Centro Interdipartimentale
per la Ricerca Applicata e i Servizi
nel Settore della Meccanica Avanzata e della Motoristica

InterMech Mo.Re.

Unità Operativa di Ricerca 1.4
Laboratorio di tecniche antincendio per l'industria meccanica

Responsabile

Prof. Ing. Paolo Tartarini

Team

Ing. Alberto Muscio, ricercatore
Ing. Paolo E. Santangelo, ricercatore dedicato
Ing. Orsola Errico, ricercatore dedicato
Ing. Marco Cavazzuti, ricercatore dedicato

FIRE PROTECTION

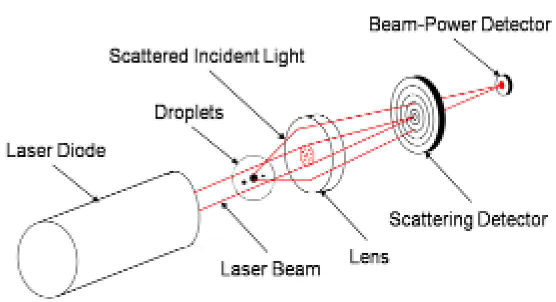
Water Mist Systems

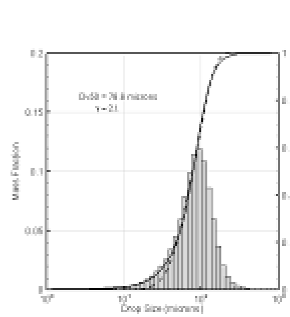
paolo.tartarini@unimore.it

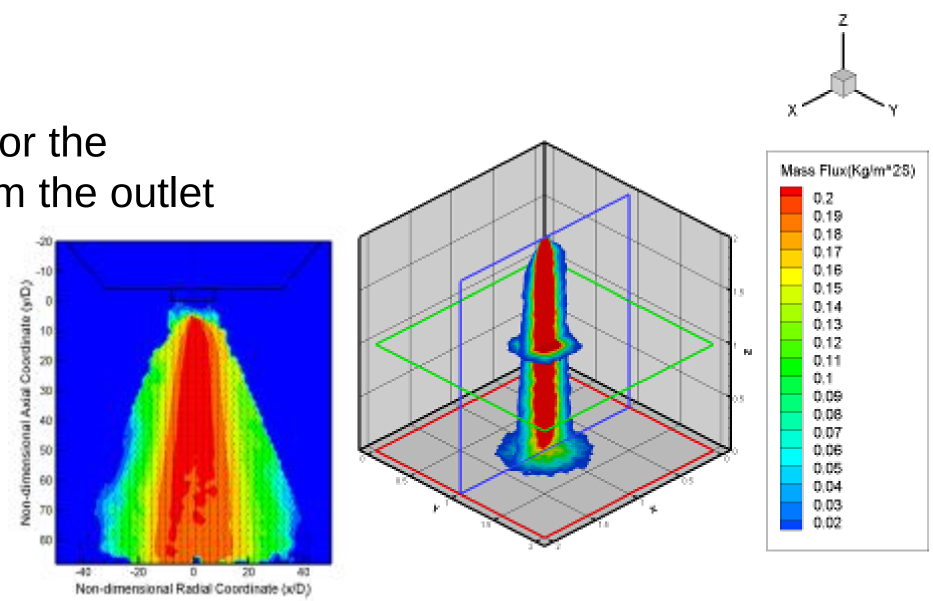
Discharge and dispersion analysis of water mist sprays

Characterization of the atomization process of a water jet exiting a high-pressure single injector :

- laser-based experimental device
- data on the drop size distribution are collected by experiments at high pressure (80 bar)
- a theoretical model has been developed to predict velocity at the injector outlet
- CFD predictions by FDS code are carried out for the distribution of mass flux at different heights from the outlet







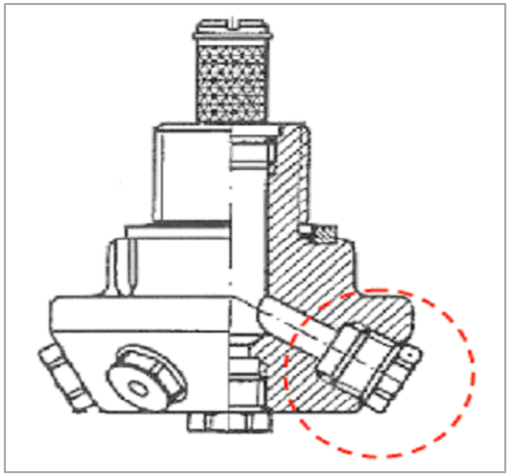
INTRODUCTION AND FOCUS

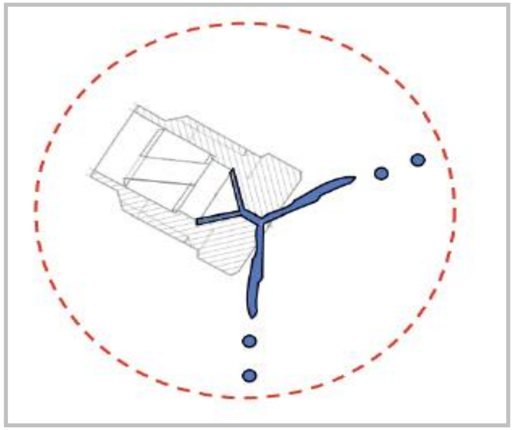
WATER MIST

SMALL DROP SIZE
(D_{v50} < 100 μm)

HIGH PRESSURE (> 35 bar)
NOZZLES

NEED FOR SPRAY
CHARACTERIZATION
(Nozzle design, CFD modeling, etc.)





