Technology for Particles, Imaging, and Velocimetry

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User Manual

Aerosol Generator PivPart40-Dry* series

Content:

Manufactured in [ ]
Typ PivPart40-Dry*
Serial No. [ ]
temperature min./max. +5/+40 °C
over pressure max. [2.5] bar
Not for use with toxic, flammable, or corrosive liquids!

Introduction

The air-operated PivPart40-Dry* is made for the generation of micro-droplets of liquids. Any liquid has to be analyzed with respect to the safety precautions, e.g. by the inspection of safety data sheets, before filling it into the generator. The combination of the generator with other pressurized parts or machines have to be done in accordance to the national and international safety regulations. Read the manual carefully before using the generator.

In almost all applications of laser based flow anemometry it is desirable to add tracers in order to achieve sufficient image contrast and to control particle size. In gas flows the supply of tracers is very often critical for the quality and feasibility of the PIV measurement and the impact onto the experimental environment for example in wind tunnels. Particles from smoke machines and thermal fog generators are not easy to handle, because many liquid droplets tend to evaporate rather quickly, and therefore change size. Solid particles are difficult to disperse and very often agglomerate. In many cases, the particles cannot simply be supplied a long time before the measurement, but must be injected into the flow shortly before the gaseous medium enters the test section. The injection has to be done without significantly disturbing the flow, but in a way and at a location, that ensures homogeneous distribution of the tracers. Since the existing turbulence in many test set-ups is not strong enough to mix the fluid and particles sufficiently, the particles have to be supplied from a large number of openings. Distributors, like rakes consisting of many small pipes with a large number of tiny holes, are frequently used. Therefore, particles, which can easily be transported inside small pipes, are required.

The particle generator described herein, produces tiny droplets of liquids by pressurized air (e.g. oil). Laskin nozzle generators and oil have been used for most of the PIV and LDA measurements of airflows. Depending on the liquid used, these particles offer the advantage of not being toxic; they stay in air at rest for hours, and do not change in size significantly under various conditions. In closed-loop wind tunnels they can be used for a global seeding of the complete tunnel volume or for a local seeding of a stream tube by a seeding rake with a few hundred tiny holes. A technical description of the atomizer is given below.

Technical description

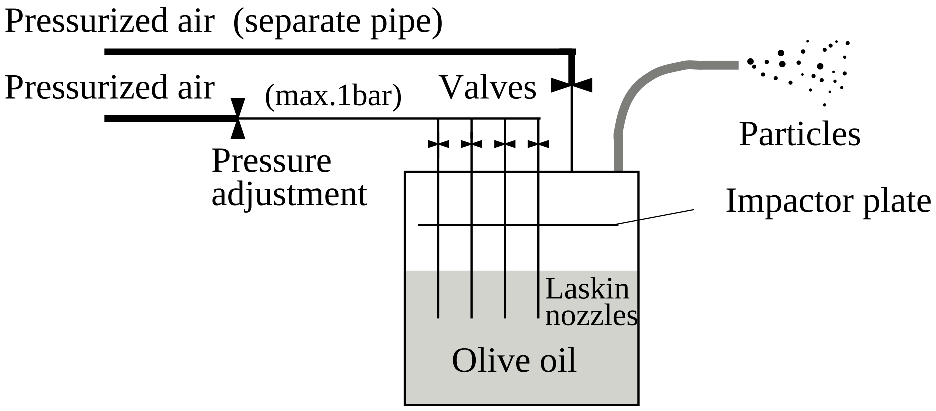

Figure 1: Principle of the PivPart05 particle generator

The generator consists of a closed cylindrical container with two air inlets and one aerosol outlet. Four air supply pipes -- mounted at the top -- dip into the liquid (e.g. vegetable oil) inside the container. Each of them is connected to the same air distributor by a tube and a valve. The pipes are closed at their lower ends (see below). Laskin nozzles with liquid holes of 1 μm in diameter are equally spaced in each pipe. A second optional inlet allows additional air supply in order to decrease the particle concentration at the outlet flow or to adjust the kinetic flow conditions at the outlet. However, this has not to be done in general.

