Influence of compressed air quality on CAST performance

Viereck, Volker
Carli, Stefan, Dr.
Volkswagen Konzernforschung
Wolfsburg
Germany

7th International ETH-Conference 18th-20th August 2003

Influence of compressed air quality on CAST performance

Viereck, Volker ; Carli, Stefan, Dr. ; Volkswagen Konzernforschung, Wolfsburg, Germany

7th International ETH-Conference 18th-20th August 2003

The CAST[1)] S/N 409 100 was one of the first ones commercially produced by Matter Engineering. It was delivered with a METAS[2)] calibration certificate. Own SMPS measurements showed differences in modal particle sizes up to 34% from the METAS-calibrated values (see Table 1), which cannot only be explained with tolerances in the SMPS systems. Table 1 shows the arithmetic mean and standard deviation results of about 50 samples for each measuring point measured with a 3936 SMPS system compared with the METAS calibrated values. Differences occur especially at the measuring points (MP) five and six for small particles. The other measuring points are still in the range of the SMPS tolerance. The standard deviations for all modal particle sizes measured by Volkswagen except of MP 6 are even better than these by METAS.

In order to find the reasons for the stated differences in particle size and number a systematic search was started. The CAST and SMPS hardware were checked and no errors were discovered. Measurements with a NANO-DMA at MP 5 and MP 6 yielded no significant differences in modal sizes, coulometric analysis affirmed the results. So the reasons had to be the CAST itself, or outside influences like operating gases or atmospheric conditions.
Systematic dependencies of atmospheric pressure on differences in modal particle sizes were not found. Change of gas bottles with the same specification gave no significant differences. It is known that the composition of combustion air has a great influence on particle size distribution, because the oxygen content in synthetic air has a tolerance up to 0.2% absolute, which causes significant differences in size and number. Because of that the manufacturer recommends dried, oil- and particle-free compressed air for combustion meanwhile. But what´s about the residual humidity?

Figure 2 shows the experimental set-up for checking the influence of combustion air humidity. Dried, oil-and particle free compressed air is splitted and additionally processed with two TSI 3074B filtered air supplies for combustion air and dilution air. Only combustion air is mixed with particle free ambient air with about 10°C dew point to avoid an influence of dilution air humidity. A membrane pump is used to avoid oil content in mixed combustion air. Combustion air humidity was varied from below 1 % r.h. @25°C up to 40 % r.h. .
Differences up to 40 % were found in alteration of number and size, especially for measuring points 5 and 6, small particles (see Figure 1 and Table 2). The influence of air humidity is on the mass flow controller is marginal (below 1%). So there must be a real effect on the combustion process, which disturbs particle growing while number grows and size descends with ascending combustion air humidity. Replacing the membrane pump by a conventional compressor to investigate the influence of compressor oil in the dilution air showed no significant differences.

METAS recommends to use combustion air with a dew point below -4°C, which means ~14% r.h. @25°C. But in the range from nearly dry air up to air with a dew point of -4°C the deviations in size and number are up to 30%. So these differences could be an explanation for the differences between the METAS measurements and the VW results, if METAS had used combustion air with a dew point of ~-4°C. But METAS specified the used air for calibration as nearly dry. So it is still unclear, which effect is the reason for the differences between VW results and METAS calibration.

Conclusion:

There are many interesting CAST applications and there is much potential in CAST. The CAST produces reproducible results within the standard deviations acquired by METAS. But absolute values for size and number differ significantly. CAST cannot be used as an absolute standard for number and size measuring instruments until the factors of influence are quantified and a way of local CAST calibration is found. The manufacturer is aware of the problems and is investigating the possible influences and, inter alia, is developing an accessory to provide suitable oxidation and dilution air.

1) CAST- Combustion Aerosol Standard by Dr. L. Jing / Matter Engineering AG
2) METAS - Swiss Federal Office of Meteorology and Accreditation

<u>Figure 1</u>: Influence of combustion air humidity on particle number and modal particle size