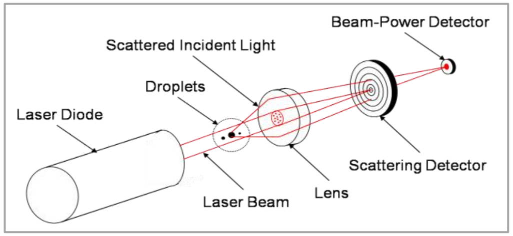
SPRAY CHARACTERIZATION: AREAS OF INVESTIGATION; PARAMETERS OF INTEREST

ATOMIZATION & DISPERSION

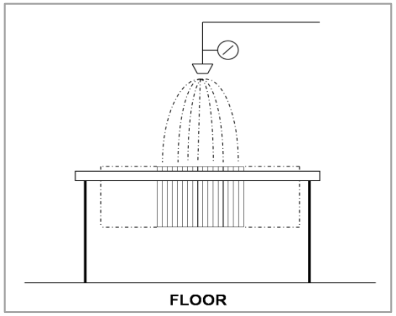
- DROP SIZE & MASS FLUX DISTRIBUTION
- INITIAL VELOCITY
- SPRAY CONE ANGLE

PRESSURE RANGE FOR THE EXPERIMENTAL TESTS:
50 - 90 bar

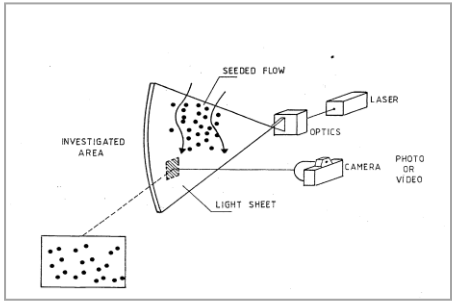
EXPERIMENTAL TESTS:
MEASUREMENT TECHNIQUES AND INSTRUMENTS



- Drop Size — *Malvern Spraytec*

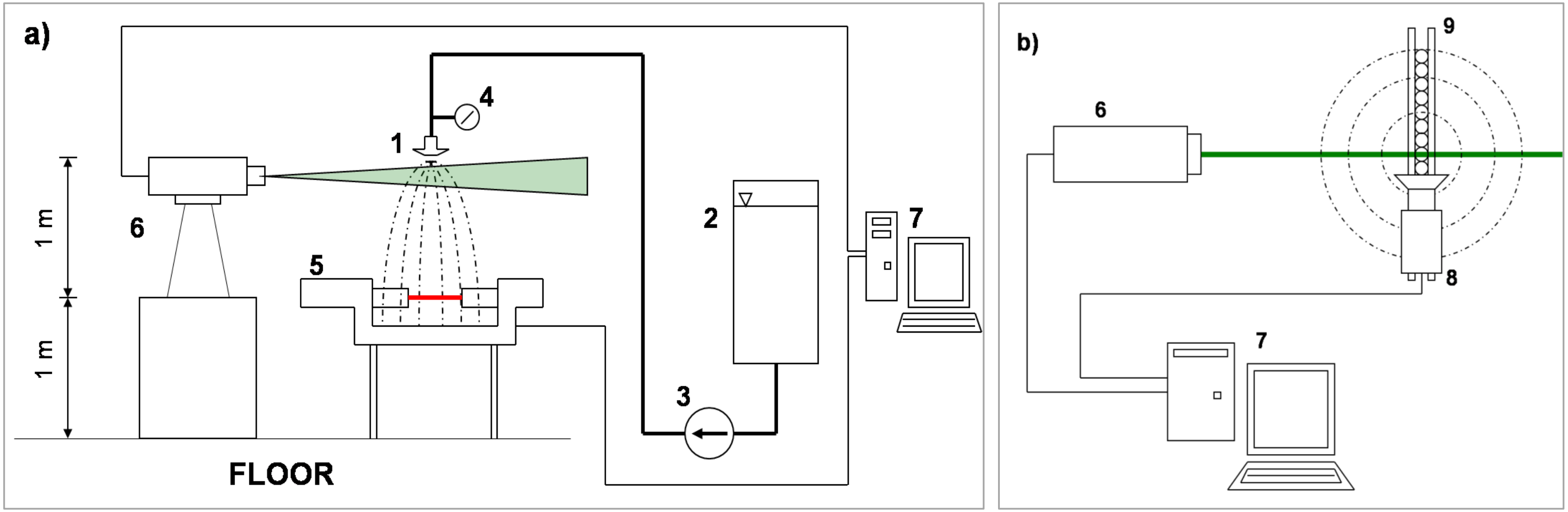


- Mass-Flux Distribution — Mechanical Patternator



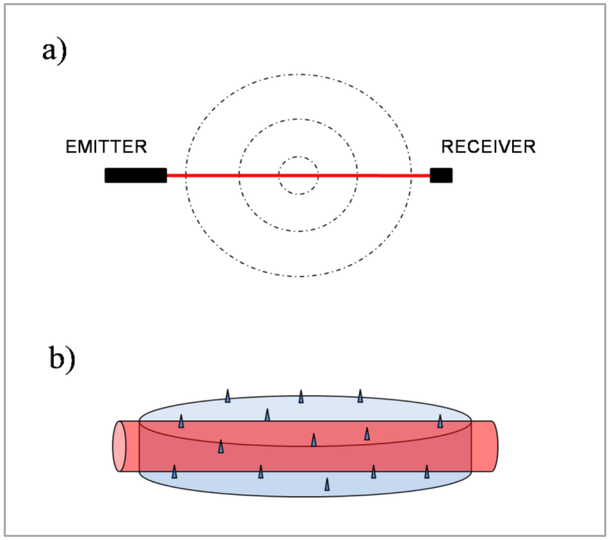
- Initial Velocity — Particle Image Velocimetry (PIV)
- Spray Cone Angle — PIV Maps / Velocity Profiles

