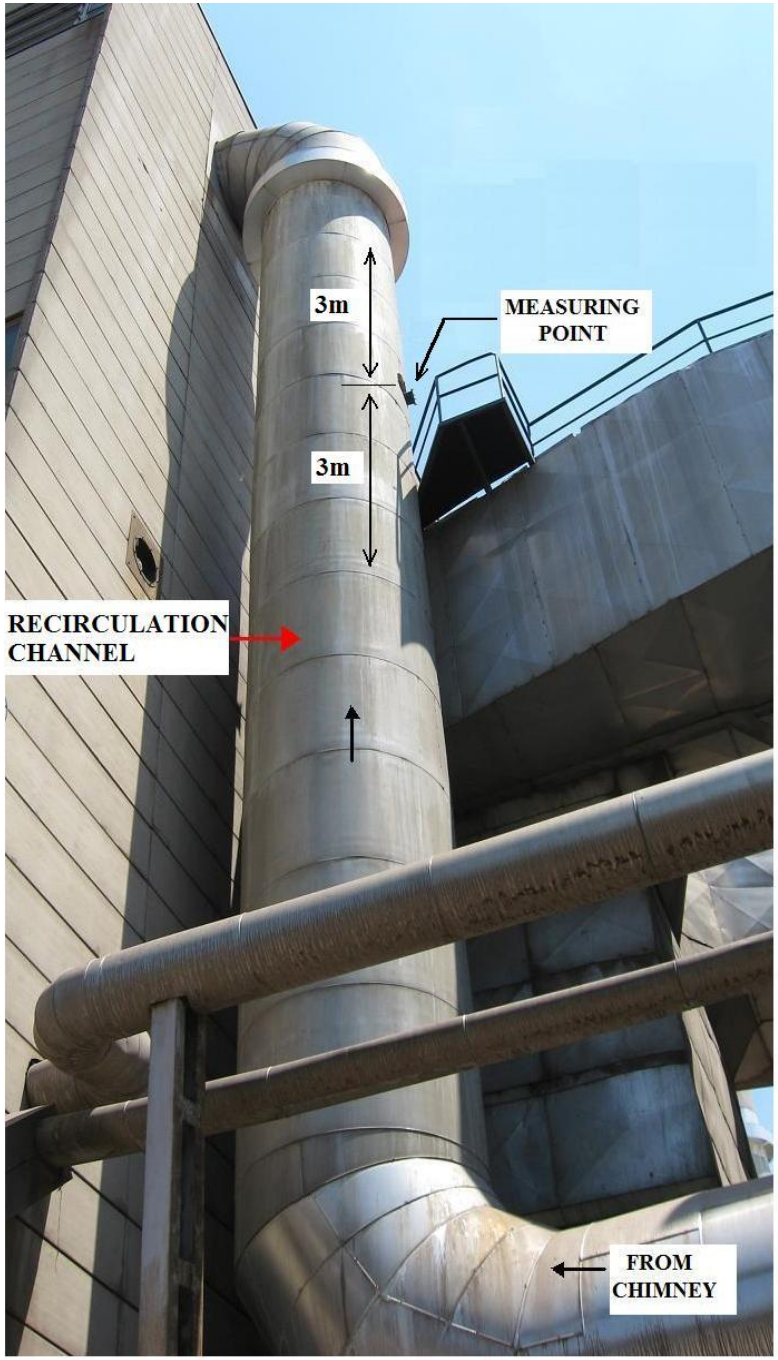
Comparison of particle concentration in recirculation pipe channel for 2xHVHF power and 2xSCR-50Hz power.

