QUT-Thermodenuder (TD)

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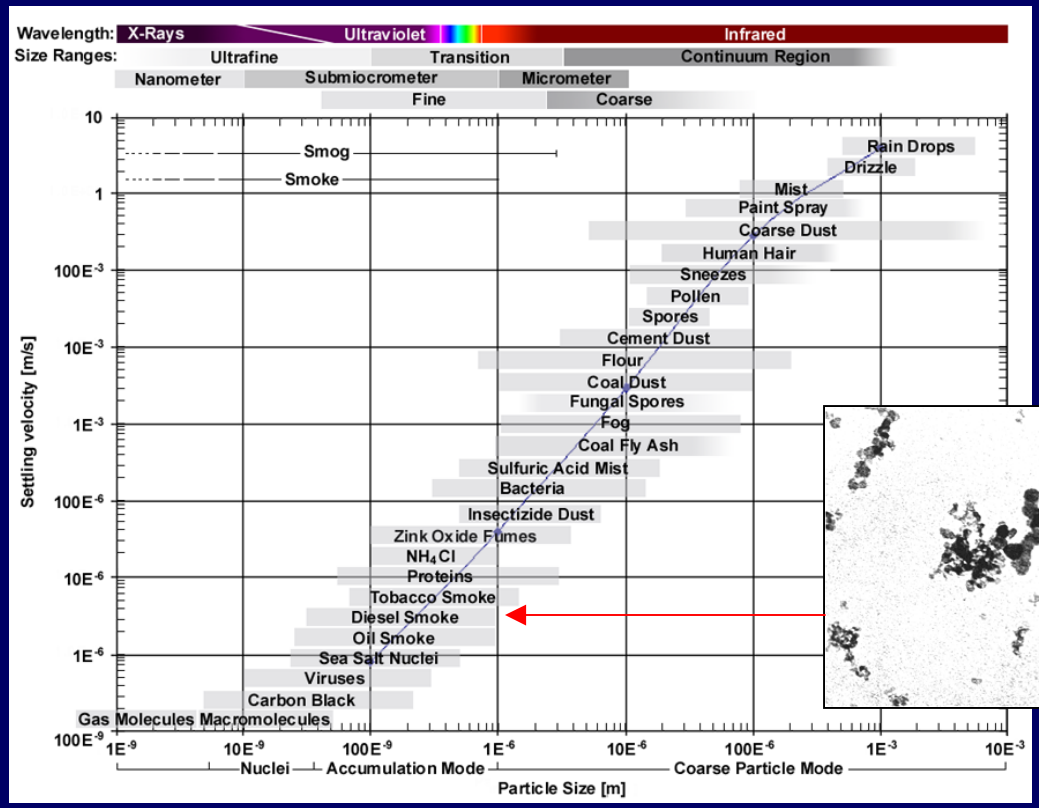
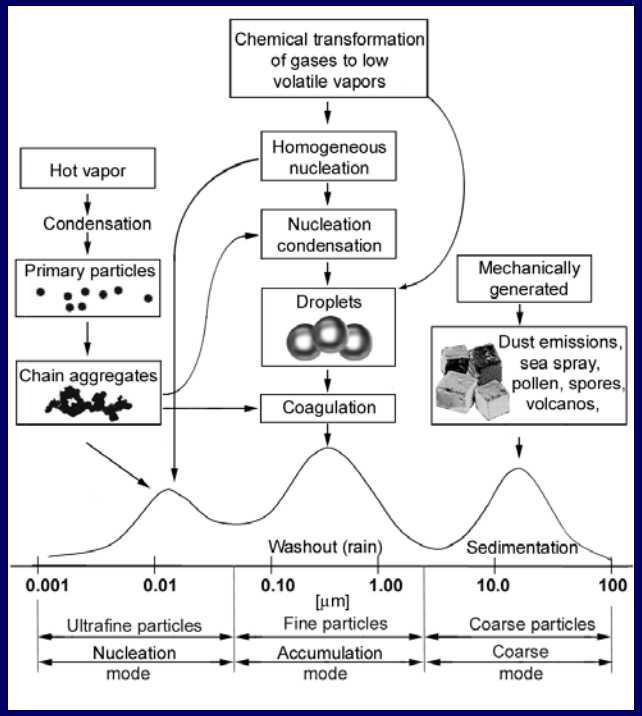
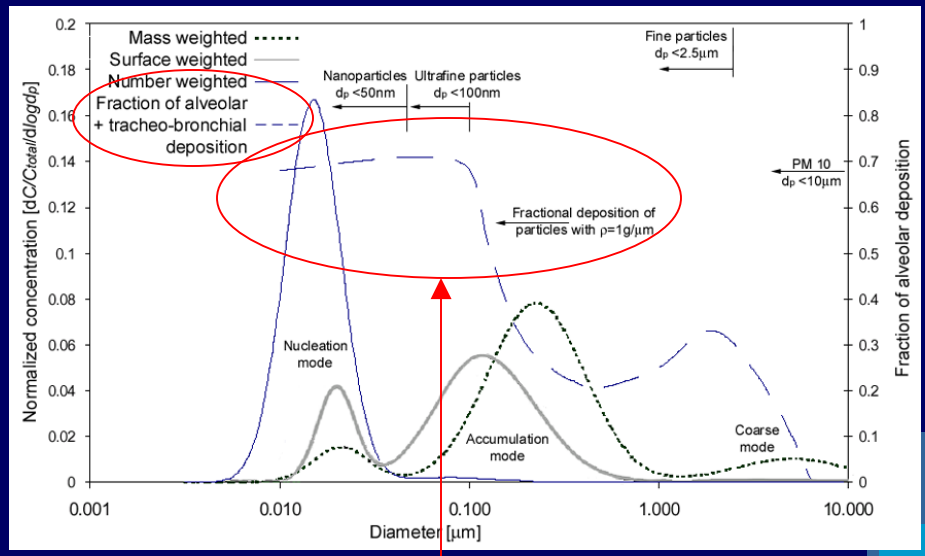
Intro - Exhaust Particles (1/4)

- Diesel Exhaust
- Petrol Exhaust



Intro - Particles Dynamics (2/4)

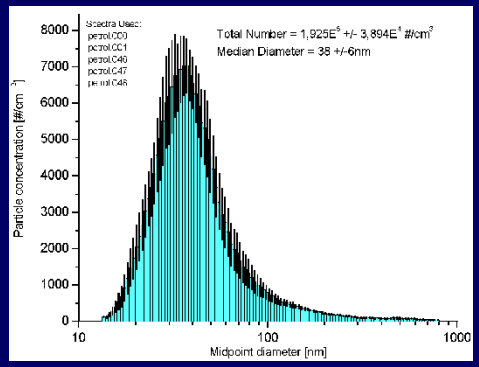


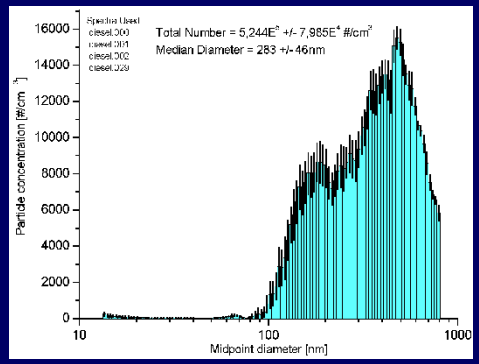


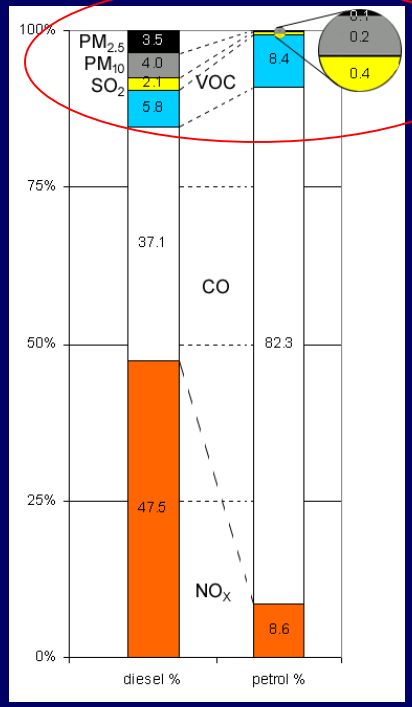
Combustion aerosols

- Primary particles (nucleation mode)
- Coagulation (accumulation mode)
- Particles of mechanical origin (coarse mode)