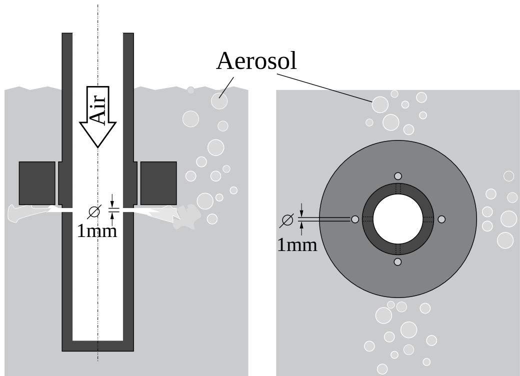

Figure 2: Sketch of the Laskin nozzles

A horizontal circular impactor plate is placed inside the container, in a way that the plate and the inner wall of the container form a small gap of about 2mm. The second air inlet and the aerosol outlet are connected directly to the top. Two gauges measure the pressure on the inlet of the nozzles and inside the container, respectively. Compressed air with a pressure difference of 0.5 bar – 1 bar with respect to the outlet pressure is applied to the Laskin nozzles and creates air bubbles within the liquid. Due to the shear stress induced by the tiny jets, small droplets are generated and carried inside the bubbles towards the oil surface. The impactor plate retains big particles; small particles escape through the gap and reach the aerosol outlet. The four valves at the nozzle inlets can be used in order to control the number of particles. The mean size of the particles generally depends on the type of liquids being atomized, but is only slightly dependent on the operating pressure of the nozzles. Vegetable oil is the most commonly used liquid since oil droplets are believed to be less unhealthy than many other particles. ***However, any kind of seeding particles, which are harmfull or cannot be dissolved in water, should not be inhaled.*** Most vegetable oils lead to polydisperse distributions with mean diameters in the submicron range. The same particle size can be generated when Di-Ethyl-Hexyl-Sebacat (DEHS) is used in combination with the generators described above. DEHS particles turn into vapor after a few hours and are therefore not polluting. The optical properties – especially light scattering – are excellent and can be compared with that of vegetable oil particles.

Technical data

Atomizer principal: multiple Laskin nozzles in x-configuration (two layers)
Performance: 40 individual air jets with according liquid holes in metric fittings
Fully adjustable through (manual) control of 40 Laskin nozzles (8,16,…40)
Typical particle size:
$d_{p,\ mean}$ <1.0 µm - peak in PDF of volume distribution q3*
In the volume distribution q3* particle diameters d_p are weighted with the power of 3 in order to account for their visibility which increases with the power of 4 in the Rayleigh-Scattering domain (d_p <0.5 µm) and with the power of 2 in the Mie Scatttering domain (d_p>0.5 µm).
Tested seeding materials:
DEHS, white mineral oil, propylene glycol and fog fluid Safex "X"
Typical seed output per jet: App. 10^8 particles/second
Air requirements: Minimum pressure 2.5 bar at 40 m^3/h
Operating overpressure: See generator label; inlet overpressure 0.7 -1.0 bar.
Weight: approximately 20kg.
Inlet and outlet: One inlet ½" for particle generation, one outlet 3/4", safety valve

Operation and Inspection

First, the liquid to be atomized has to be filled into the generator through the ***outlet*** (see Fig. 7). The level of the liquid should be approximately 10 centimeters above the bottom of the container (see ***level indicator*** on Fig. 7). Then, pressurized air has to be connected to the ***inlet*** (see Fig. 7). The ***inlet pressure adjustment*** (see Fig. 7) has to be set to set to reach an inlet pressure level, which is between 0.5 bar and 1 bar larger than the outlet pressure level (compare ***inlet pressure gauge*** and ***outlet pressure gauge*** Fig. 7). The outlet pressure is usually atmospheric as long as the outlet is not blocked or connected to distribution devises or pressurized devises. Precautions to ensure higher pressure levels at the inlet than at the outlet have to be made in order to avoid the liquid flowing backwards, if the outlet is pressurized or blocked. The outlet pressure should not exceed the surrounding pressure level by more than the pressure specified on the generators label (check at ***outlet pressure gauge*** see Fig. 5). The amount of particles can be adjusted with ***four quantity valves*** (see Fig. 7).

