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Single Spray Nozzle Tests

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Abstract

This report summarizes the measurement results of single spray nozzle tests carried out in a testing station specifically built for this purpose at Lappeenranta University of Technology (LUT) in 2015. Water was injected through a spray nozzle and the developed droplet distribution was measured with the shadowgraphy application of the PIV system.

The main objective of the tests was to get experience from the use of the shadowgraphy application in order to be able to evaluate its suitability for demanding measurements of different characteristics of spray nozzles. The need for such measurements in Nuclear Engineering Laboratory at LUT emerged when studies focusing on spray operation in nuclear power plant containments were included in the research plan of the INSTAB project of the SAFIR2018 programme.

Five different measurement positions were selected underneath of the spray jet to be used in the tests. The interest was to find out if it has any effect on the droplet size distribution when the measurement area is shifted vertically and horizontally. The majority of the droplets were in the size range of 0.2-0.8 mm in the centreline positions whereas the droplet distribution was broader in the two other positions, which were 300 mm away of the centreline axis.

There are many user-defined parameters in the shadowgraphy application which are used for processing of the particle images. The selection of these parameters has a strong effect on the measurement results and therefore emphasis should be put to making the experimental arrangement as simple as possible.

The measured droplet size distributions revealed that the scaling factor of the used application was too large for these tests in order to get a full range of different droplet sizes. In future spray nozzle tests the camera of the PIV system should always be placed as close to the measurement area as possible in order to get the scaling factor to be as small as possible.

Key words

containment spray, shadowgraphy, full cone nozzle

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SINGLE SPRAY NOZZLE TESTS

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Distribution

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Heikki Purhonen, Research Director	SAFIR2018 limitations

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Disclaimer

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CONTENTS

NOMENCLATURE

Latins

D	diameter	[mm]
D_{10}	average diameter	[mm]
D_{32}	Sauter mean diameter	[mm]
h	vertical distance	[mm]
n	sample size	[-]
N	number of sample images	[-]
x	vertical distance	[mm]
y	horizontal distance	[mm]

Abbreviations

COPSAR	Containment Pressure Suppression Systems Analysis for Boiling Water Reactors project
INSTAB	Couplings and instabilities in reactor systems project
LUT	Lappeenranta University of Technology
NKS	Nordic nuclear safety research
NORTHNET	Nordic Nuclear Reactor Thermal-Hydraulics Network
PIV	particle image velocimetry
SAFIR2018	National nuclear power plant safety research programme
VTT	Technical Research Centre of Finland
VYR	State Nuclear Waste Management Fund

1 INTRODUCTION

The need to size spray droplets in Nuclear Engineering Laboratory at Lappeenranta University of Technology (LUT) emerged when studies focusing on spray operation in nuclear power plant containments were included in the research plan of the INSTAB project of the SAFIR2018 programme. The existing PIV system was upgraded to allow the execution of shadowgraphy measurements. The initial spray droplet measurements are performed in a simplified testing environment as the shadowgraphy application is an optical measurement system and it is beneficial to keep the experimental setting as simple as possible to guarantee the best possible optical environment. Initially a preliminary test facility was constructed for training purposes but it was soon found out that its features were not adequate to test sprays with a capacity size bigger than 10 l/min. Thus an improved testing station was constructed. In this report the new testing station and the series of experiments conducted with it are presented and follow-up developments are discussed.

2 TESTING STATION FOR SPRAY MEASUREMENTS

2.1 PRELIMINARY TEST FACILITY

For introductory training by the PIV system supplier and for preliminary spray testing a small scale spray testing station was constructed. The spray nozzle was installed with simple pliers to a pallet hoist that could be lifted to a 1300 mm elevation from the ground level. The injected water was taken from a simple tab water line with a maximum pressure of 7 bar. The water inlet line had a pressure gauge to measure the pressure of the injected water and it had a ball valve to control the pressure.