Intro - Exhaust composition (3/4)





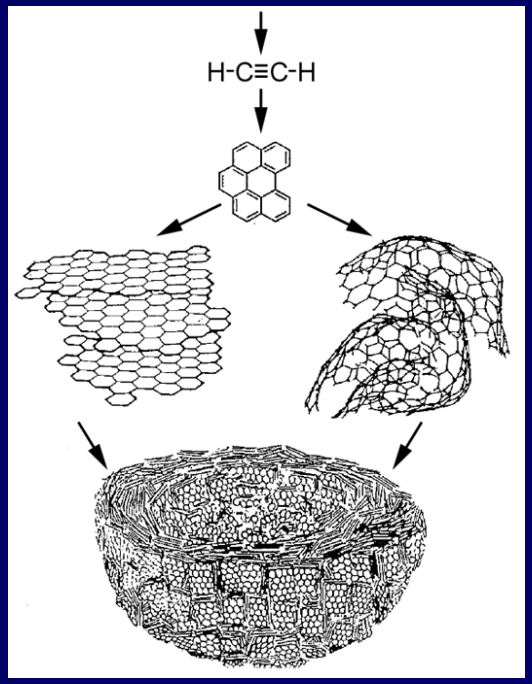


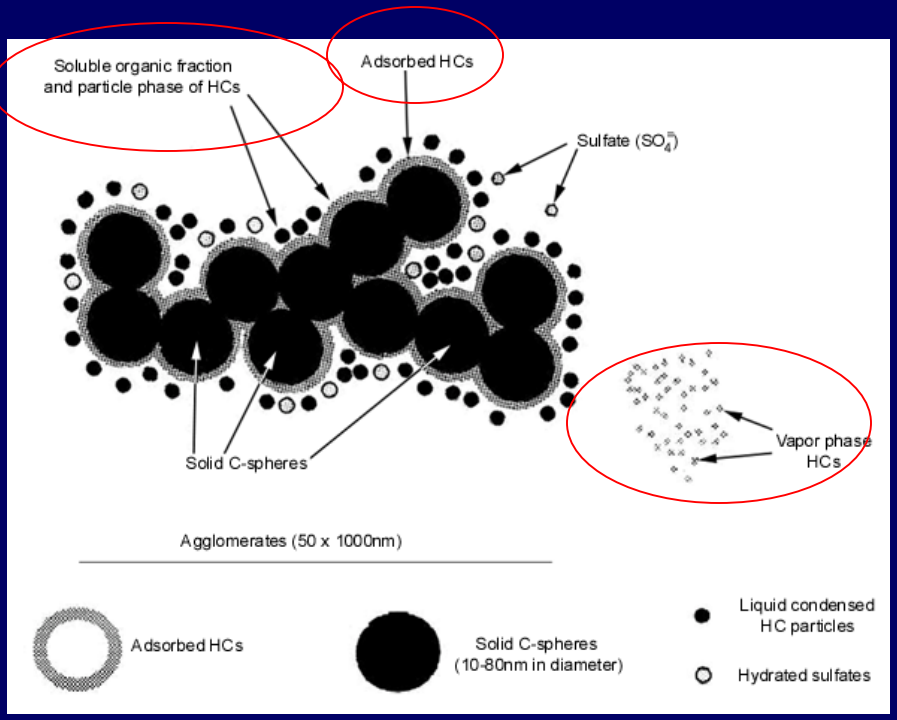
Particle Fraction

- Petrol exhaust consists predominantly of short-chained HCs
- Diesel exhaust consists of approx. 450 different combustion products (incl. PAHs)

Intro - Diesel soot

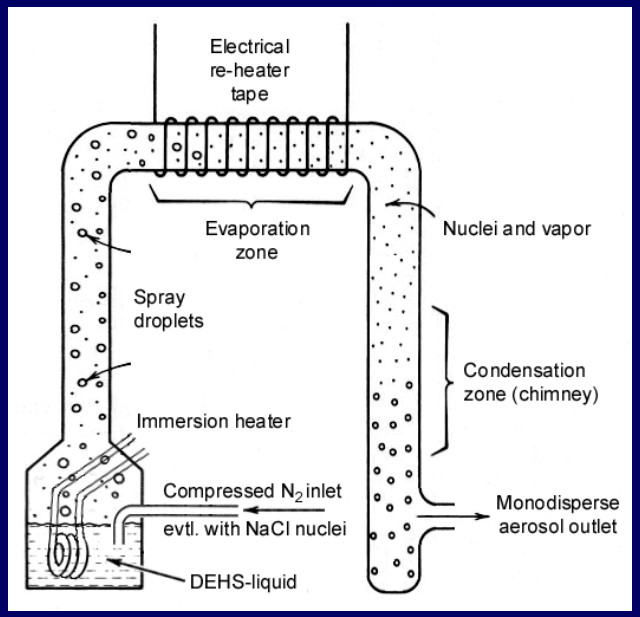
(4/4)

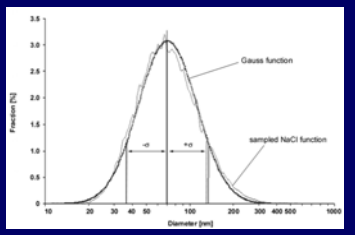




- At least 40 are toxic contaminants like arsenic, benzene, cadmium, dioxins, toluene, formaldehyde and even some major chemical carcinogens like 3-nitrobenzanthrone ($C_{16}H_9NO_3$) and 1,8-dinitropyrene ($C_{16}H_8N_2O_4$) are found in either a gas or particle form

Instrumentation - CMAG (1/5)



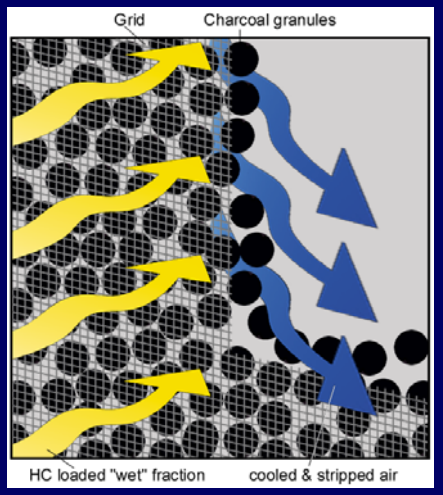


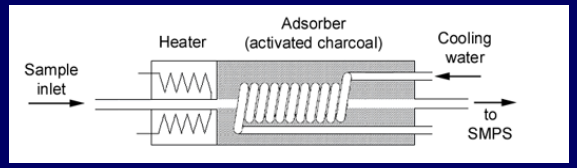
σ_g <1.15
monodisperse

- Condensation Monodisperse Aerosol Generator, it produces highly monodisperse spherical and nearly charge -neutral particles (solid or liquid) in very high concentrations with diameter ranging from 0.1 to 8μm.

Instrumentation - TD

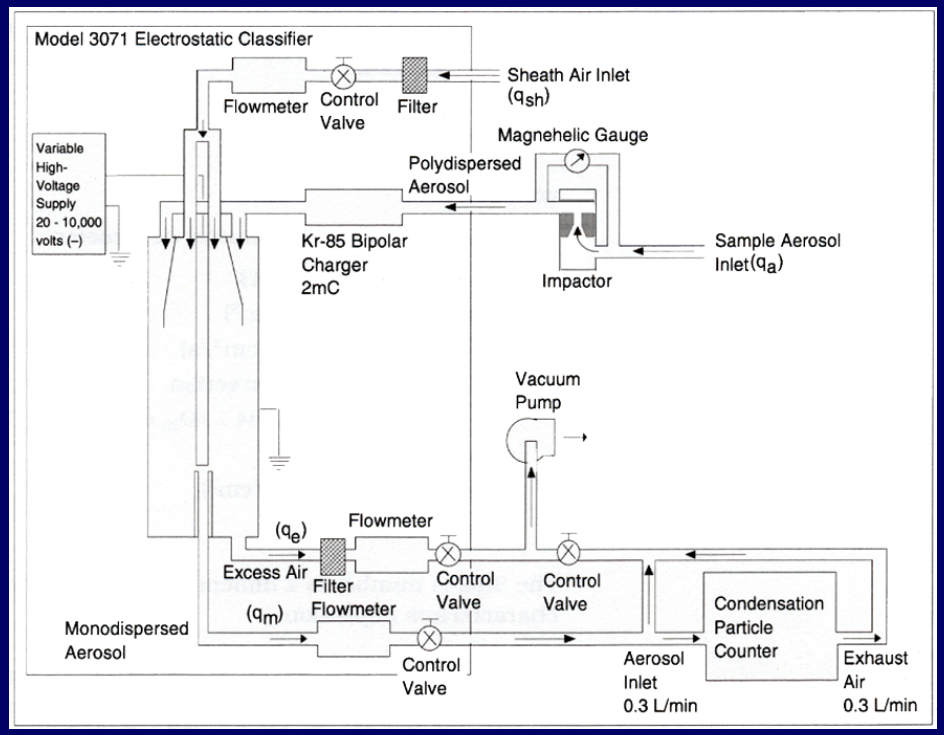
(2/5)