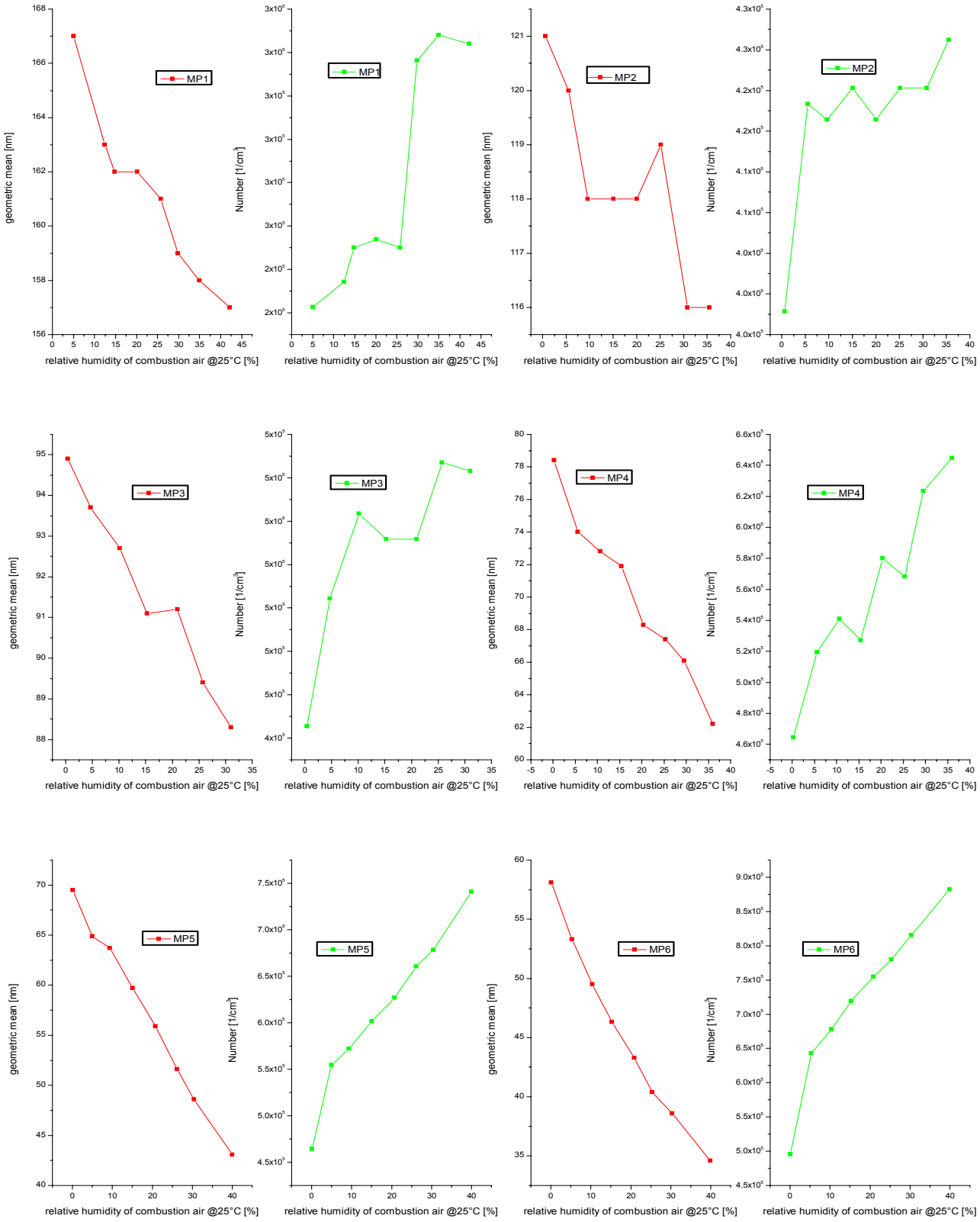

Table 1: Differences between VW measurements and METAS calibration

		Volkswagen measurements			METAS-Calibration			
measuring point	physical value	value	standard deviation (+/-)	standard deviation (%)	value	standard deviation [+/-]	standard deviation [%]	values difference METAS /VW [%]
MP1	Mode [nm]	164.3	2.8	1.7	181	9	5.0	10.2
MP1	GSD	1.69	0.01	0.5	1.66	0.085	5.1	1.7
MP1	Concentration [1/cm³]	278866	16925	6.1	251000	29000	11.6	10
MP2	Mode [nm]	123.0	3.4	2.8	129	6.5	5.0	4.9
MP2	GSD	1.64	0.01	0.5	1.59	0.08	5.0	2.8
MP2	Concentration [1/cm³]	423794	37837	8.9	420000	55000	13.1	0.7
MP3	Mode [nm]	96.1	2.4	2.5	96.5	4.95	5.1	0.5
MP3	GSD	1.61	0.02	1.0	1.57	0.08	5.1	2.3
MP3	Concentration [1/cm³]	493632	63928	13.0	464000	55000	11.9	6.1
MP4	Mode [nm]	76.5	1.9	2.5	69.4	3.5	5.0	9.3
MP4	GSD	1.60	0.02	1.3	1.57	0.08	5.1	1.6
MP4	Concentration [1/cm³]	501018	56278	11.2	510000	60000	11.8	1.8
MP5	Mode [nm]	66.0	3.0	4.0	47.4	2.5	5.3	28
MP5	GSD	1.62	0.03	1.8	1.61	0.08	5.0	0.7
MP5	Concentration [1/cm³]	478187	36159	7.6	620000	95000	15.3	29.6
MP6	Mode [nm]	50.2	3.7	7.3	33.1	2.05	6.2	34
MP6	GSD	1.69	0.06	3.3	1.57	0.08	5.1	7.3
MP6	Concentration [1/cm³]	458451	33314	7.3	740000	150000	20.3	38