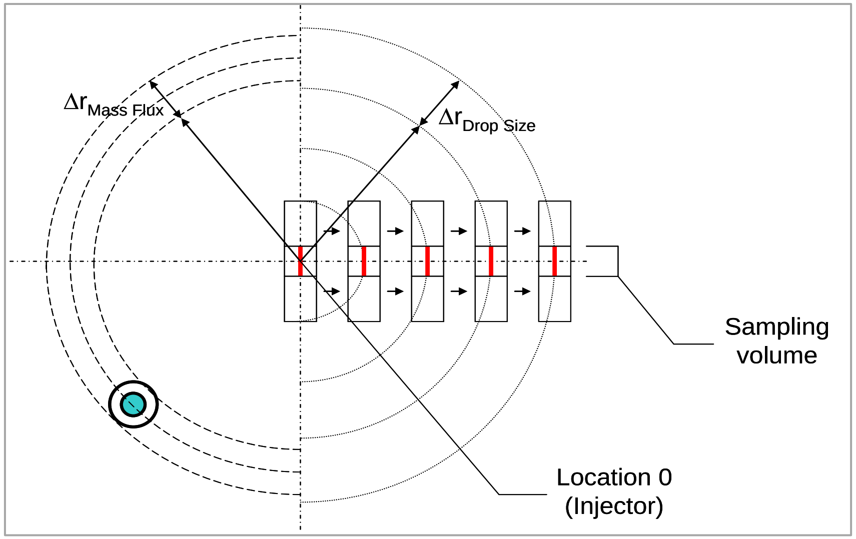
EXPERIMENTAL FACILITY



Sketch of the experimental facility. a) view from side: 1. Nozzle, 2. Tank, 3. Electric Pump, 4. Pressure Gauge, 5. *Malvern Spraytec*, 6. PIV Laser Emitter, 7. Data-Acquisition System; b) view from above: 8. PIV CCD Camera, 9. Mechanical Patternator.

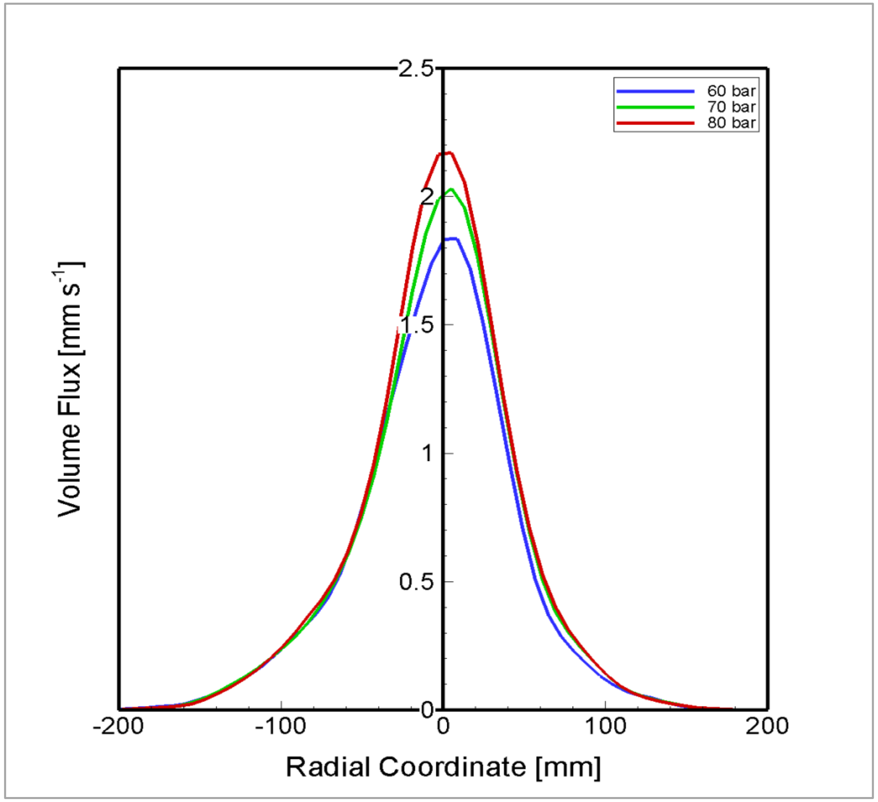
DROP-SIZE AND MASS-FLUX MEASUREMENT: METHODOLOGY





Drop-size measurements are weighted through mass-flux distribution. Raw results given by *Malvern Spraytec* are biased because of the mismatch between the shape of the laser beam (sampling volume) and the shape of a spray section. Hypothesis of radial symmetry has been applied.