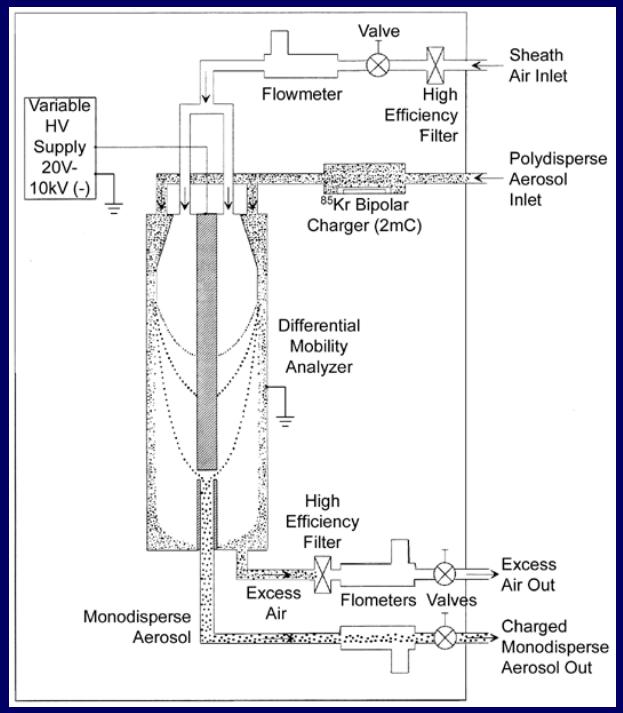
- Thermodenuder or Thermodesorber; is an instrument to strip off the volatile HC fraction from solid particles, yielding the **true character** of an aerosol.
- Stripping principle: Maxwell-Boltzmann Speed Distribution.

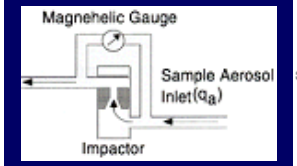
Instrumentation - SMPS (3/5)

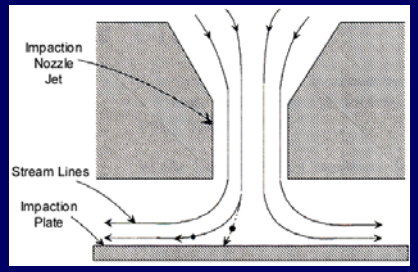


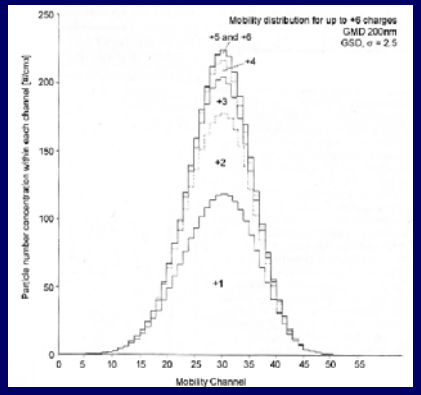
- Scanning Mobility Particle Sizer, is a set of instruments that is used to measure airborne particles in the size range of 3 to 1000nm; it employs an EC to determine particle size and a CPC to determine particle concentration.

Instrumentation - SMPS/EC (4/5)



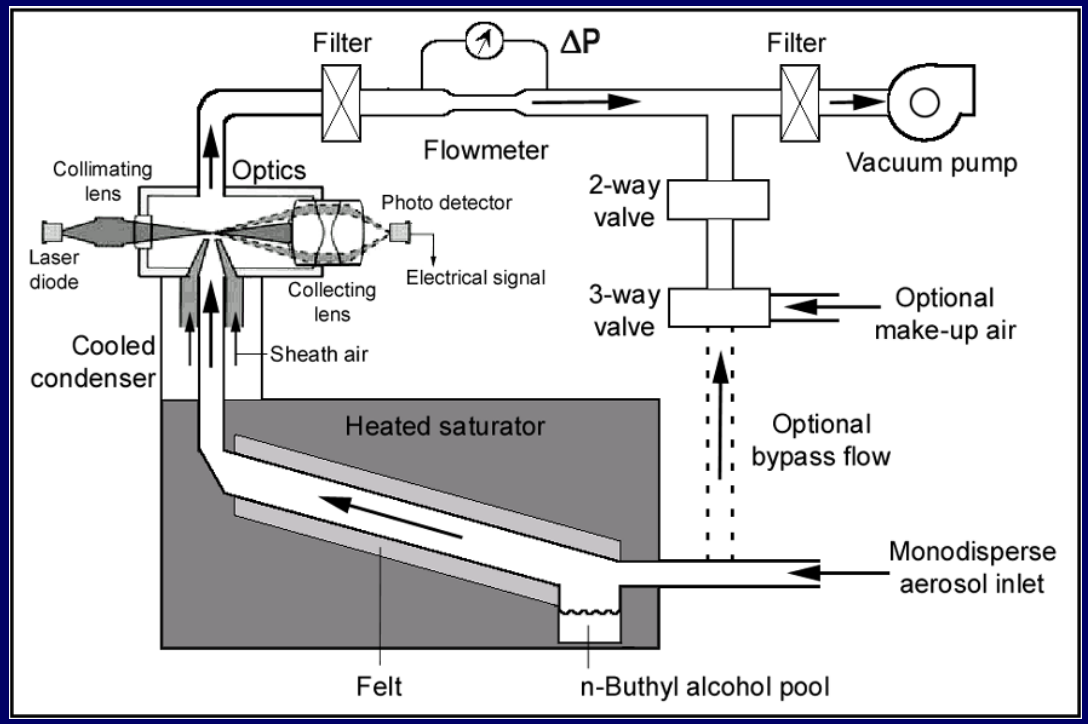






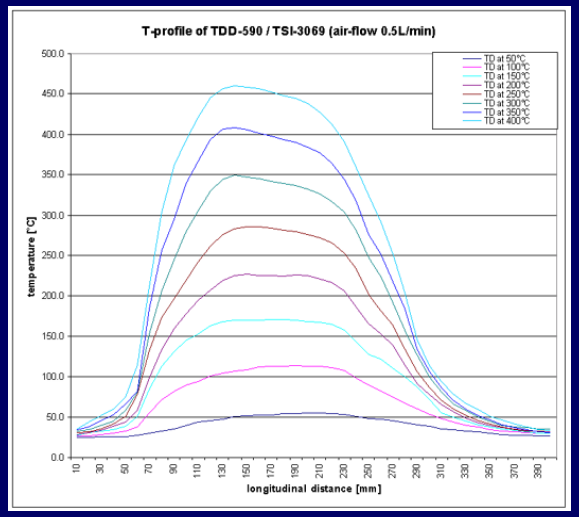
- Electrostatic Classifier, is an instrument to analyze a polydisperse aerosol or to generate monodisperse particles of uniform size from a polydisperse source.

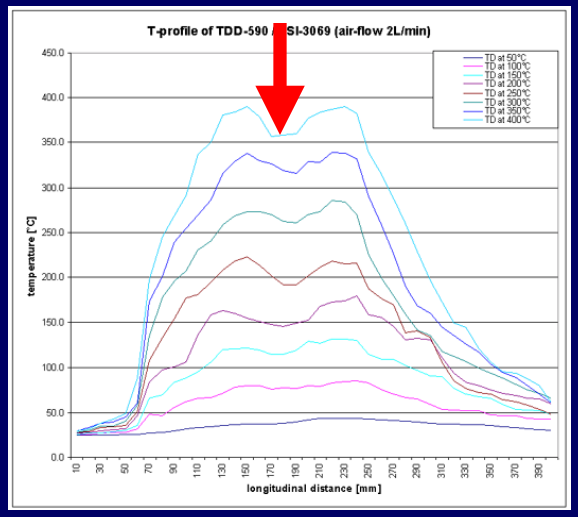
Instrumentation - SMPS/CPC (5/5)



- Condensation Particle Counter, is an instrument that measures the number concentration of small particles with high efficiency.