The generator requires cleaning when fluids have been used for aerosol generation, which are polluting in nature, e.g. because they tend to change there physical state or viscosity with time. The safety valve has to be checked annually or in shorter time intervals, if pollution occurred or if there is any other reason to doubt its function. When checking the safety valve, avoid eyes to be injured by any substance blowing out of the opening. Wear safety goggles. One can check the safety valve by removing it from the top and mounting it to the inlet pressure regulator exit. Increase the pressure carefully from zero to the maximum pressure specified on the valve and the generator. A tolerance of 10% of the specified pressure must not be tolerated. Exchange valve if necessary, but ensure sufficient mass flow rate and release pressure margin.

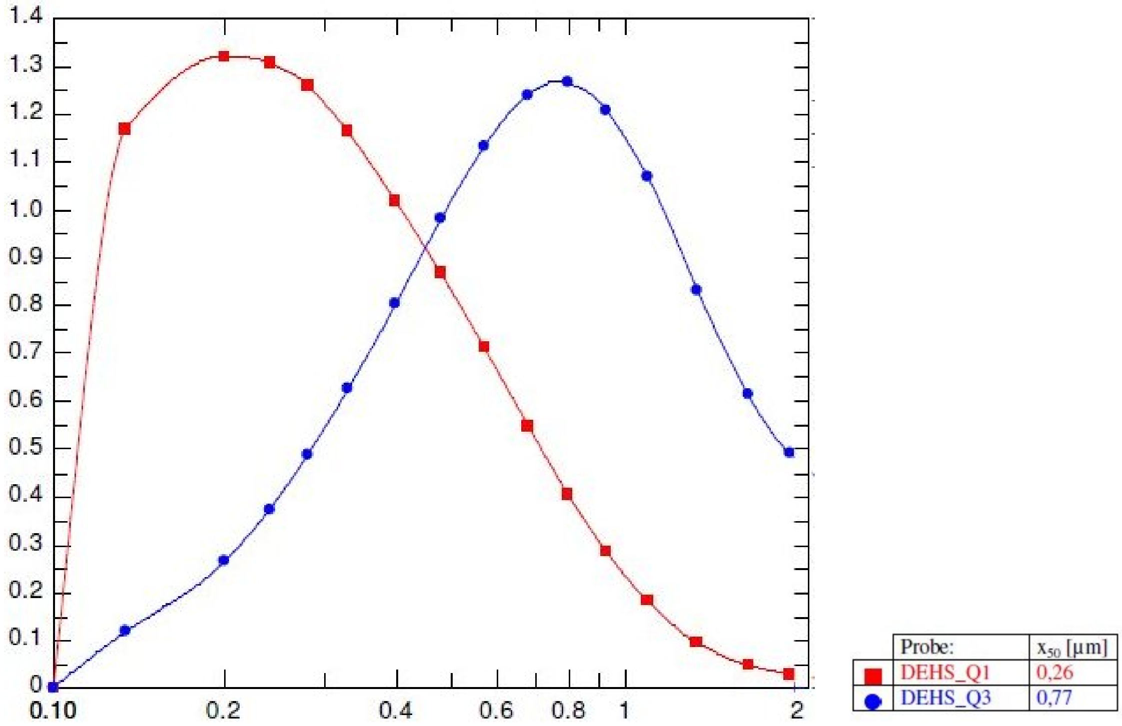

Figure 3: PDF of particle sizes of DEHS atomized at 0.7 bar overpressure
red: q1* probability density function of the distribution of length
blue: q3* probability density function of the distribution of volume (accounts for visibility)