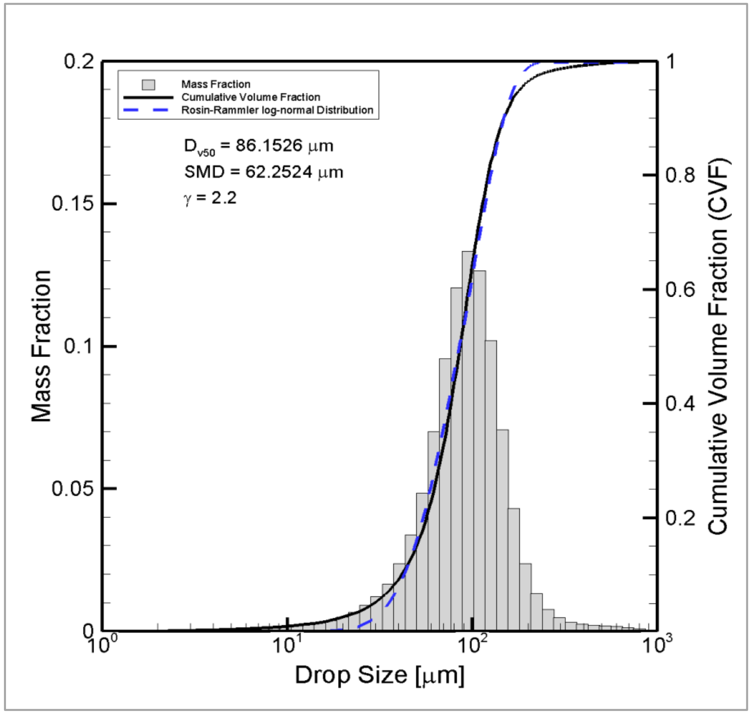
MASS-FLUX DISTRIBUTION: EXPERIMENTAL RESULTS



The radial coordinate has been reconstructed setting the center of mass as the 0 point (*real 0*). It is not perfectly coincident with the geometric 0 point because of little experimental asymmetries (distance lower than 18 mm).

DROP-SIZE RECONSTRUCTION

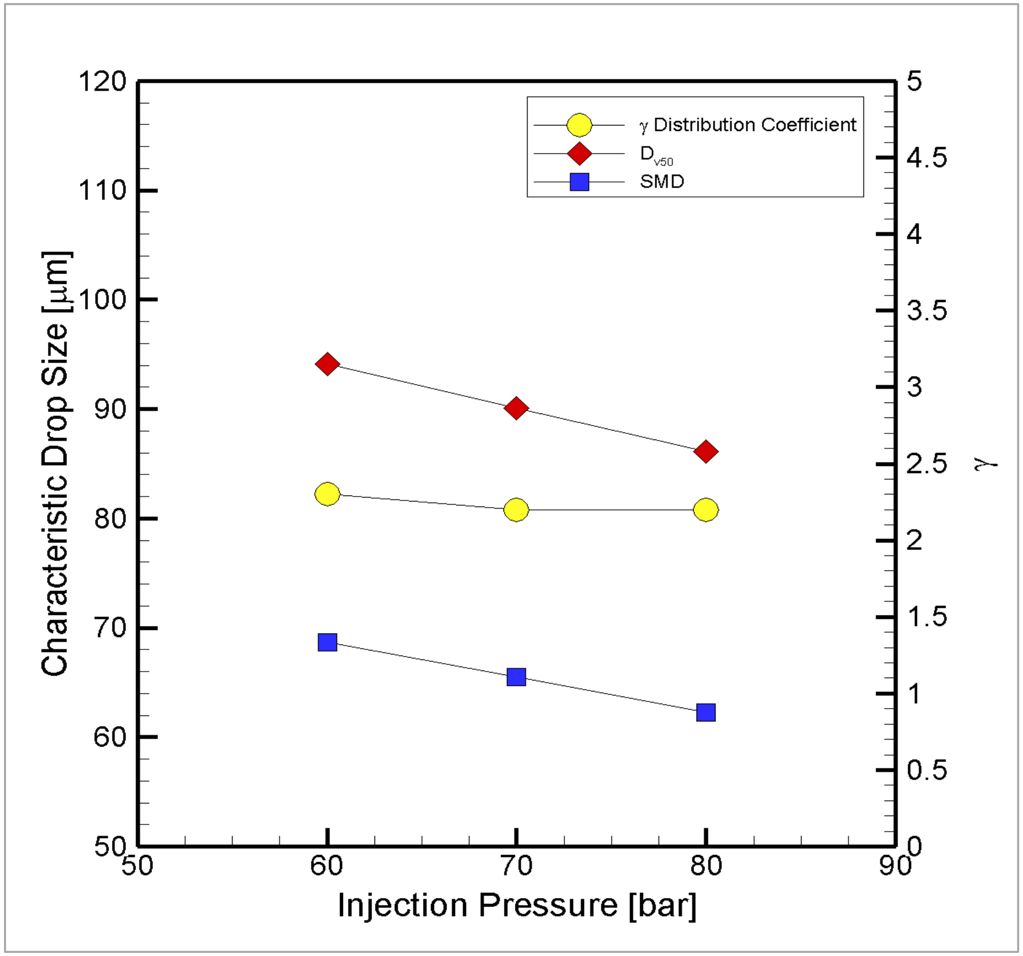
- Volume-flux distribution has been mirrored with respect to *y* axis;
- A polynomial curve has been employed to fit the obtained points;
- Drop-size data have been averaged over mass-flux curve to reconstruct the experimental CVF (Cumulative Volume Fraction) vs. Drop Size curve.