TSI-TD (the commercially available instrument)



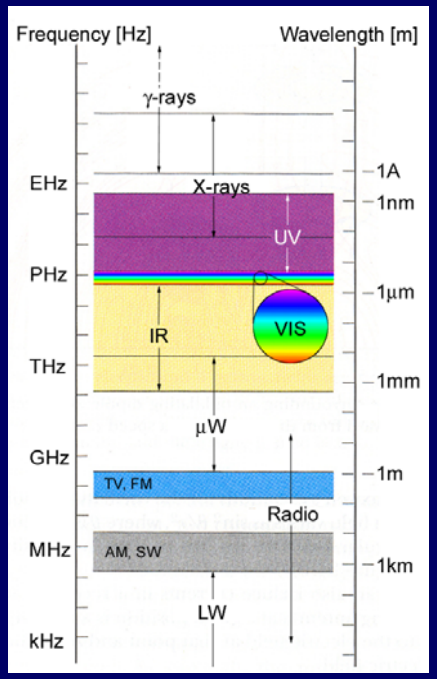


Why building a new TD?

- Indirect heating concept results in sluggish heater response
- Irregular T-profile (glass-metal interface)
- Interior made of glass (making modifications very difficult)

Construction of the QUT-TD (1/10)

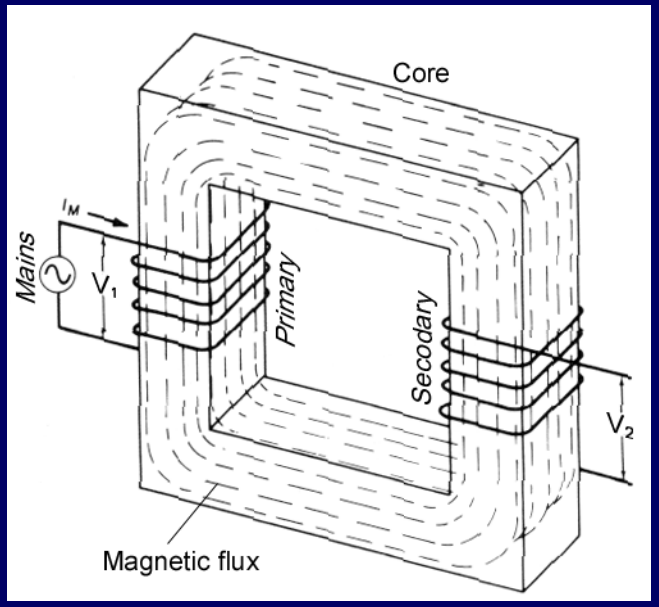
Heating systems can be made from X-ray or γ-sources; infrared (IR), ultraviolet (UV), visible light (VIS-laser), plasma, adiabatic sources, or electrical induction heaters, or resistance heater

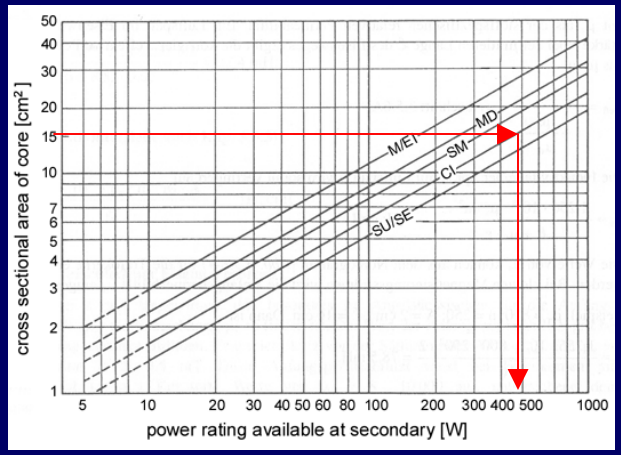


Why resistance heating?

- Time restrictions
- OWHS regulations
- Most of the material already on campus

Construction of the QUT-TD (2/10)

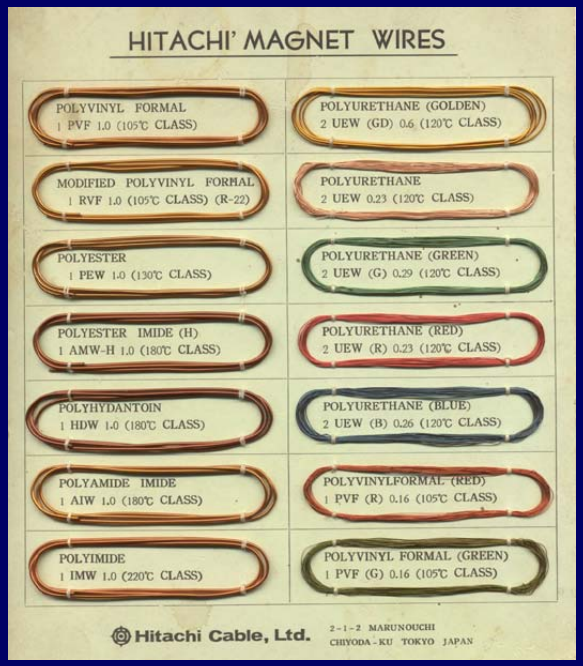




The powerhouse – a recycled Tank Coil (reusing core & secondary)

- Galvanic separation ($V_{Prim} < V_{Sec}$)
- Step-down transformation ($<32V_{AC}$)
- Calculation of the "turns-per-volt" ratio (2turns/V = 480 turns)

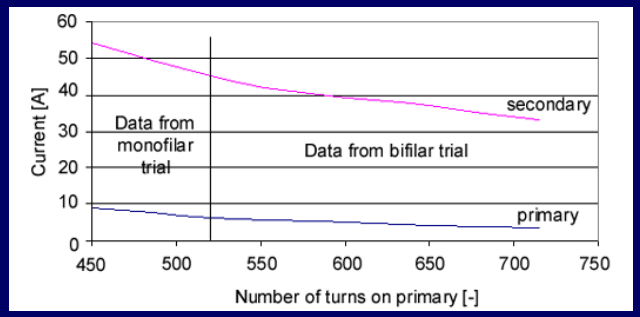
Construction of the QUT-TD (3/10)

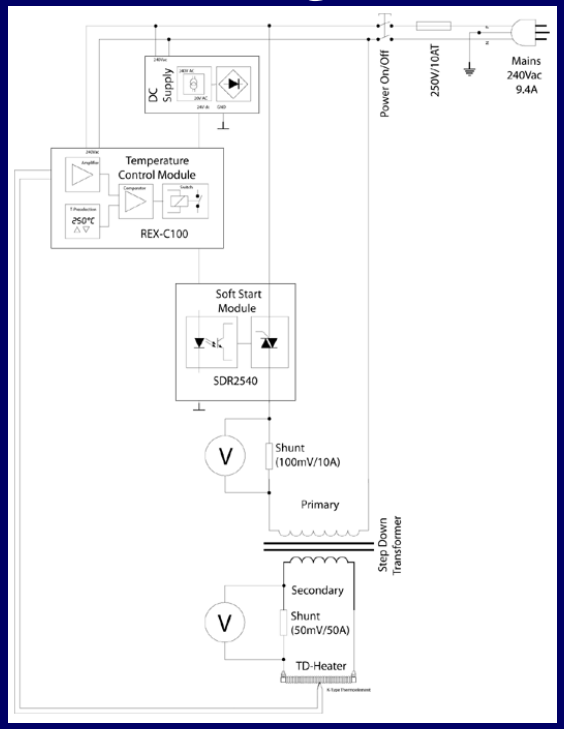


The making of the Primary (several attempts required)

- Coil-Winding-Machine
- Bifilar vs. monofilar Primary

Construction of the QUT-TD (4/10)

