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Simultaneous optical sizing and pyrometric measurement of the size, velocity and temperature of individual combusting coal particles

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ABSTRACT

We report the optical instrumentation, namely combined Shadow Doppler Velocimeter (SDV) and Two-Colour Pyrometer (TCP), and its application to the spatially-precise measurement of the size, velocity and temperature of lignite particles of a range of moisture content, in a nearly-homogeneous, high temperature flow of combustion products. This experiment is designed to characterize the ignition behaviour of predried pulverised lignite fuels in terms of moisture content. The technical application is the retrofitting of predrying plant to lignite-fired power stations to raise thermal efficiency. The combustion products were produced by a 3 kW premixed natural gas flat flame McKenna burner and had mean temperature of 1700 K and 8% O_2 up to 200 mm above the burner exit. Ambient air entrainment into the combustion gases was avoided by use of a rectangular quartz confinement, mounted downstream of the burner exit. The temperature and size distributions of individual lignite particles (German Rhenish: moisture content of 11% (*dry*) and 31% (*wet*), Greek lignite: moisture content of 18% (*dry*) and 31% (*wet*), size range of less than 150μm) were obtained along the centreline of the burner (up to 140mm away from the burner exit). In order to eliminate the ambiguity in temperature measurement due to the heterogeneous nature of ignition of coal particles (i.e. either as incandescent solid particles termed *char* or as the incandescent *soot* particles in the gaseous, volatile-fuelled flame surrounding a devolatilising and relatively cool lignite particle), two discrimination criteria for soot and char were introduced and evaluated. The first of the discrimination criteria was based on the particular TCP optical arrangement (a so-called "*vignette criterion*" generated by introducing a pinhole aperture in the receiving optics which limited the maximum soot cloud amplitude at a given temperature). In this scheme, emission at any given temperature, can be

classified as originating from soot below a threshold amplitude and from char above it. The second criterion was derived from the measured emissivity (*emissivity criterion*) calculated from the particle size, measured by SDV, and the temperature, measured by TCP: emissivities of the order of 0.1 were classified as due to sooty flame and emissivities near unity were classified as due to incandescent char. These two discrimination criteria were applied to the experimental data, and found that the emissivity criterion was well correlated with the vignette criterion. In addition, a Two-Colour CCD Imaging (TCCI) technique was also introduced to measure flame mantle particle size and temperature simultaneously with the SDV and the TCP to evaluate the TCP performance by direct viewing of individual particles using a commercial Maksutov-Cassegrain telemicroscope through two colour optical filters. The detailed experimental findings are that, the Greek lignite particles larger than about 60 μm tended to ignite slower than German Rhenish samples. The German Rhenish samples with higher moisture content have a slight swelling tendency relative to *dry* German samples at the larger residence time. On the other hand, the Greek lignite particles larger than 80 μm showed some evidence to suggest that reduced moisture content favours fragmentation behaviour after the ignition. The CCD and TCP measurement indicated that the *dry* German Rhenish samples have distinct large volatile cloud with constant high soot temperature (≈ 2000 K).

Key words: ignition, flat flame burner, two colour pyrometer (TCP), Shadow Doppler Velocimeter (SDV), CCD camera.