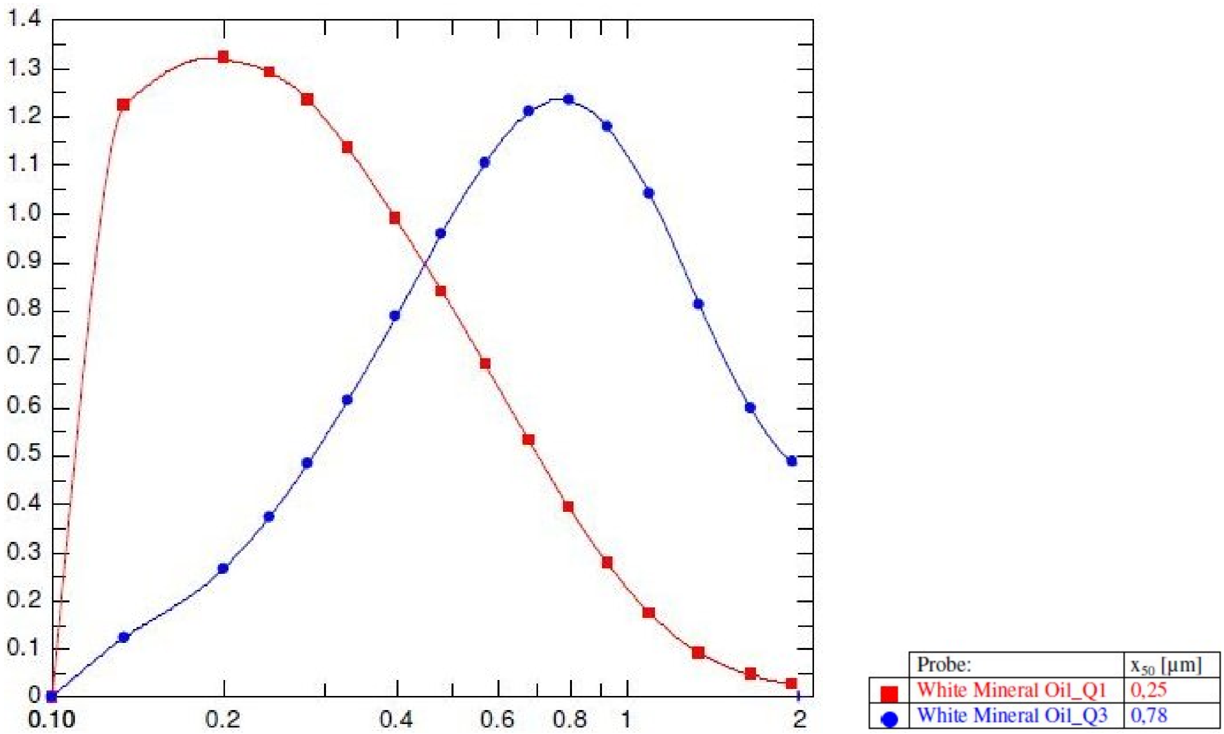

Figure 4: PDF of particle sizes of white mineral oil atomized at 0.7 bar overpressure
red: q1* probability density function of the distribution of length
blue: q3* probability density function of the distribution of volume (accounts for visibility)