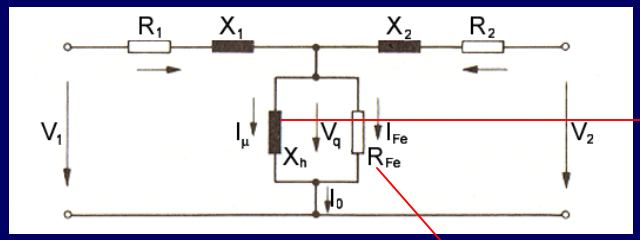


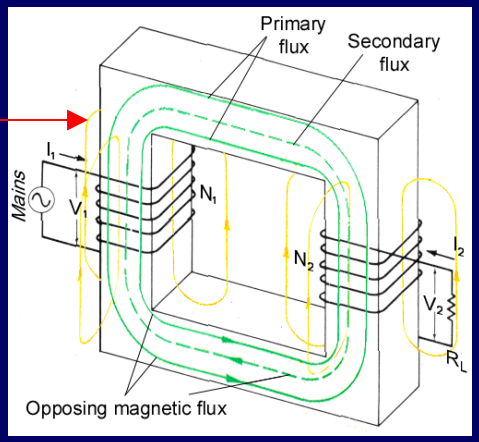


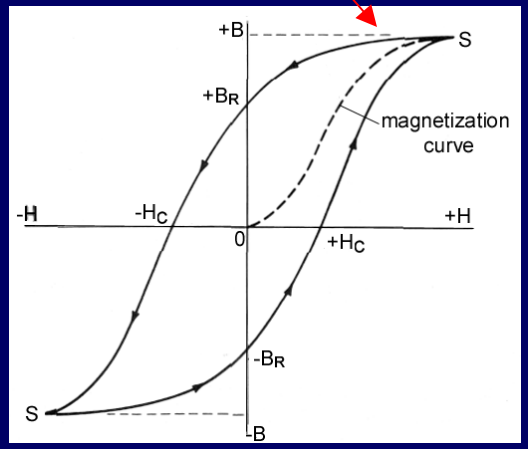
Determining core data

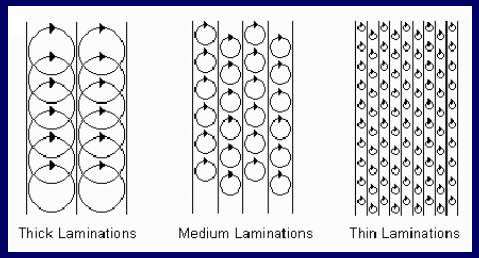
- Running the application with various loads
- Verification of feasibility

Construction of the QUT-TD (5/10)





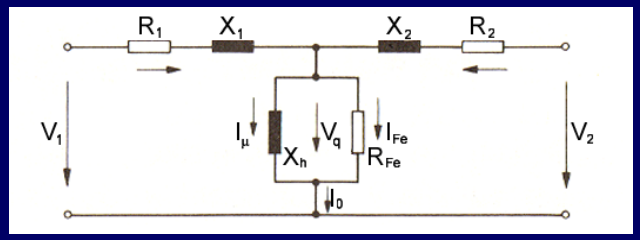


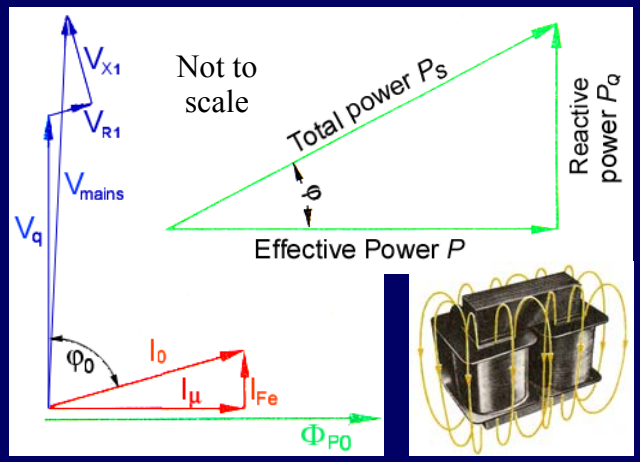


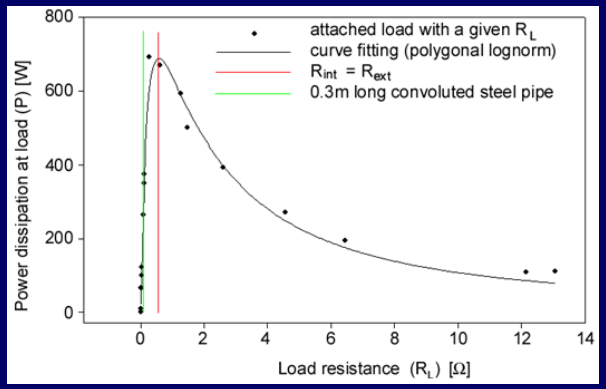
Losses within the transformer

- Copper ($_1R_2$) and hysteresis (R_{Fe}) losses
- Reactances ($_2X_1$) and stray field components (X_h)

Construction of the QUT-TD (6/10)



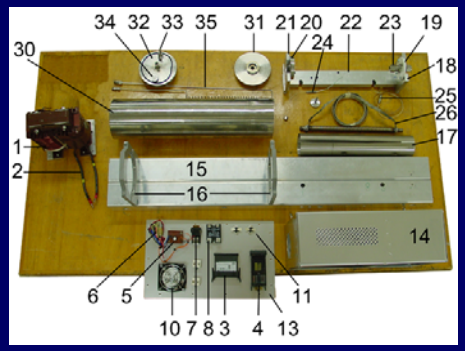


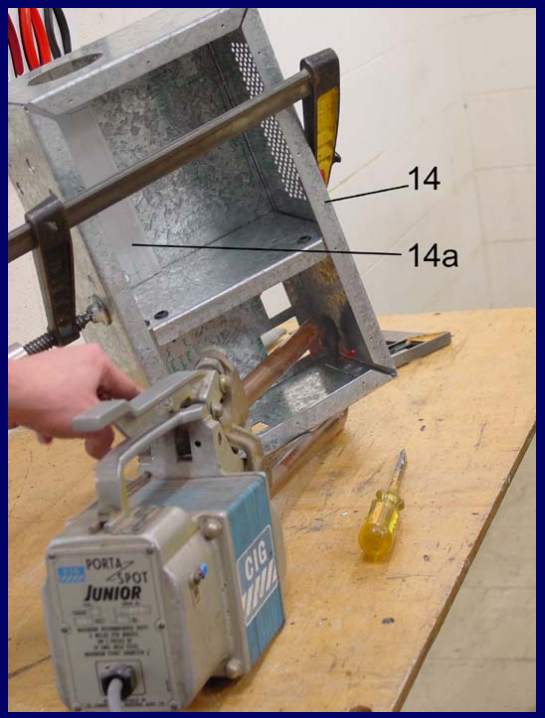


Efficiency factors

- Reactive power component P_Q = 2150VAr
- Effective power component P = 384W
- Efficiency η = 70% w/ 0.3m heater pipe ($R_2 < R_L$)

Construction of the QUT-TD (7/10)

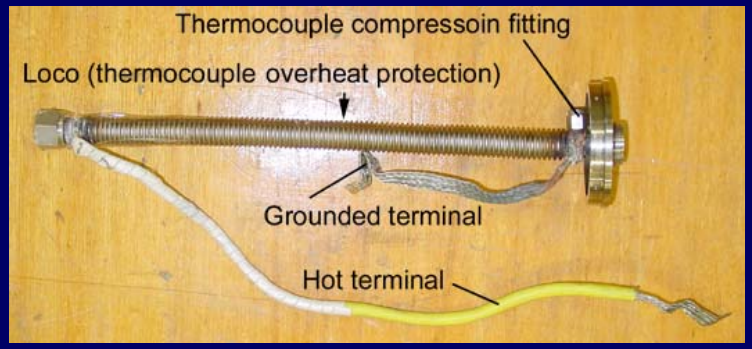


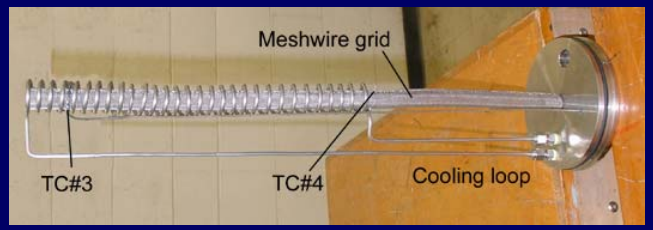


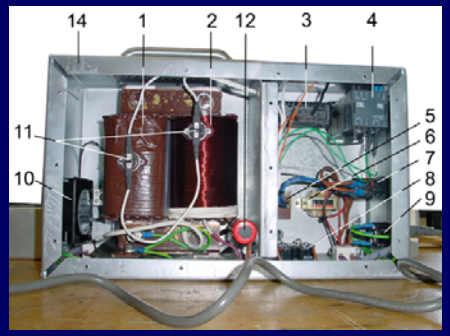
Working on each unit ….