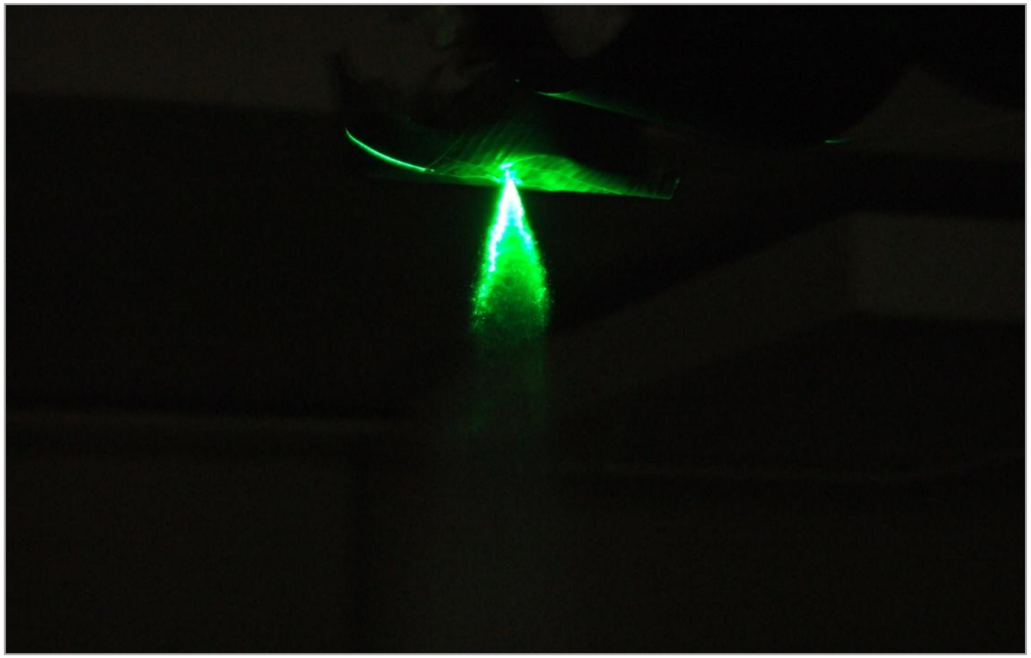
Rosin-Rammler Log-Normal Distribution

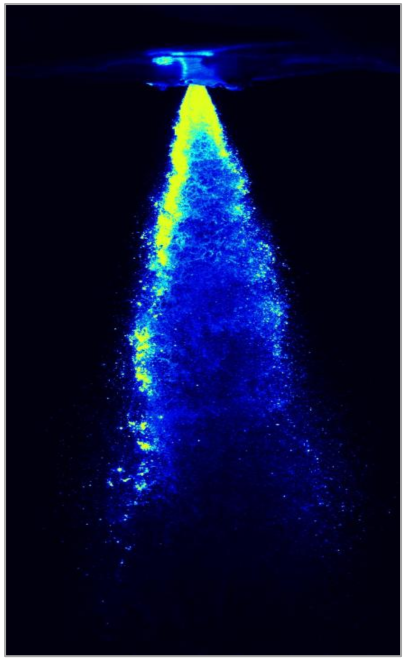
$$CVF = \begin{cases} (2\pi)^{-1/2} \displaystyle\int_0^{D_{CVF}} (\gamma' D)^{-1} e^{-\frac{[\ln(D/D_{v50})]^2}{2\gamma'^2}} dD & (D_{CVF} \le D_{v50}) \\ 1 - e^{-0.693(D_{CVF}/D_{v50})^{\gamma}} & (D_{v50} < D_{CVF}) \end{cases}$$