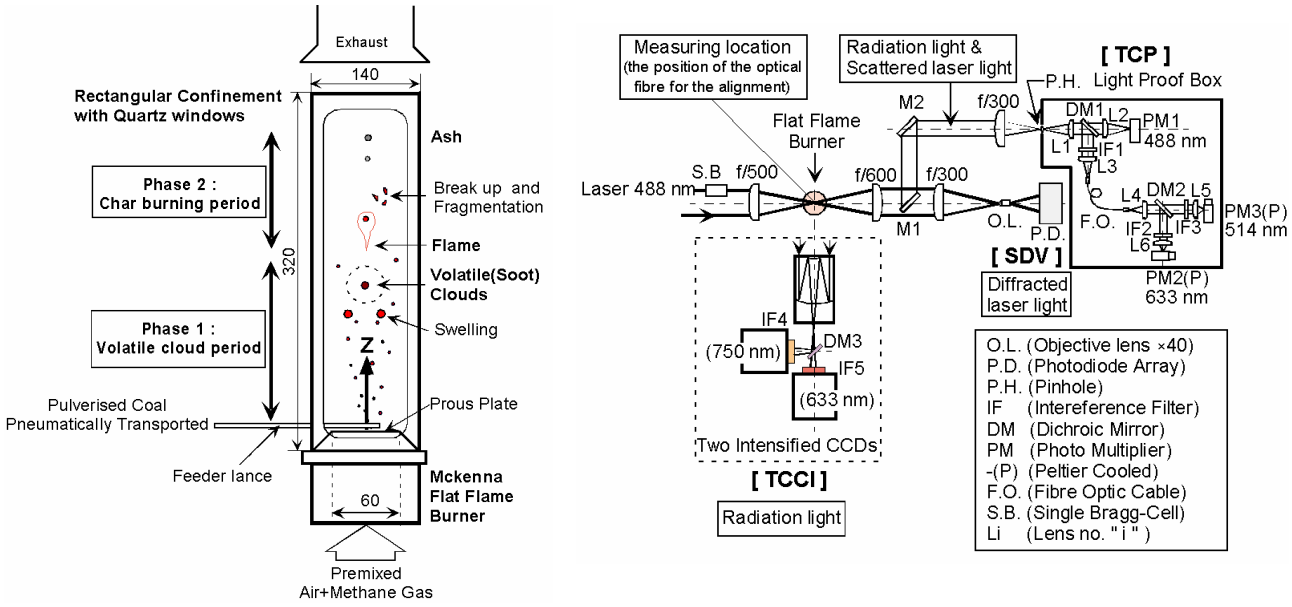

Figure 1:The laboratory scale test facilities [McKenna flat flame burner with rectangular quartz confinement (left), and the optical setting of the combined SDV/TCP/TCCI system (right)]

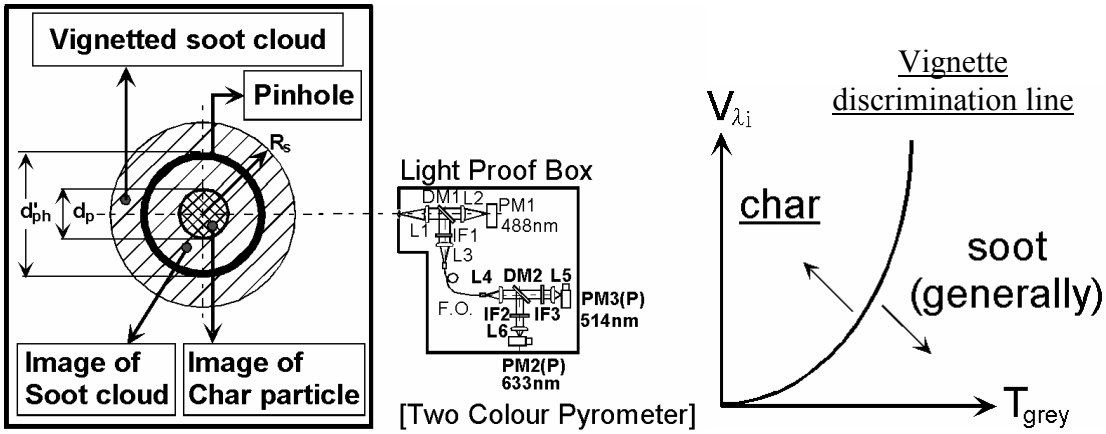

Figure 2: The TCP pinhole *vignette* discrimination criterion technique.