RECIRCULATION PIPE CHANNEL-begin

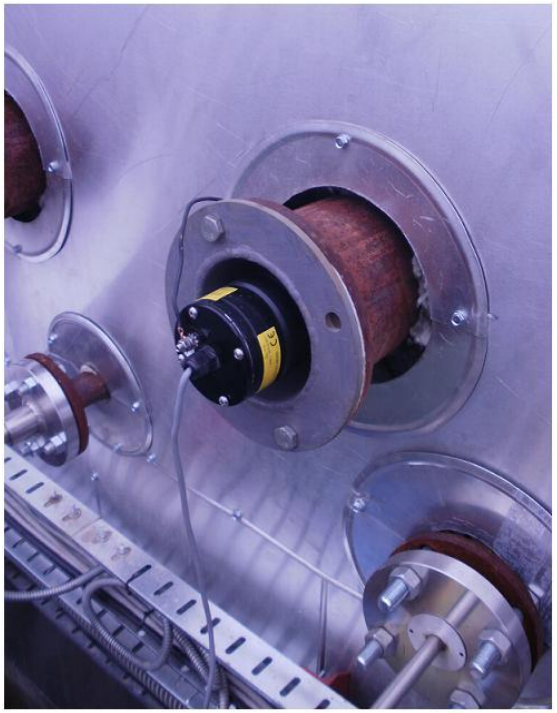
RECIRCULATION PIPE CHANNEL-end

- The triboelectric sensor probe (steel road with sensing head) is mounted in the recirculation pipe of the right ESP branch.
- This mounting location has been selected so that the gas flow is laminar so as to insure stability and accuracy.
- Only in this mounting location is possible to meet the requirement 3D (D is diameter of recirculation pipe, and it is equal to 1.5m), in order to avoid the effects of pipe curvature and the effects of turbulence.
- Alternative solutions, i.e. eventual mounting within the post-confusor channel has been abandoned, since it was not possible to identify location that would be far enough from the channel curves or the fan, so as to ensure a laminar flow.
- As it is well known, mounting of the triboelectric probe in zones with pronounced turbulence contributes to significant errors.

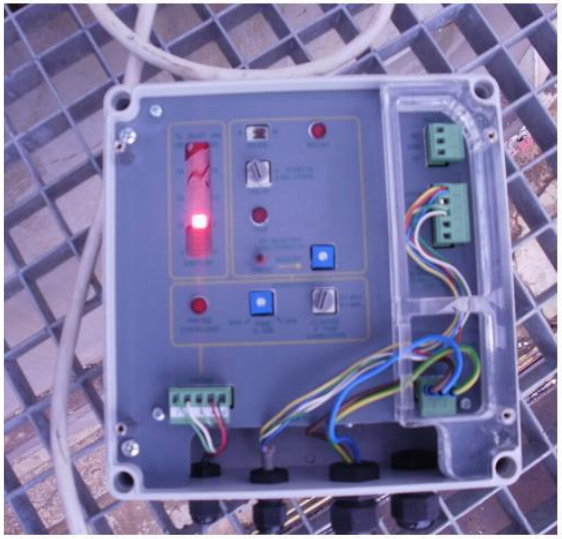
From to previous picture



(a)



(b)