- With the angels of the QUT workshop (Bob, Jim, Mari)
- George and some manual skills of course;

Construction of the QUT-TD (8/10)



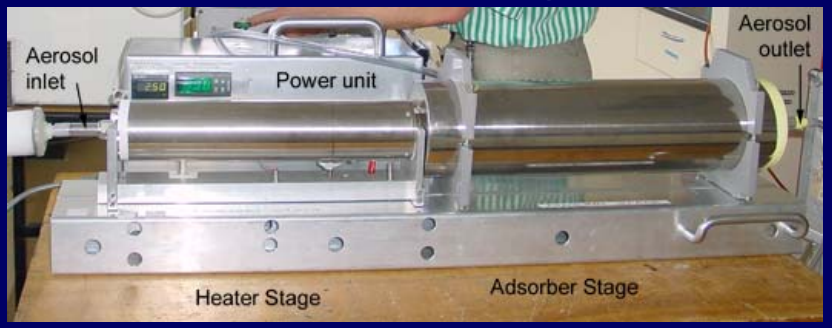


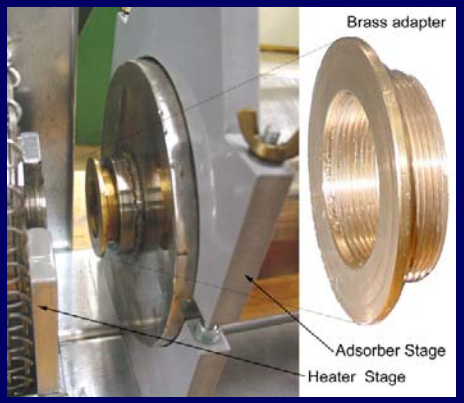


…. until they can be assembled to working modules

- Power Unit driving the heater stage
- The heater stage
- The adsorber stage

Construction of the QUT-TD (9/10)

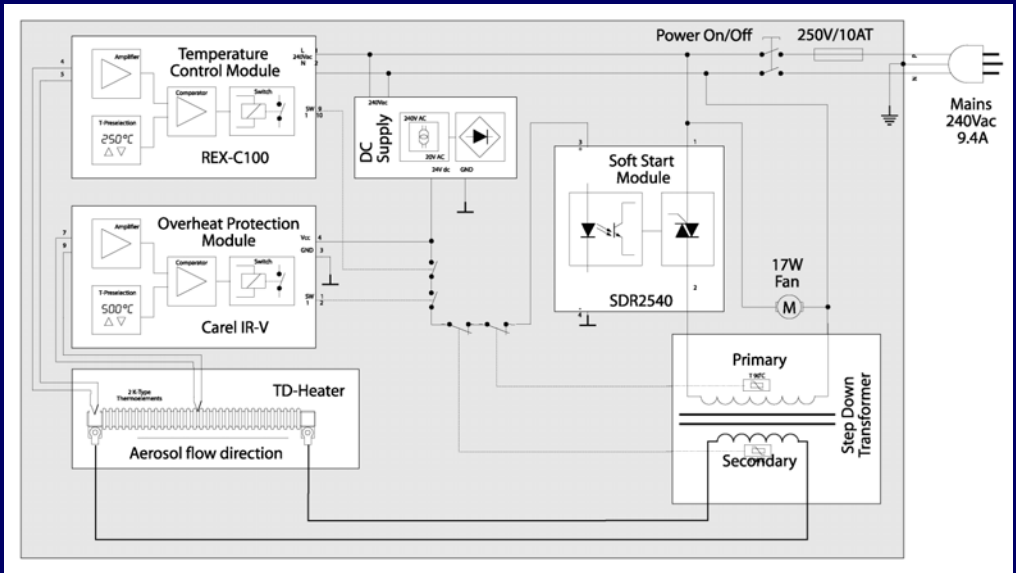


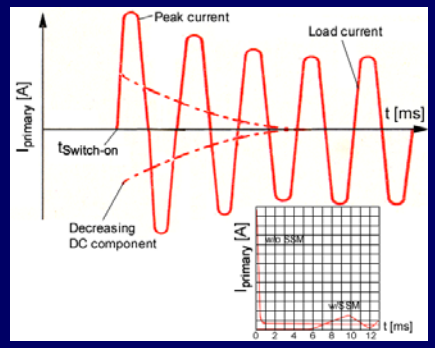


Last minute modifications

- Jammed thread at heater-adsorber interface
- Finger-guard (OWHS)
- Extra TCs w/n the adsorber stage

Construction of the QUT-TD (10/10)



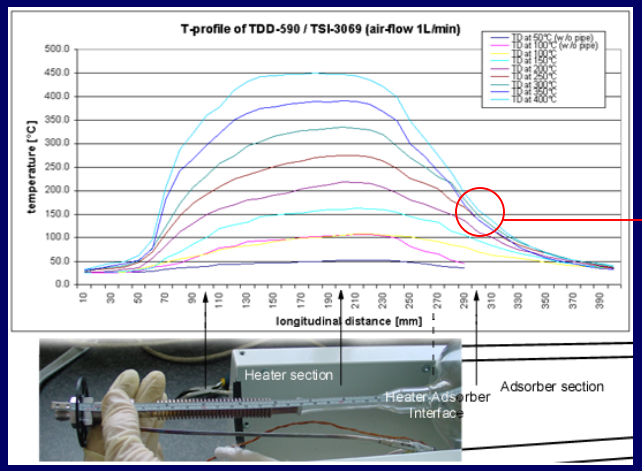


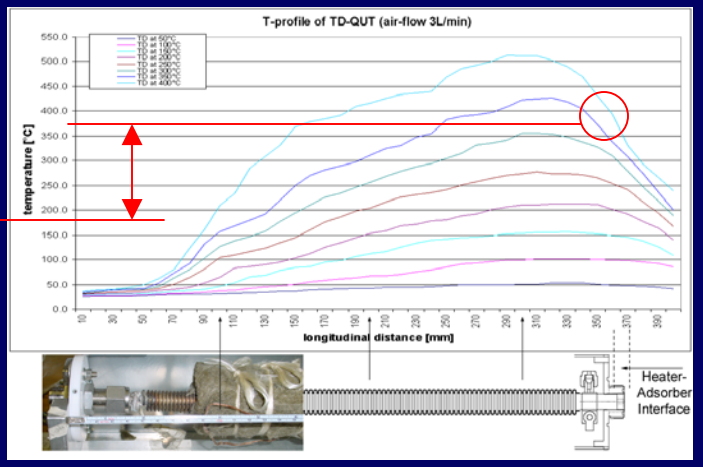
Switching an inductive load

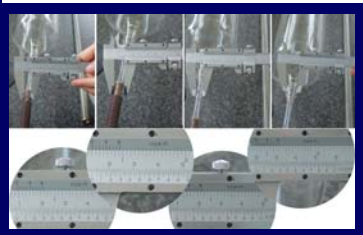
- Soft Start Module (SSM) to switch an inductive load
- PID T-controller (negative feedback loop)
- Overheat protection devices (controller & thermoswitches)

Instrument Testing

(1/6)

