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To whom it may concern,

Following the request of **TavTech Ltd.**, I have conducted an experimental examination of the impingement of their high-velocity jet system, at my lab (**MyFET, TAU**), specializing in flow and heat transfer visualization and measurement.

The experiments were conducted under the standard operating conditions of the injection system (shown in Fig. 1), with several different jet heads. For all configurations the injection nozzles were held vertically (verified by the symmetry of measurements and by water level), at key distances above the horizontal solid target. A microscale pressure measurement was implemented on the target surface, based on the Omega PX26 30psi differential sensor, calibrated and with 1% full-scale accuracy, attached to a 31-gauge flat end needle embeded in the surface (see Fig. 1a). A microscale x-y-z stage was employed to position the measurement with an accuracy of 5micron, and measurements were taken at twice the needle inner diameter – every 250microns (see Fig. 1c). The conduction of the experiments was documented by photography and environment temperature and pressure data was aquired at 50Hz to a Data acquisition module (C-series RTD module on NI 9181) controlled by Labview software, in order to record and verify the reliability and steadiness of the measurements (see Fig. 1b).

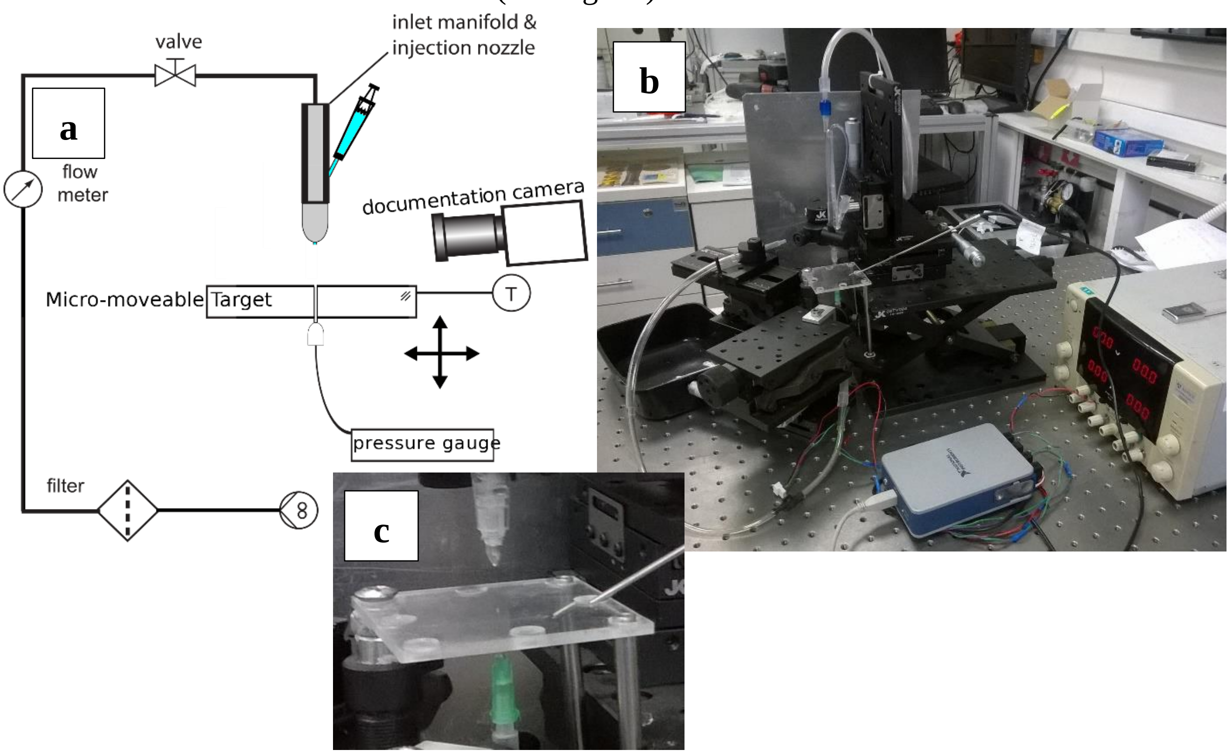

Fig. 1: Experimental system setup: I) schematic of layout; II) photo of system; III) close-up of nozzle, and micro-pressure measurement in the target (green needle)

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From these accurate wall-side pressure measurements, the pressure distributions (Figs. 2 & 3) and their limits subject to geometry were identified. The key findings were:

<u>N05 nozzle:</u>

This is the basic nozzle, it is also used as a reference, and is therefore examined in detail. The small sampling needle gave the local pressure at high resolution, despite the small nozzle of this injection head (0.5mm). The pressure was quite symmetrical and the center of the high-speed air jet was identified. As the pressure scan shows (Fig. 2a), a high-pressure zone exists up to a radius of about 0.3mm around the center, from there it decays monotonically to zero around 1.5mm. This distribution shape and width changes only slightly, with increasing distance from the wall, though pressure values drop-off rapidly, revealing that above 8mm the air-jet generates less than 1atm (15psi) pressure across the impingement zone – as required.