After some experience from the preliminary testing station was gained a more developed testing environment was decided to be constructed. It should allow more flexible positioning of the spray outlet towards the camera and diffuser and altogether enable more convenient approach to shadowgraphy measurements of sprays in the future.

2.2 CURRENT TEST FACILITY

An improved version of the testing station was designed and constructed taking into account the experiences gained from the preliminary testing environment. In the new testing station the spray can be moved along three axis towards the measurement area with better precision. The centreline of the spray, or the centre of the spray outlet, can be defined within a millimetre range from the measurement area. The adjustments are made manually. The centreline position is defined with a plumb line when calibrating the system and defining the measurement area. The spray is attached to an extension pole that is fixed to a rigid frame. The pole can be moved vertically and the fixing can be moved horizontally.

To produce pressures over the normal operating pressure, a pump is installed to the water line. In the line there is also measurement instrumentation for pressure, volumetric flow and temperature. The values of pressure, volumetric flow and temperature are recorded with LabView 2104 software. The maximum possible volumetric flow is around 240 l/min. The measuring setup is presented in the Figure 1.

Figure 1. New measuring setup for spray studies.

The camera is protected in a plastic box with a viewing window. The diffusor is protected with a cone as the spray droplets would otherwise wet the diffusor lens creating shadows to the background light. The cone is 520 mm long. The measurement area has a wooden rail on the floor in order to keep the water not flowing freely to laboratory space as can be seen in the Figure 2.

The sides of the wooden rail are 3040 mm x 3050 mm with a height of around 13 mm. The spray nozzle is hanging from the pole that is secured to a rigid support frame. The spray can be lifted 2700 mm above the floor level. The sprayed water is collected to the sewer.

Figure 2. The spray testing station with the support structure and the wooden rail.

A need to update the imaging system by acquiring a lens with a larger focal length emerged during the tests conducted in the preliminary testing facility. In order to get the scaling factor small enough with the existing 110 mm lenses, the camera should have been placed physically too close to the spray depending on the case. Two lenses with different focal lengths were tested and the scaling factors after calibrating the camera to an image plane are plotted in the Figure 3.