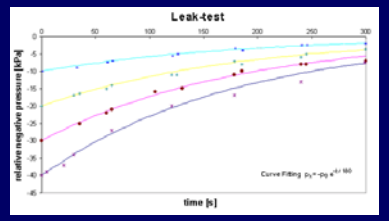






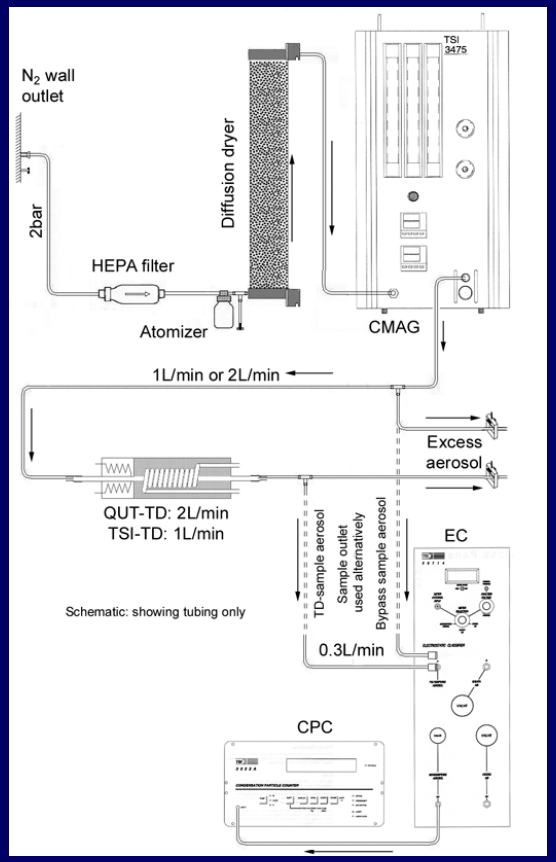
Basic Parameters

- T-profile of both TDs
- Leak-test of QUT-TD



Instrument Testing

(2/6)



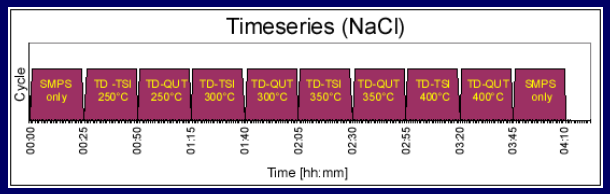
Sample Aerosols

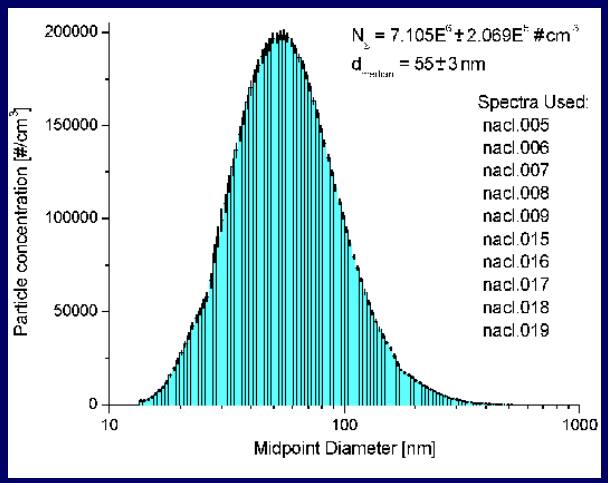
- NaCl aerosol (penetration)
- DEHS aerosol (sebacic acid $M_W = 426.7 g/mol$)

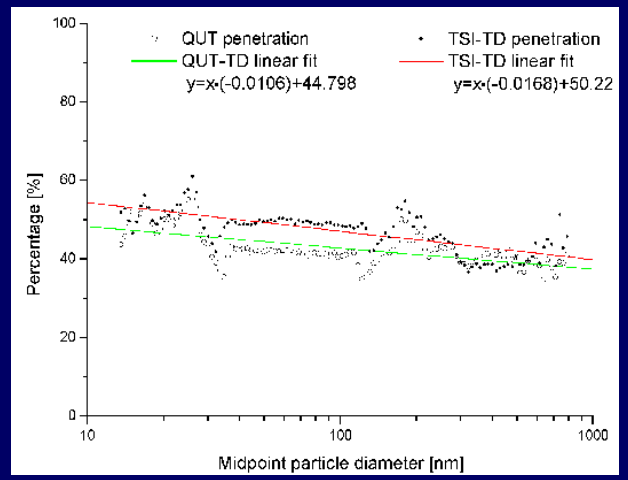
$CH_3(CH_2)_3\ CH(CH_2)_2CH_3\ OOC(CH_2)_8COO\ CH(CH_2)_2CH_3\ CH_3(CH_2)_3$

Instrument Testing

(3/6)



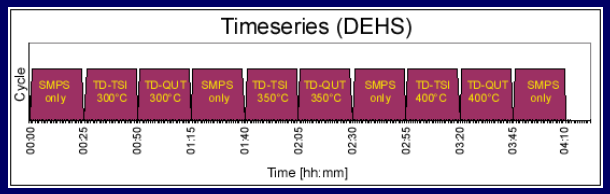


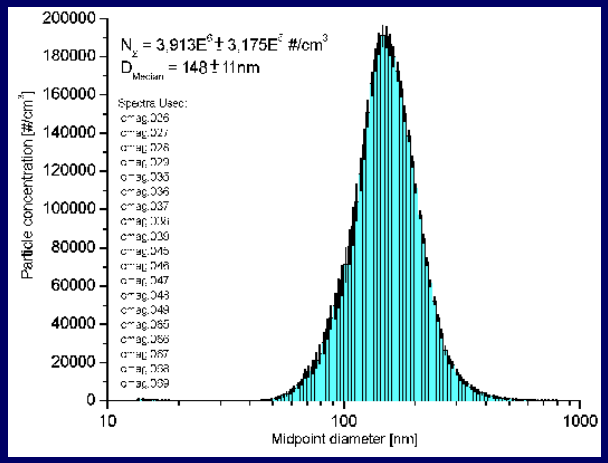


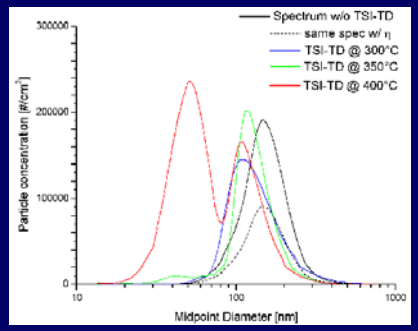
NaCl

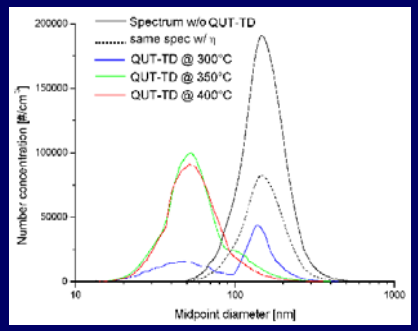
- T @ 250ºC (particle concentration >>)
- Efficiency η approx. 50% (TSI slightly better)

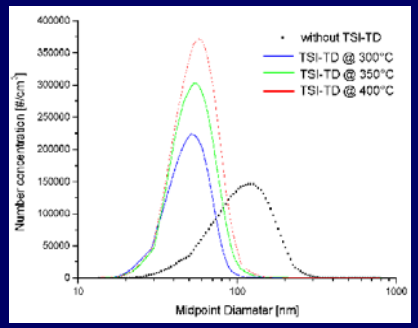
Instrument Testing (4/6)