DROP SIZE: EXPERIMENTAL RESULTS



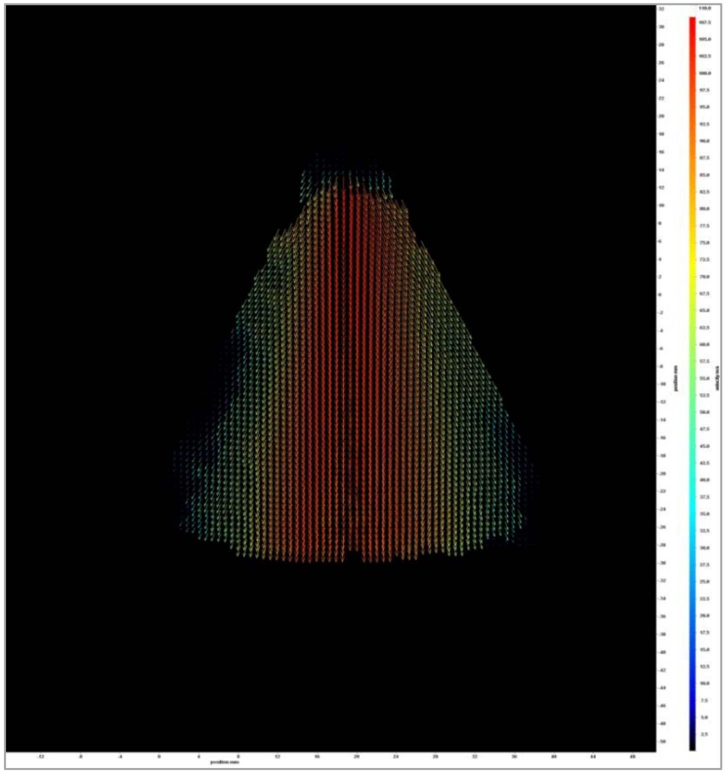
PIV VISUALIZATION OF INITIAL SPRAY

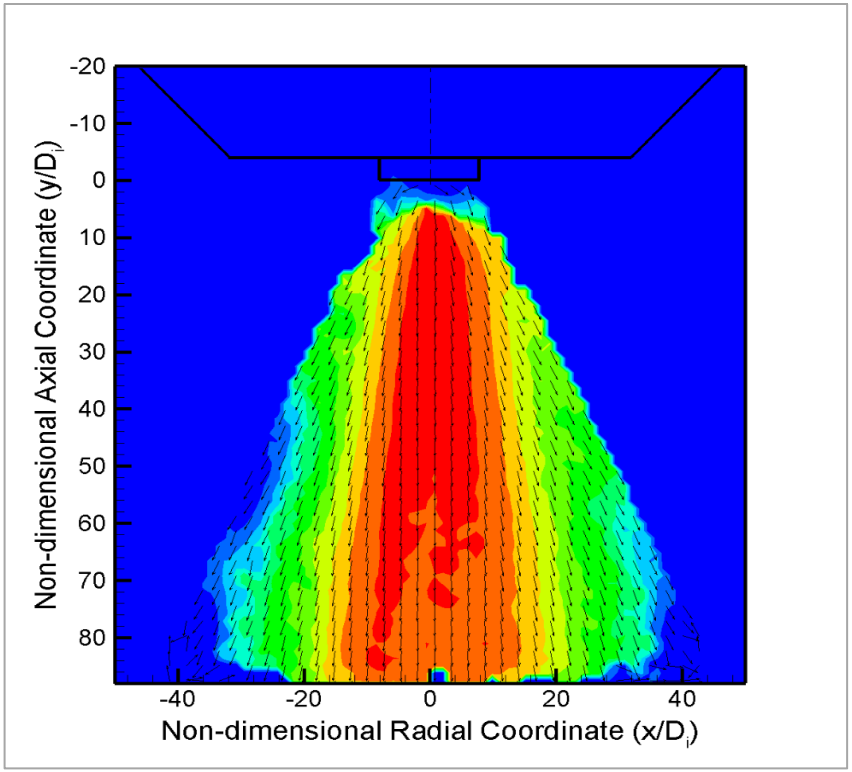




- No seeding particles have been added: droplets are tracking particles themselves.
- Initial velocity has been measured only on the plane containing the injector axis, because tangential component becomes negligible after about 5 mm along the axis.
- Breakup occurs in the first 2 mm; the investigation region covers the first 40 mm.