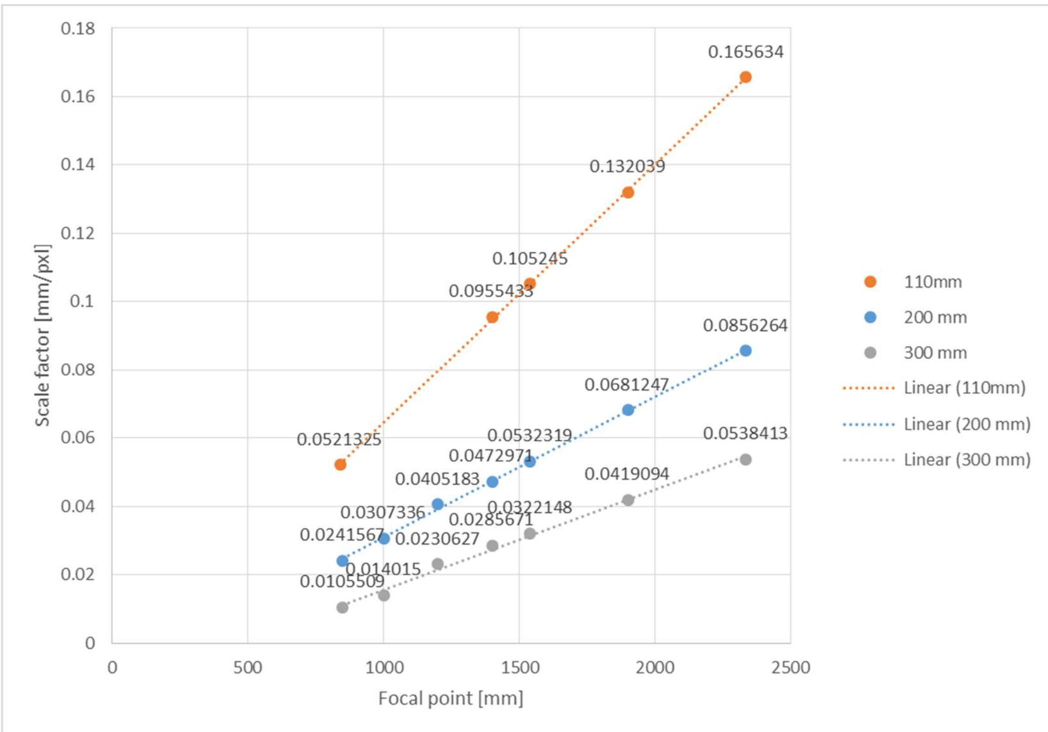

Figure 3. Different scaling factors depending on the focal point of the lens.

As it is beneficial to have as small a scaling factor as possible the imaging system was upgraded with a Tamron 70-300 mm zoom lens. With the new zoom lens it is also possible to get the scaling factor down thus enabling measurements of smaller droplets as well as more freedom in the placing of the camera away from the spray. The imaging system for the shadowgraphy measurements include LaVision's Imager Pro X 4 megapixel camera. For protection purposes the imaging system is placed inside a sealed plastic cover box.

3 PROCESSING OF THE PARTICLE IMAGES

Shadowgraphy is an optical measuring technique that uses bright, pulsed background light to create shadows from the measured particles. The images are recorded with digital camera and for the backlight, a laser is used with a diffuser. The diffuser breaks down the laser beam into a larger illuminated area. The illuminated area is not uniformly lit due to the fact that the laser beam has an intensity profile that is in Gaussian shape. Misalignment of the diffuser compared to the camera can also have an effect on the intensity profile. The measuring volume is defined by the focal plane and the depth-of-field of the imaging system. Particles outside the measuring volume have blurred outlines. The shadowgraphy images are recorded and analysed with LaVision's ParticleMaster Shadow software.

3.1 INVERTING THE PARTICLE IMAGE

The analysing software initially inverts the recorded particle image making the shadowed areas bright and vice versa. The inversion is made by subtracting the shadow image from the background reference image. The reference image represents the background light created by the diffuser. An example of the process is presented in the Figure 4.

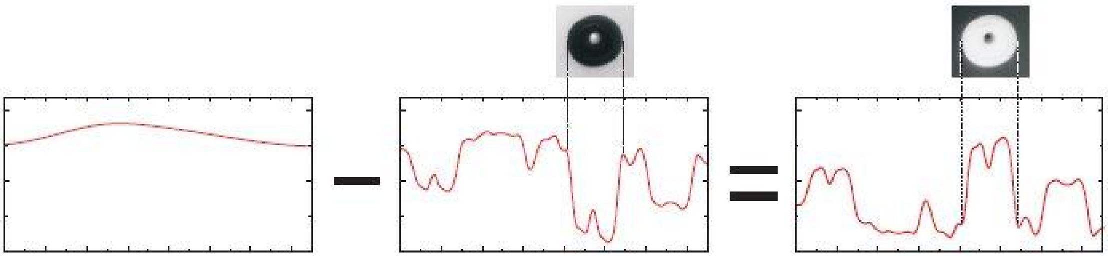

Figure 1. Shadow images are inverted by the analysing software [1].

The reference image (left in Figure 4) is the reference background image. When the background image is not constant the reference background image is calculated for each shadow image separately. This is usually the case when the laser's pulse is not stable or the spray pattern is dense.

3.2 PARTICLE RECOGNITION

The sizing algorithm does the sizing in two steps. First, the user defines a value above a threshold which will be a percentage between the maximum and the minimum intensity in the inverted shadow image. The algorithm tries to find coherent areas that are above the threshold value and arranges a rectangle around the pixels that are adjacent to each other as well as above the threshold intensity level. The pixels that meet these two requirements belong to a single segment. Any pixel below the threshold value will be discarded. As the threshold value is dependent on the relation of the maximum and minimum intensities in the images, an image without shadows can also have areas that are interpreted as shadows but are actually just noise. A user also defines a minimum shadowing value which means that in the inverted image the particle must exceed a constant value to be interpreted as a particle. In the case of noise the threshold value will be lower than the minimum shadowing intensity value.