The addition of Saline droplets (representative of other liquids used in realistic applications), caused a slowing of the jet – as the air needs to accelerate the droplets, and consequently even lower pressures, while preserving the jet's characteristic distribution (see Fig. 2b). Therefore, wet operation is considered even safer in pressure terms.

<u>N23 nozzle:</u>

This nozzle was sampled only at a single height, as it is an upscaled version of the previous one. The key height, which generates ~15psi of peak pressure, was found at 16.5mm – a compromise between 20.5mm (dictated by laminar scaling laws) and 13mm (for fully developed turbulence). This is in accordance with the intermediate Reynolds number for this nozzle (Re=9,000). It is seen that such a high-speed jet does not widen very much (see Fig. 2c), as would be expected from a purely laminar jet, and has a similar width to the N05 nozzle, though as its intensity is much higher, it must be held further away.

<u>PRP nozzle:</u>

This nozzle is also similar to the first one, but has the addition of an air-shield, located around 4.5mm from the central jet. It is fed from the same compressor, but at a higher flow rate. Therefore, a similar safe-distance ($p_{\max} \cong 15$psi) was found slightly farther away – at a height of H=9mm for this head (see Fig. 2d). The primary difference identified here is that the jet is much wider than the first one, most probably due to the shield's additional flow and reduced jet interaction with the surroundings.

<u>N01 nozzle:</u>

This nozzle is unique as it encorporates three basic nozzles in a row, located about 1mm from each other. Here too symmetry was identified around the centeral nozzle, though the distribution along the multi-nozzle axis is quite different than that perpendicular to it (compare profiles in Fig. 3a & 3b). It is seen that the neighboring nozzles obstruct the outflow, leading to higher pressures at the center. Furthermore, with increasing distance

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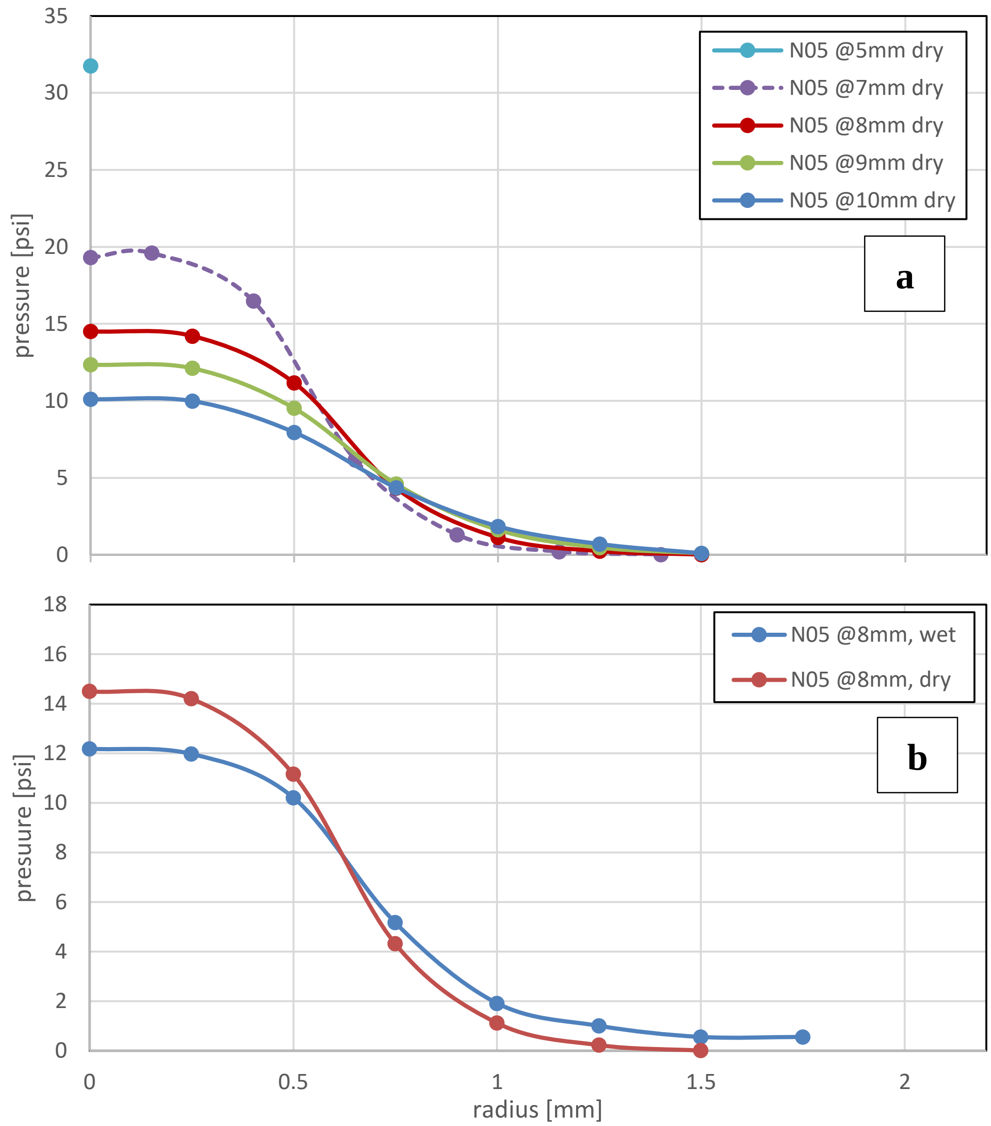
from the surface the jets become more similar to each other and rounder. However due to the assymetric configuration the outer jets are seen to bend outwards, increasing with distance from the surface (as indicated by arrow in Fig. 3a). On the other hand the jets become rounder (as shown in Fig. 3b). Here the safe distance was found to be just above 8mm – very similar to the single jet, though with a much different overal distribution (compare Fig. 3a to Fig. 2a).