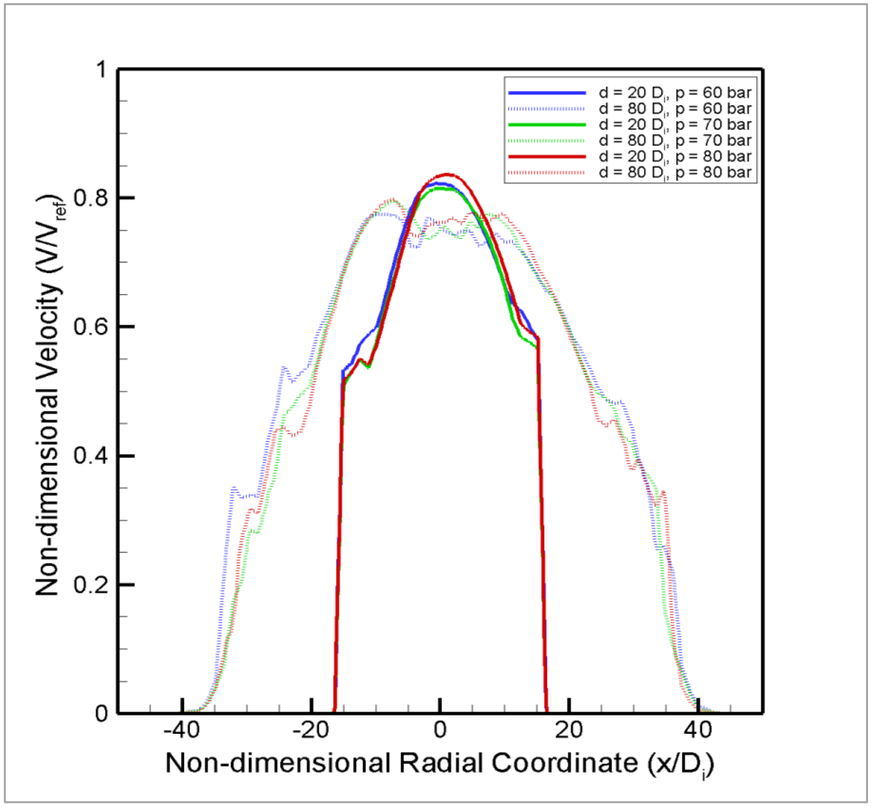
PIV MAPS OF THE INITIAL SPRAY

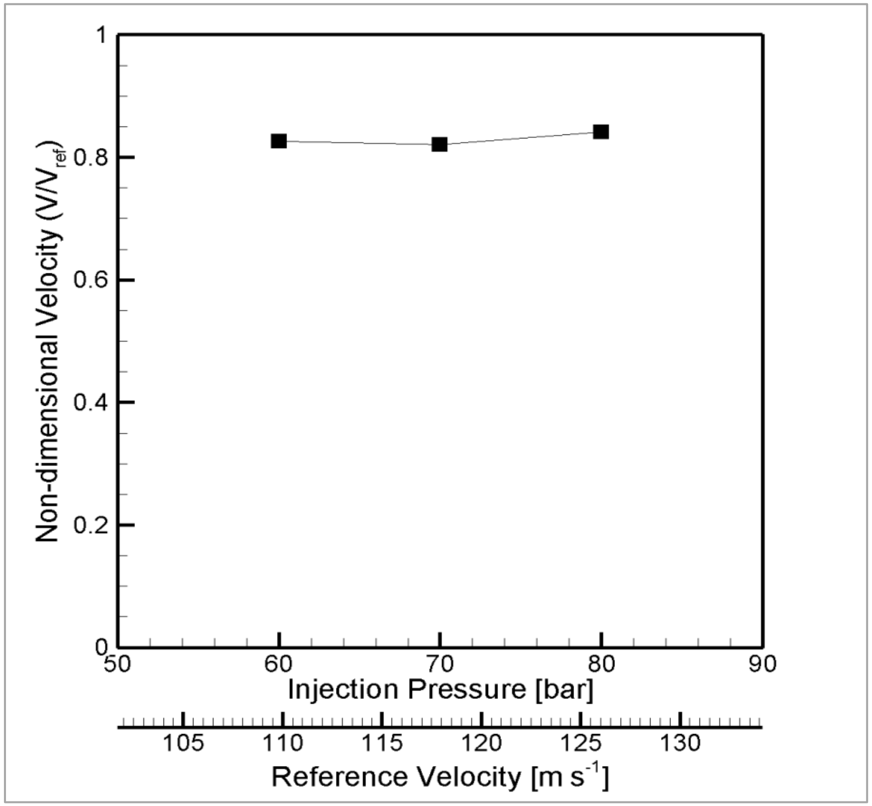




Velocity vectors and contours at 80 bar

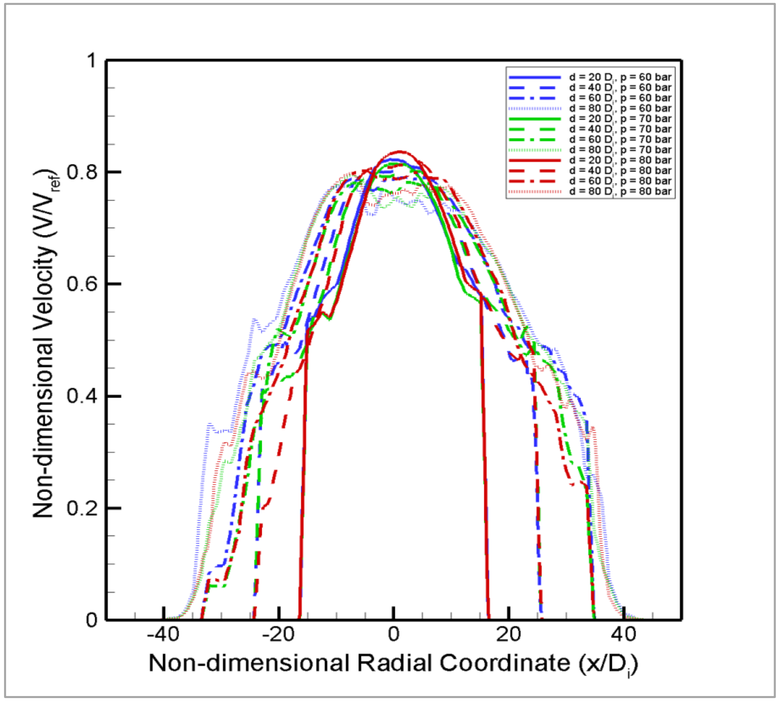
INITIAL VELOCITY: EXPERIMENTAL RESULTS

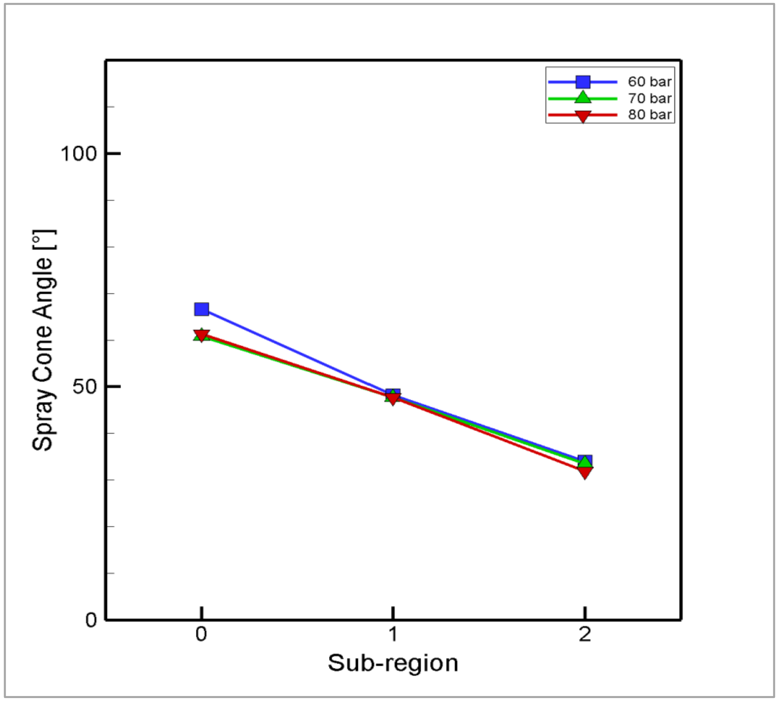




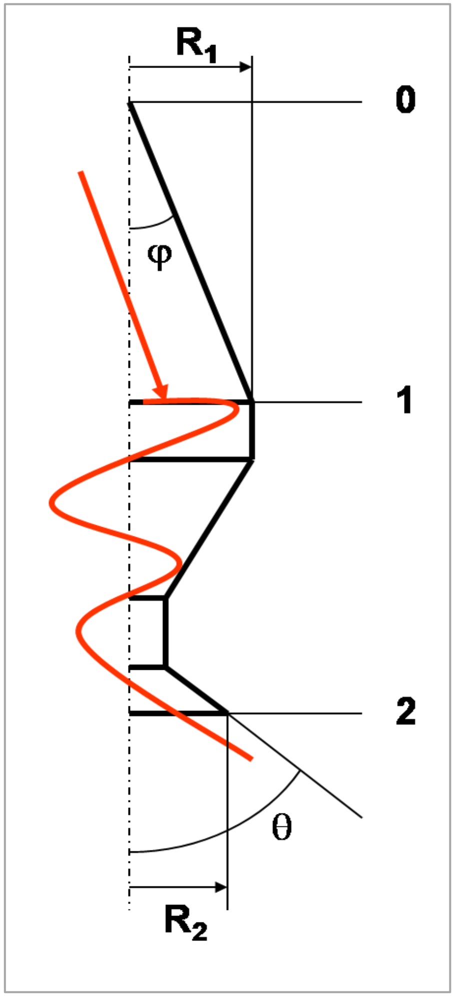
Radial velocity profiles along the injector axis and initial velocity magnitude

EVALUATION OF SPRAY-CONE ANGLE





PHYSICAL MODEL – PREDICTIVE CORRELATION



An inviscid model (Bernoulli model) has been developed following a classical approach to pressure-swirl atomizers (Lefebvre, 1989).

$$V_2 = \left(\frac{2 p_{PG}}{\rho_L} \right)^{1/2}$$