3.3 PARTICLE PROPERTIES

After the first segmentation, the algorithm makes the second segmentation by defining a low level and high level value for the particle. In Figure 5 an example is presented.

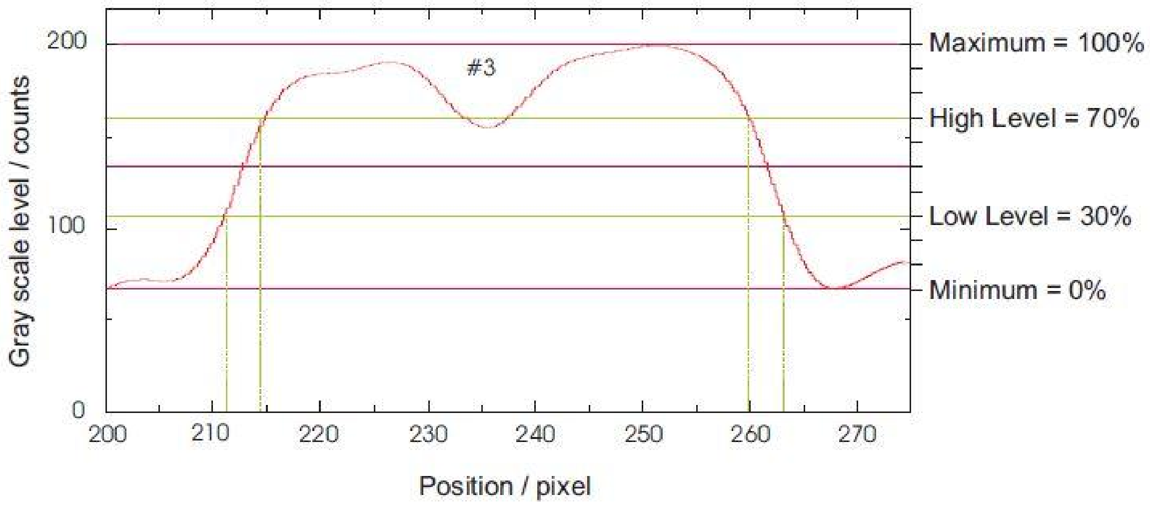

Figure 2. Low and high local threshold values [1].

The user can define the low level and high level values. Low level area will be larger than high level area in all cases. In case of a blurred out-of-focus particle the low level area, depending on the value, will be much larger than the high level area. In the analysing software there is an option to set a limit on how much larger the minimum area can be in relation to high level area thus getting rid of blurry particles. The diameter of the particle is defined to be the mean of the low level and high level diameter. Thus the diameter is always an estimate as the converted real life shadow image does not have a top hat shape.

4 SINGLE SPRAY NOZZLE TESTS

The preliminary testing series were conducted with a single full cone spray nozzle having an orifice diameter of 6.2 mm. The nozzle properties provided by the manufacturer are presented in Table 1 and Table 2 [2].

Table 1. Capacity of the spray nozzle used in the tests with different pressure values

Pressure over nozzle [bar]	0.5	1.5	0.7	1.5	2.0	3.0	4.0	6.0	7.0
Capacity [l/min]	11.8	13.1	15.2	22.0	25.0	30.0	34.0	41.0	44.0

Table 2. Spray angle of the nozzle used in the tests with different pressure values

Pressure over nozzle [bar]	0.5	1.5	6.0
Spray angle [deg]	88	91	83

The main purpose of the experiment series was firstly to test the new experimental setup and its feasibility in the future spray droplet size measurements. Secondly, the interest was also to look if it has any effect on the results when the measurement area is shifted vertically and horizontally. In total five different measurements were conducted in three different vertical positions and three different horizontal positions keeping the middle point the same in the vertical and horizontal measurement series. The vertical points were in the spray's centreline. The main parameters for the measurement points are presented in the Table 3.