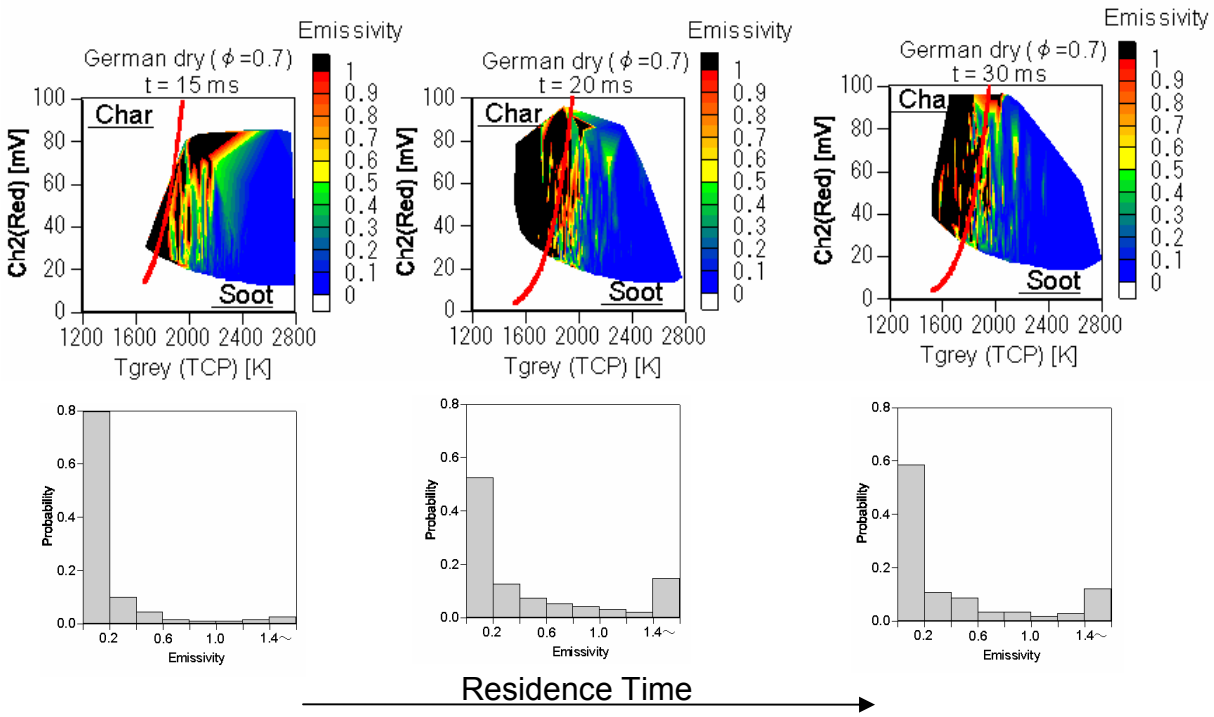

Figure 3: The *vignette* and *emissivity* discrimination criteria between char and soot for German Rhenish *dry* sample.

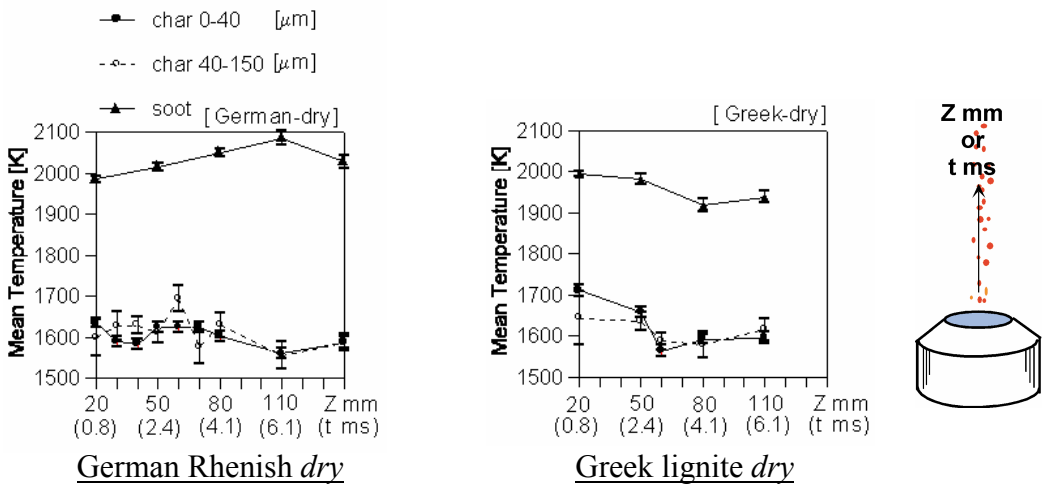

Figure 4: Z axial profiles of mean temperature of char and soot.