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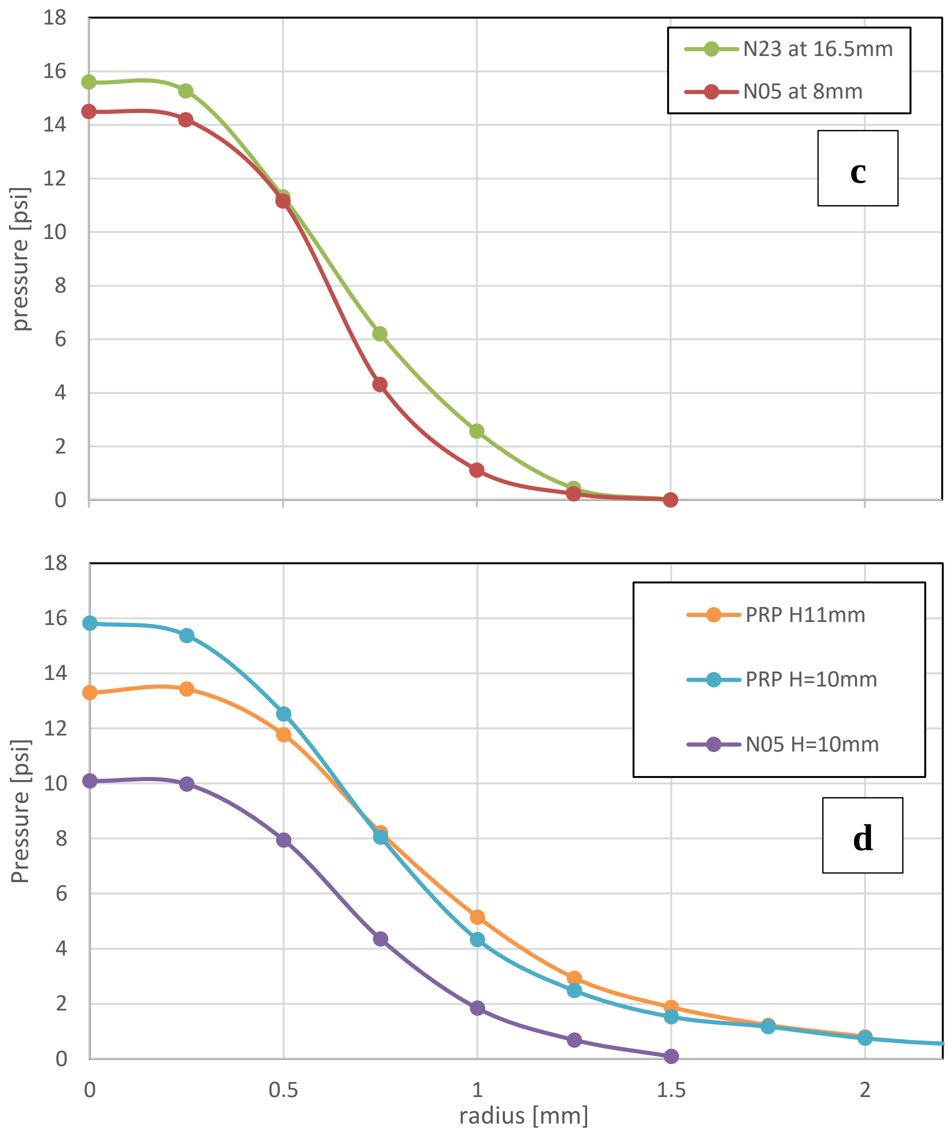