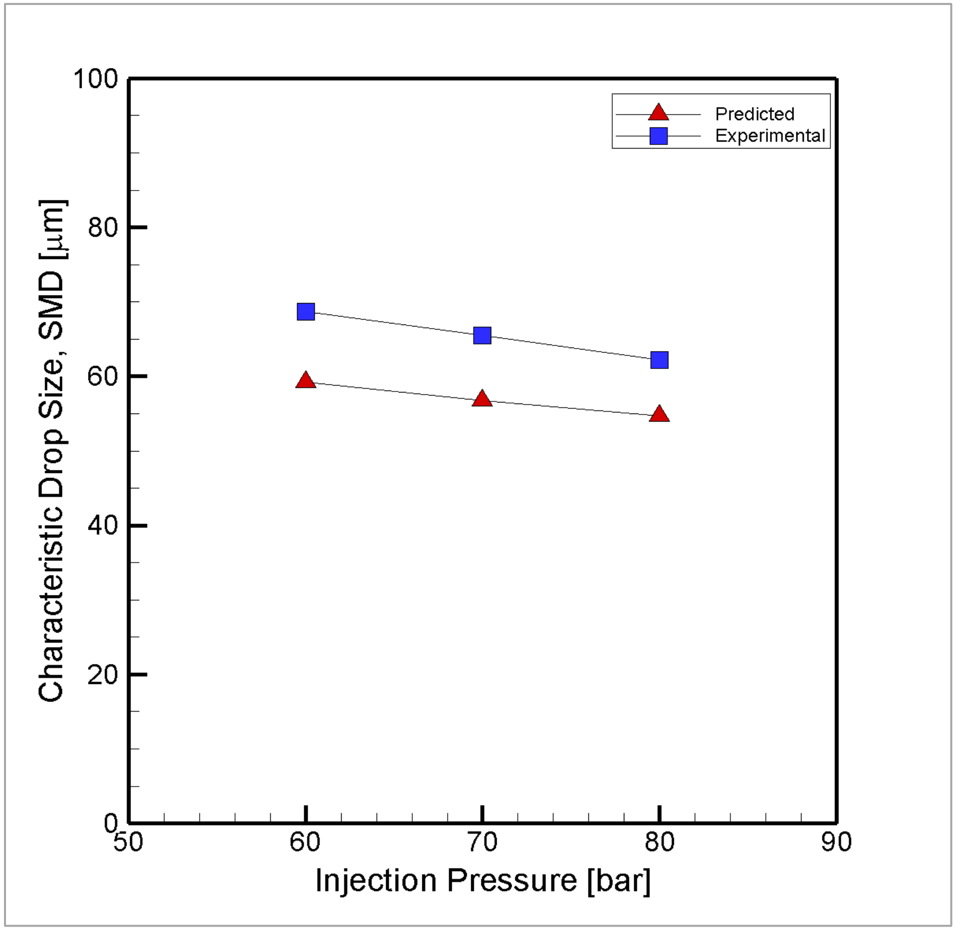
$$\dot{m}_L = \rho_L A_F V_2 = \rho_L C_D A_{TOT} V_2 = C_D A_{TOT} (2 \rho_L p_{PG})^{1/2}$$

$$C_D = \frac{FN}{A_{TOT}} \left(\frac{\rho_L}{2} \right)^{1/2}$$

Radcliffe's correlation

$$SMD = 7.3 \cdot \sigma^{0.6} \cdot \nu^{0.2} \cdot \dot{m}_L^{\ 0.25} \cdot p_L^{\ -0.4}$$

COMPARISON BETWEEN EXPERIMENTAL AND THEORETICAL RESULTS



bettati ANTINCENDIO

RegioneEmilia-Romagna

In collaboration with

DIMeC - Dipartimento di Ingegneria Meccanica e Civile
Università degli Studi di Modena e Reggio Emilia

UNIVERSITY OF MARYLAND
GLENN L. MARTIN INSTITUTE OF TECHNOLOGY
A. JAMES CLARK SCHOOL OF ENGINEERING
Department of Fire Protection Engineering