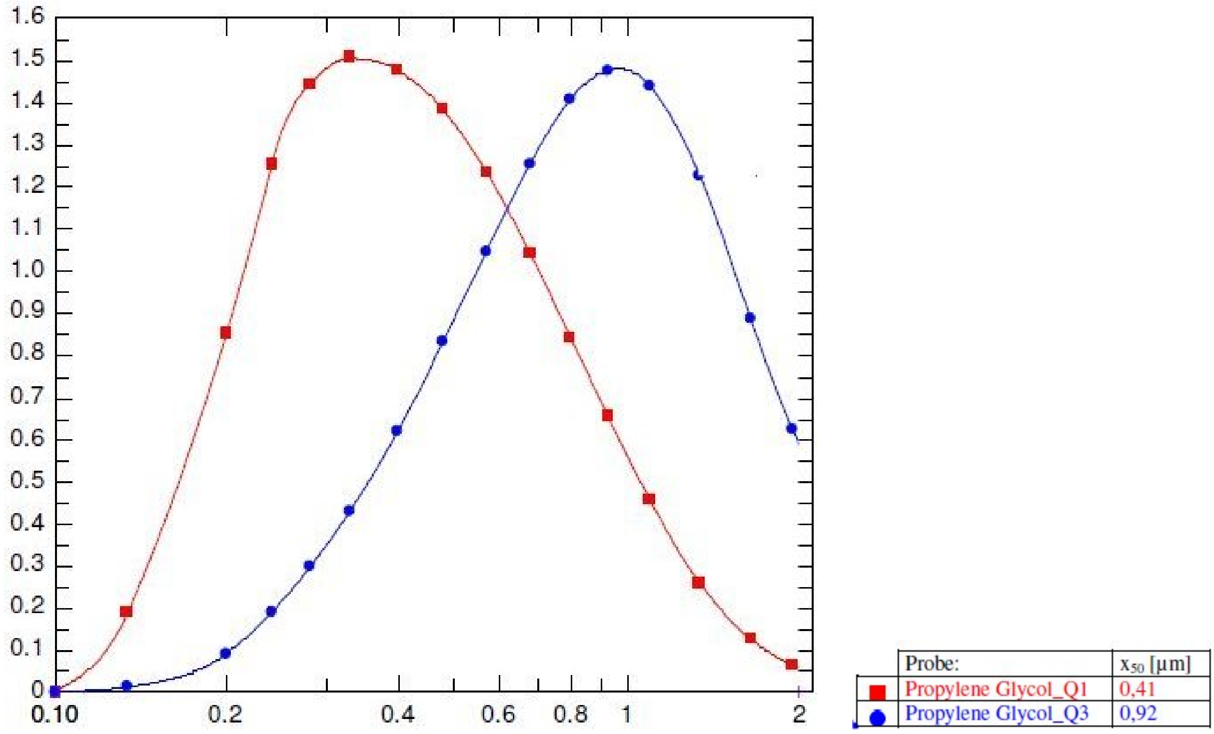

Figure 5: PDF of particle sizes of propylene glycol atomized at 0.7 bar overpressure
red: q1* probability density function of the distribution of length
blue: q3* probability density function of the distribution of volume (accounts for visibility)