Figure 2: Experimental set-up for variation of combustion air humidity

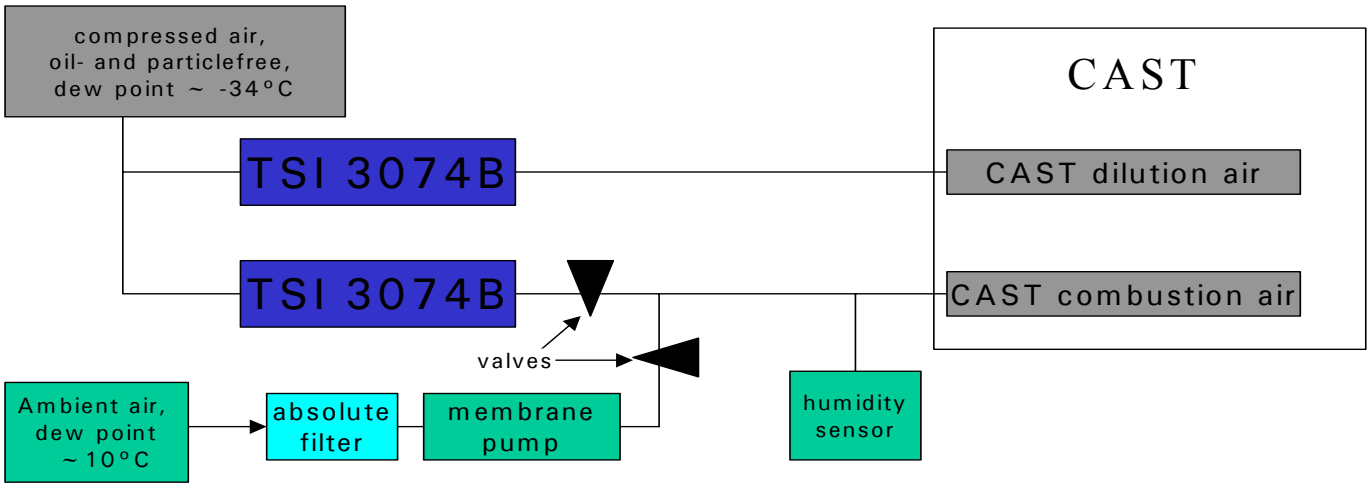

Table 2: Influence of combustion air humidity on particle number and modal particle size

measuring point	physical value	maximum	minimum	difference [%]
MP1	geometric mean	167nm	157nm	6
MP1	number	294000 / cm³	231000 / cm³	21.4
MP2	geometric mean	121nm	116nm	4.2
MP2	number	431000 / cm³	398000 / cm3	7.7
MP3	geometric mean	94.9nm	88.3nm	7
MP3	number	514000 / cm³	453000 / cm³	13.5
MP4	geometric mean	78.4nm	62.2nm	20.7
MP4	number	645000 /cm3	465000 /cm³	27.9
MP5	geometric mean	69.5nm	43.3nm	37.7
MP5	number	741000 / cm3	465000 / cm³	37.2
MP6	geometric mean	58.1nm	34.6nm	40
MP6	number	882000 /cm³	496000 / cm³	43.8

Situation:

CAST values for modal particle size differ up to 34% between VW results and the METAS-calibration!

Investigation:

- Systematic influence of atmospheric pressure was not found
- Expected influence of oil content from air source could not be certified
- However, dependency of combustion air humidity and particle size was found especially for small particles up to 40%
- Still this effect cannot explain the differences between VW and METAS measurements

Conclusion:

Other factors of influence have to be checked carefully and quantified until CAST can be used as an absolute standard for particle size and number measuring instruments