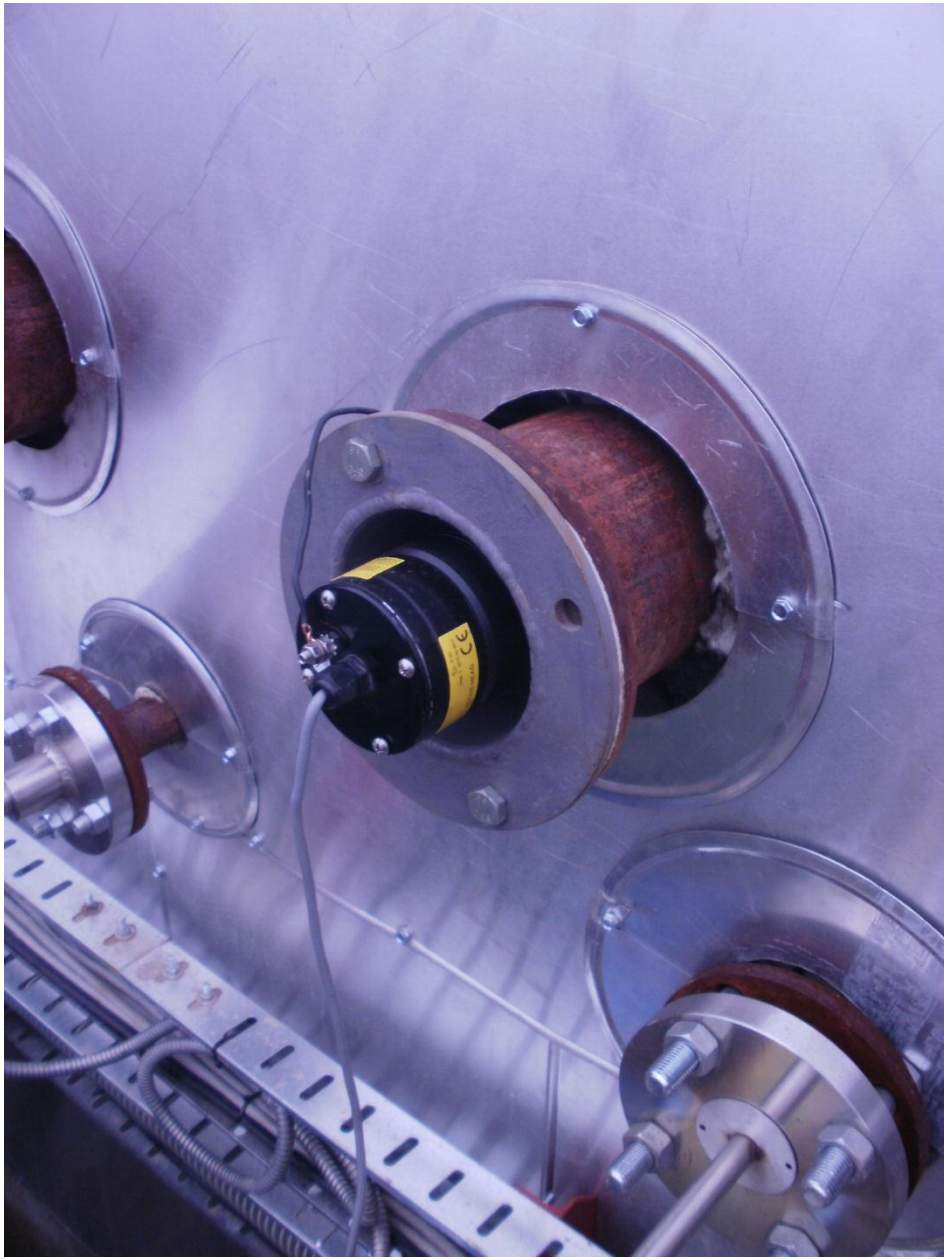
(c)

Triboelectric measuring station on TPP "Morava"

(a) disposition of recirculation channel,

(b) measuring point of triboelectric probe,

(c) transmitter and processing electronics.



CONCLUSION

- In the paper are presented operating principles, methodologies, and methods of use triboelectric sensors for measuring the particle mass concentration in flue gas at the ESP station on thermal power plants.
- It is provided particular emphasis on AC coupled triboelectric sensors.
- In concrete application the TPP "Morava"-Svilajnac, Serbia, are used EMP5 particulate emission monitors (AC coupled triboelectric sensing head with associated electronics), manufacturing *Tyco-GOYEN*.
- These monitors have proven to be very reliable and satisfactory accuracy, and as such are fully respond to the technological requirements of the ESP plant at TPP "Morava".
- Also, they have able to detect most particles regardless of composition; they are very sensitive and applicable over a wide range of particulate.
- In this application they are applied to a range 0-800mg/m^3.

THANK YOU IN ATTENTION!!

zeljko.despotovic@pupin.rs