Table 3. Vertical and horizontal distances for the experiments

	x [mm]	*h* [mm]	*y* [mm]
position 1	800	1900	0
position 2	400	1500	0
position 3	1200	2300	0
position 4	800	1900	300
position 5	800	1900	-300

In Table 3, x is the vertical distance from the nozzle tip to the centre point of the measurement area, h is the vertical distance from the nozzle tip to the ground and y is the horizontal distance from the nozzle tip to the centre point of the measurement area (negative value indicates the position to be on the left side of the centreline from camera's point of view).

Pressure over the nozzle was chosen to be around the capacity size of the tested nozzle. The measured pressure values are presented in the Figure 6. The measured volumetric flow rates and temperatures of injected water are presented in Figures 7 and 8. In these figures time is on the horizontal axis. The zero point indicates the time for the first particle image. The last image was taken at 166.70 seconds.

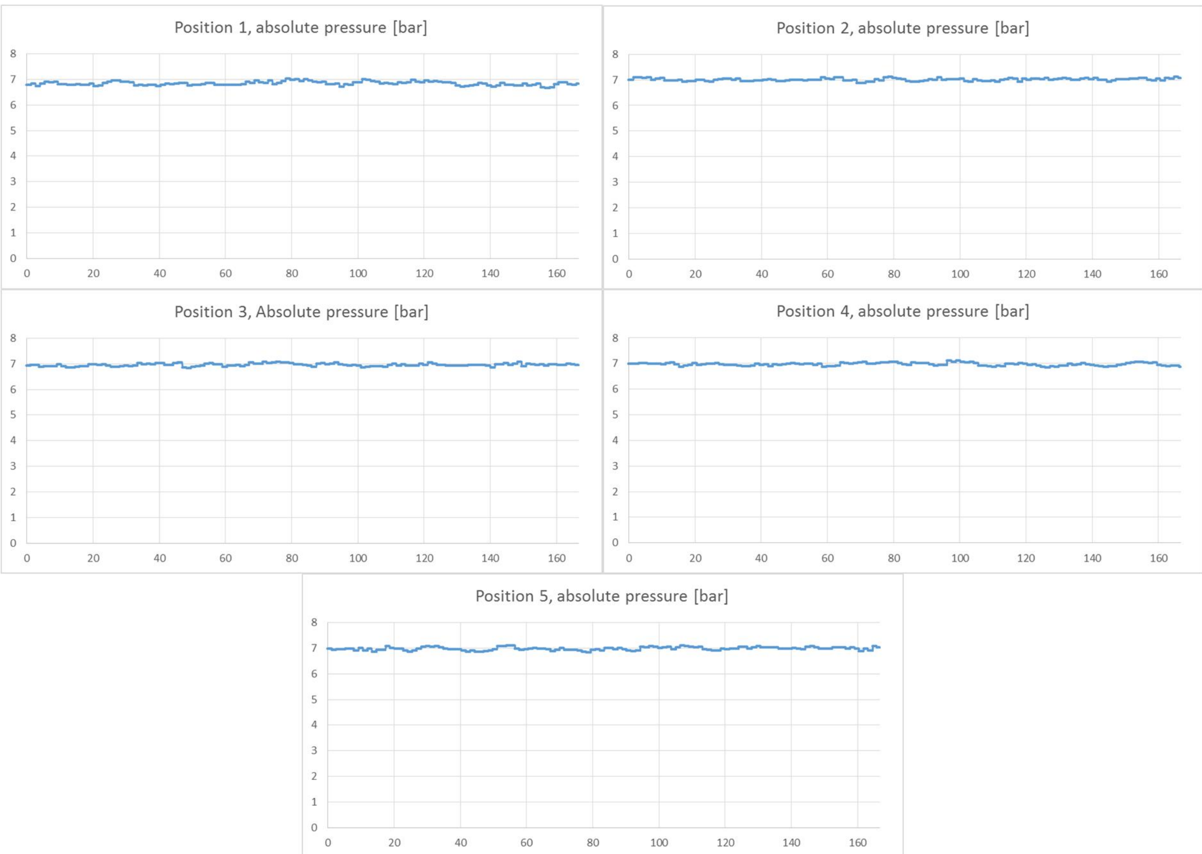

Figure 6. Pressure over the spray nozzle in the five different experiments.