Fig. 2: Single jet nozzle pressure comparisons: a) Reference case – single 0.5mm jet and its dependence on distance from the impinged surface; b) comparison of wet (saline droplets) vs. dry working conditions; c) comparison to a wider single jet – 0.8mm, which requires greater working distance; d) comparison to the same diameter jet with the addition of an air shield – generates a wider impinged zone.

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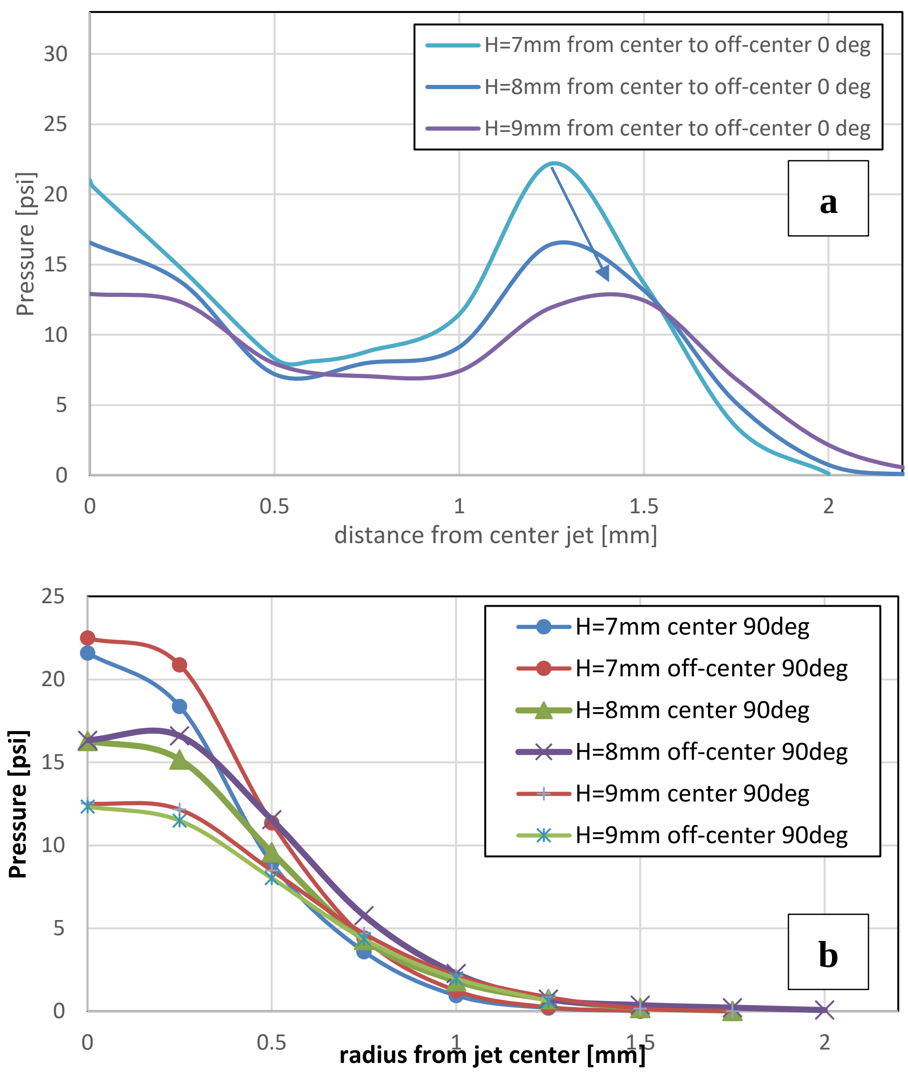

Fig. 3: Multi jet nozzle pressure comparisons: a) Triple 0.5mm jets inline (0 degrees), pressure along this line and its dependence on distance from the impinged surface; b) comparison of

It is therefore safe to conclude that all nozzle heads **can meet the pressure limits** on the surface, if identified key distances are met (as listed above).

Further details of these measurements and findings can be provided, upon request.

Sincerely,

Herman Haustein, PhD, Tel Aviv University