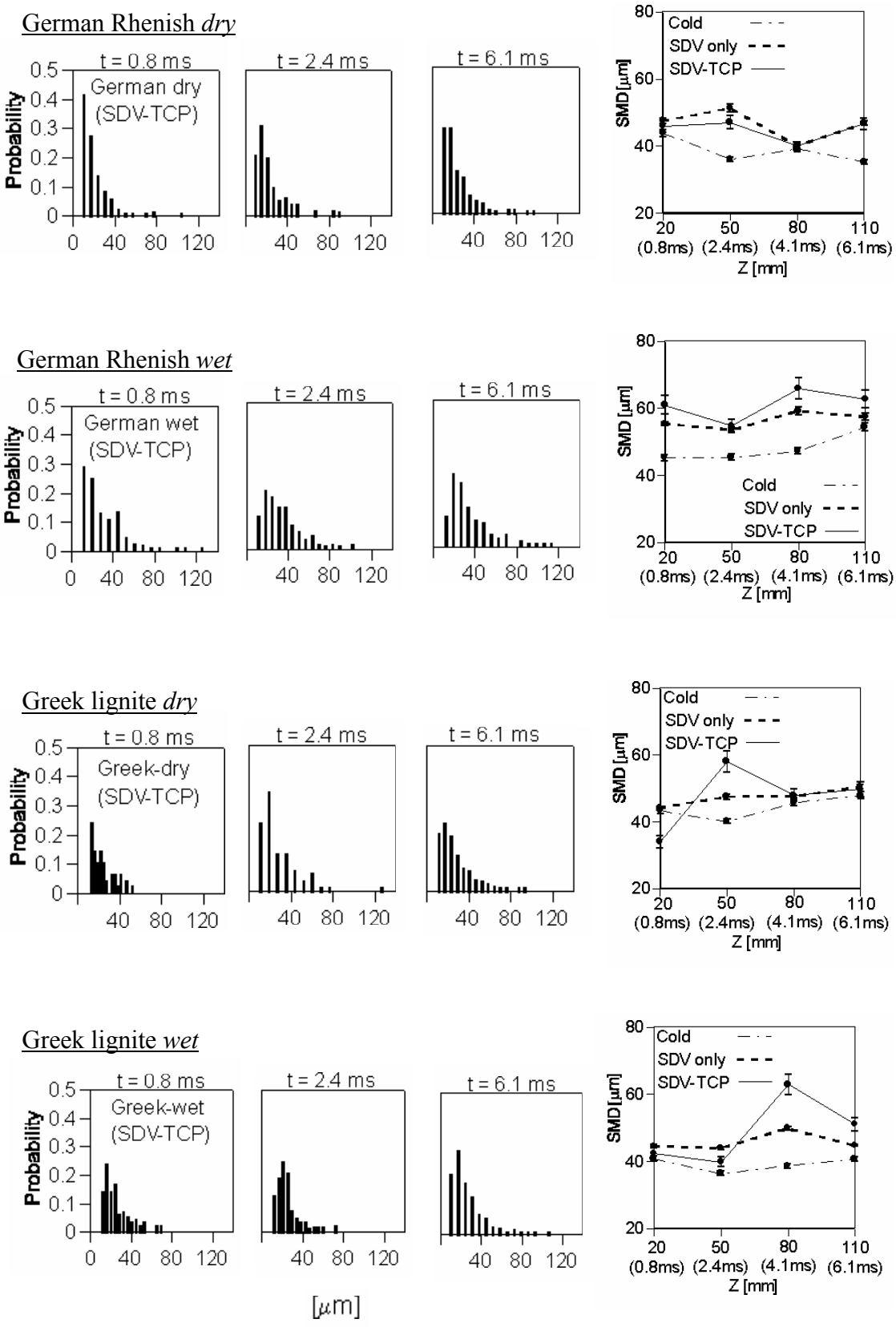

Figure 5: Z axial profiles of the char size distributions. [*Cold*: *initial* without flame condition, *SDV-only*: particles in the combusting gas conditions, *SDV-TCP*: burning char particles only.]