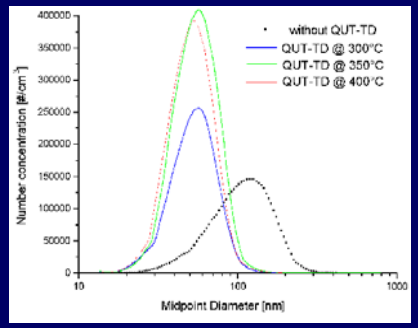








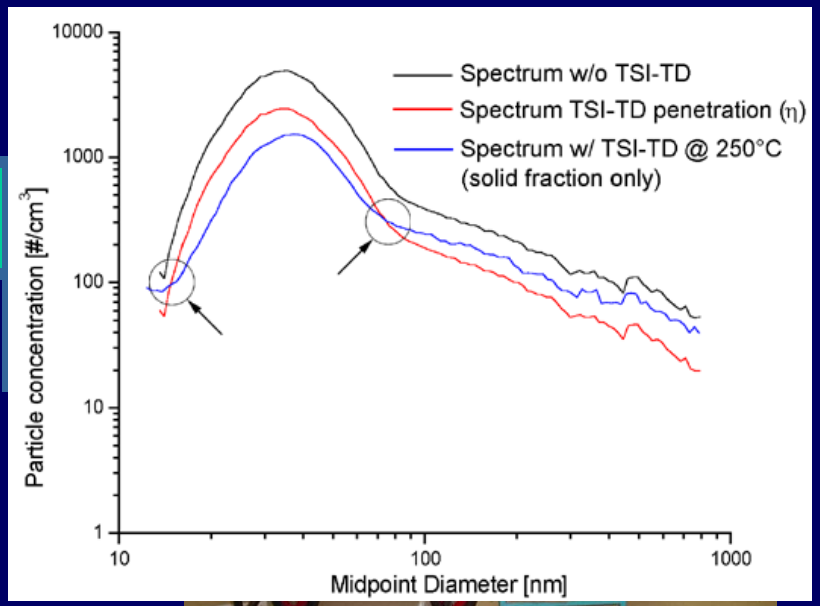


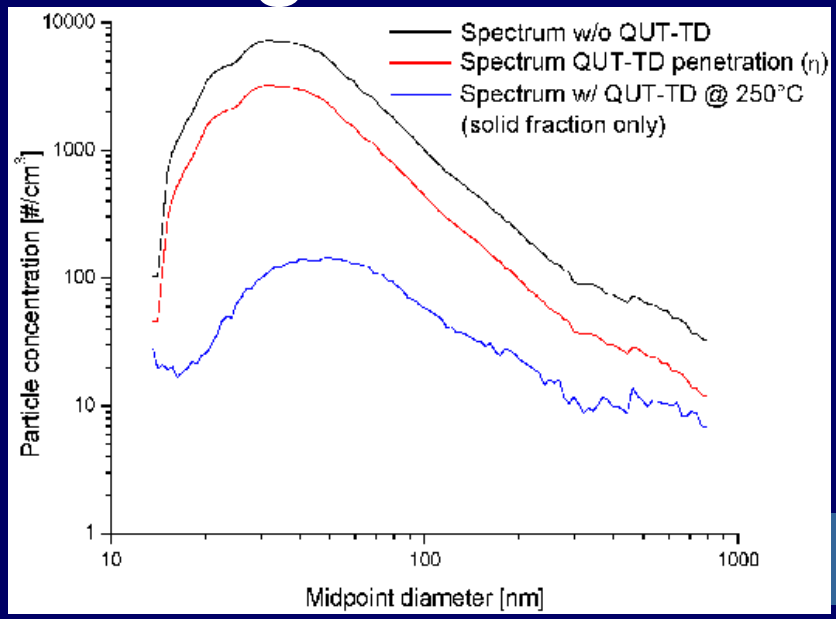


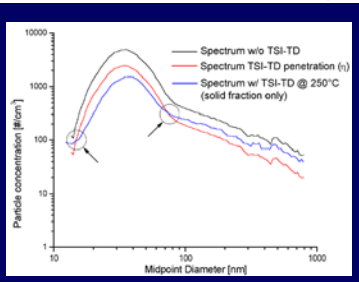
DEHS

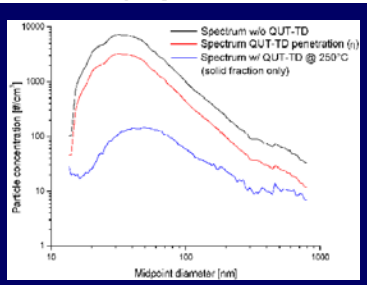
- With NaCl nuclei
- DEHS only (M_W = 426.7g/mol; BP = 248ºC)

Instrument Testing (5/6)





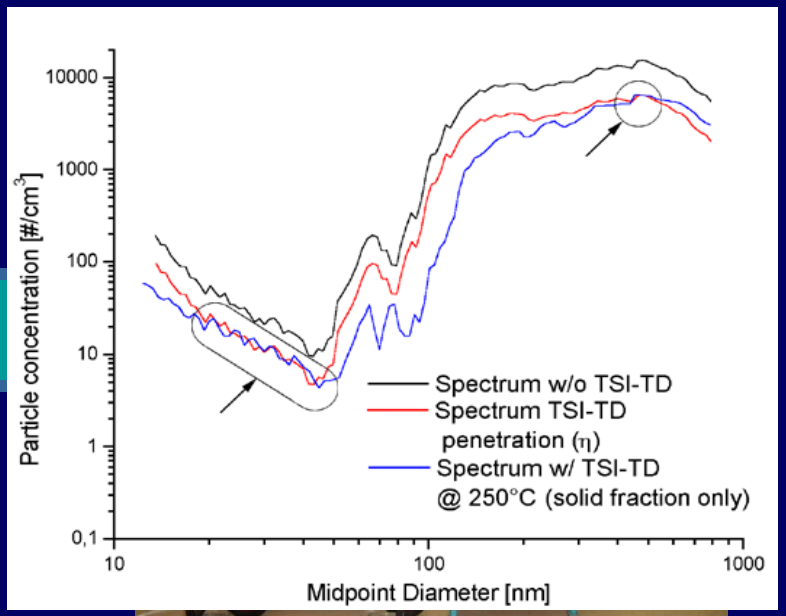


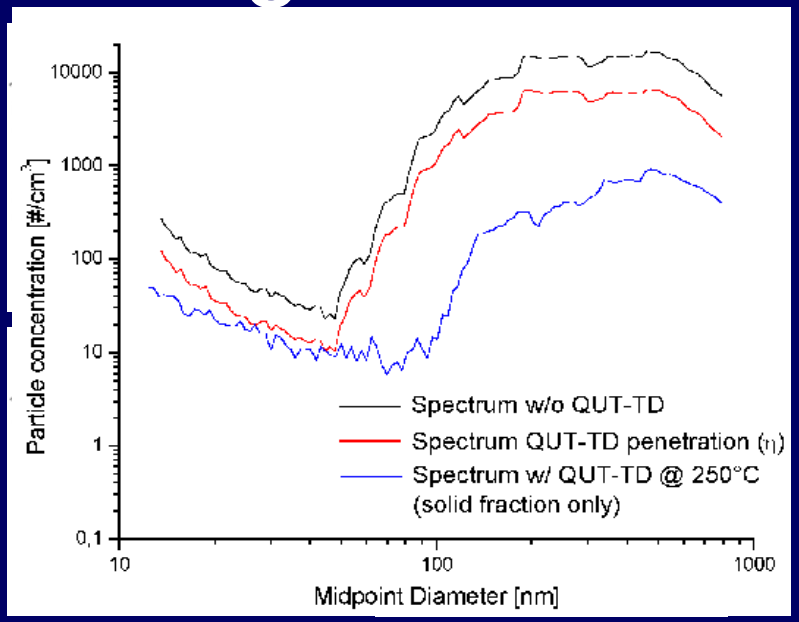


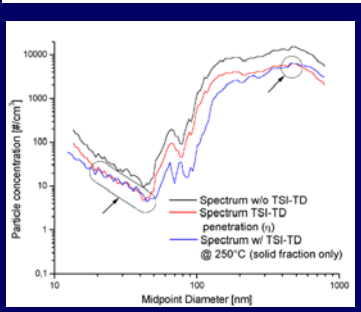
Petrol Exhaust (PE)

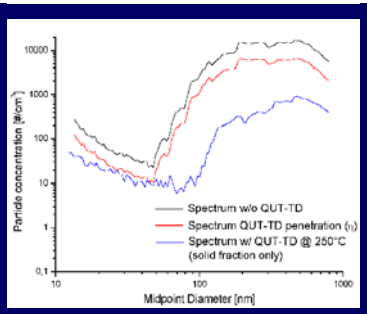
- Bypassed TDs
- TD in sampling line

Instrument Testing (6/6)









Diesel Exhaust (DE)

- Bypassed TDs
- TD in sampling line

Conclusions & Rec's

Conclusions

- TSI-TD doesn't meet specifications (flow-rate & T-profile)
- Adsorptive properties of QUT-TD far better than TSI-TD
- T-range better w/ QUT-TD (>600ºC) than w/ TSI-TD (<400ºC)
- Glassware of TSI-TD makes it unsuitable for field applications
- High power consumption of QUT-TD restricts it to lab-applications

Recommendations

- Improve "leak-proofness" of QUT-TD (O-ring of cap-disk - adsorber)
- Induction-heater concept for QUT-TD to reduce power consumption
- More testing required with smaller particle concentrations

…. and finally ….

- Thanks for YOUR attention