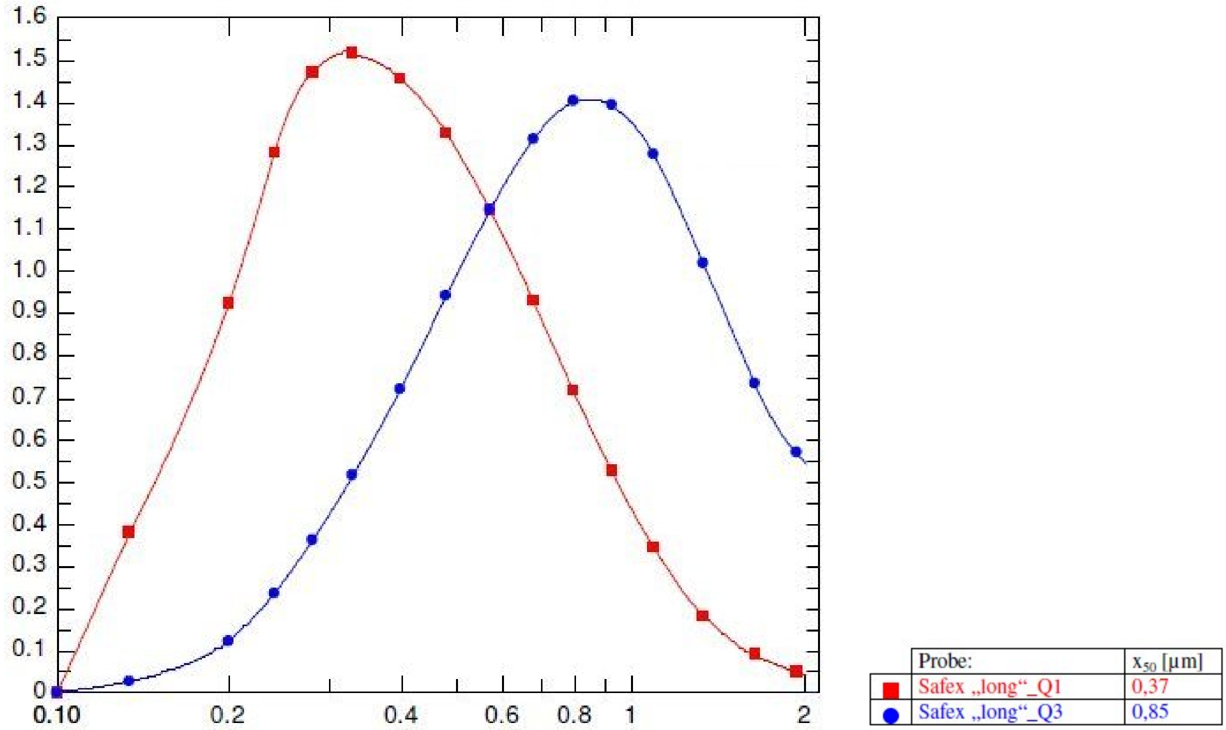

Figure 6: PDF of particle sizes of Safex "long" fog fluid atomized at 0.7 bar overpressure
red: q1* probability density function of the distribution of length
blue: q3* probability density function of the distribution of volume (accounts for visibility)

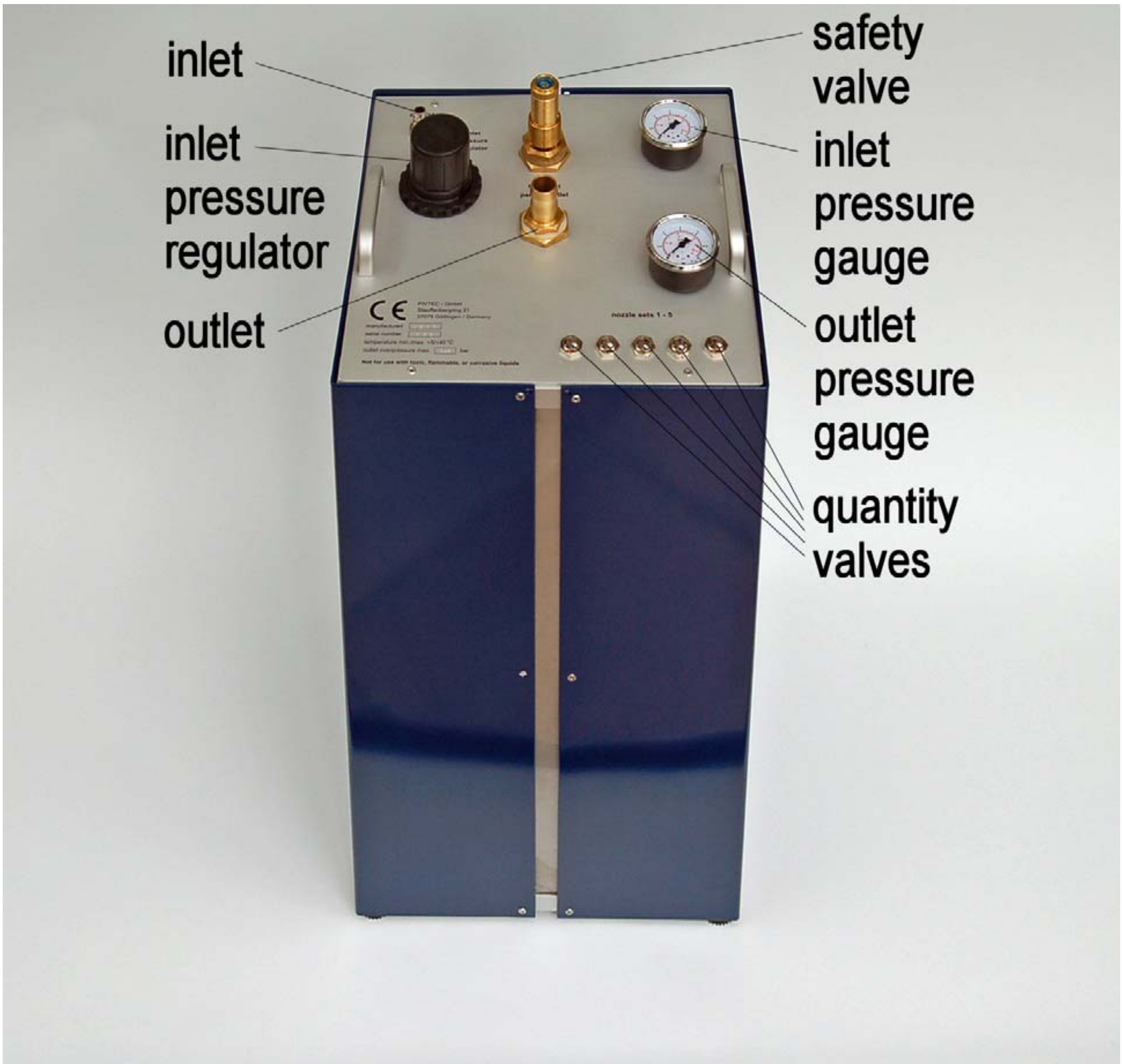

Figure 7: The PivPart40-Dry* particle generator

Recommended working liquids:

Typical seed materials include vegetable oil, DEHS, and white mineral oil. Vegetable oil is frequently used in wind tunnel applications at atmospheric pressures and temperatures, as it is inexpensive and produces micron-sized droplets. Olive oil has a higher flash point or decomposition temperature, and is the liquid of choice for many internal combustion engine flows. DEHS is frequently used for filter testing and laser anemometry. Where operation at very high temperature, and reduced pressures is required, silicone vacuum fluids are preferred. These liquids were developed for use in vacuum diffusion pumps and combine very low vapor pressure with high flash points and surface tension and cinematic viscosities similar to the vegetable oils.

Safety considerations:

Working Back Pressure

The atomizer is designed using standard bar pressure components and is certified for operation between -0.1 bar minimum and 2.5 bar maximum working backpressure.

Aerosol Inhalation

Working liquids for the atomizer are chosen for the droplet size range they produce in conjunction with their evaporation rates. Droplets are typically produced in the size range 0.5-5.0 µm. Since these are easily inhaled, the seed material and operational procedures should also be chosen with regard to toxicity, possible allergic reaction and irritation. The user should refer to COSH data sheets for the liquids being used (or in the USA, OSHA) for the relevant hazard information and handling/ventilation requirements. Safety data for DEHS can be found at distributors web-sites e.g. WWW.Merck.de (CAS-No. 122-62-3).

In general, the seeder should be used in well-ventilated areas. Forced ventilation is preferred to eliminate seed build up in confined areas. If this cannot be achieved, then personnel should wear appropriate respiratory filters for the droplet size range being produced

Operated at Its maximum seed production rate, the device will atomize liquid at rates of approximately 1 mm^3s^{-1}. For many experiments, the seed is not required continuously and in these cases the total volume of seed material ejected is very small. For typical IC engine work, the seeder will be in operation for the order of 100 seconds, so that in a single run the total quantity of seed ejected is no more than 0.1ccm. This should be borne in mind when considering environmental requirements for filtering exhaust or ventilation flows from experimental areas.

Static Electricity

If combustible liquids are used in the seeder, precautions should be taken to avoid static electricity and the risk of explosion. In extreme cases anti-static tubing may be desirable from the output of the seeder to the experiment.