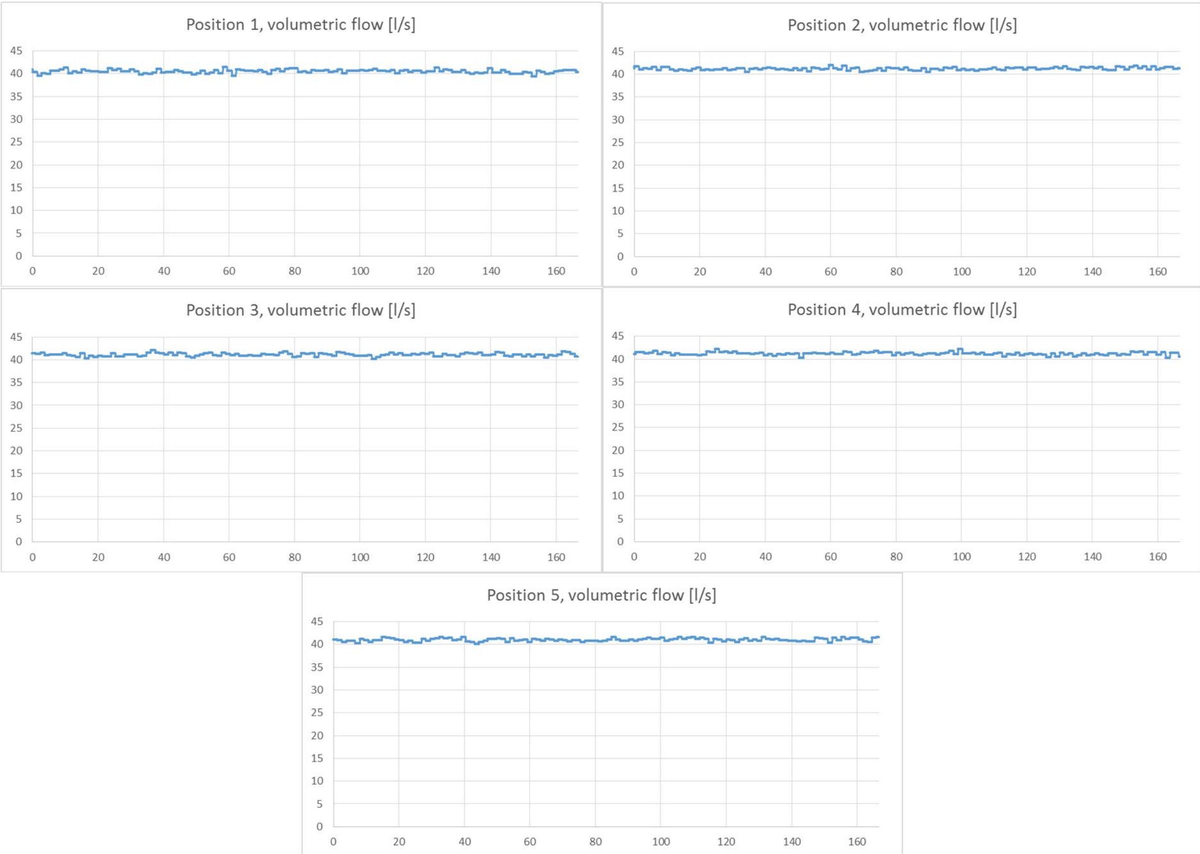

Figure 7. Measured volumetric flow rate of injected water in the five different experiments.

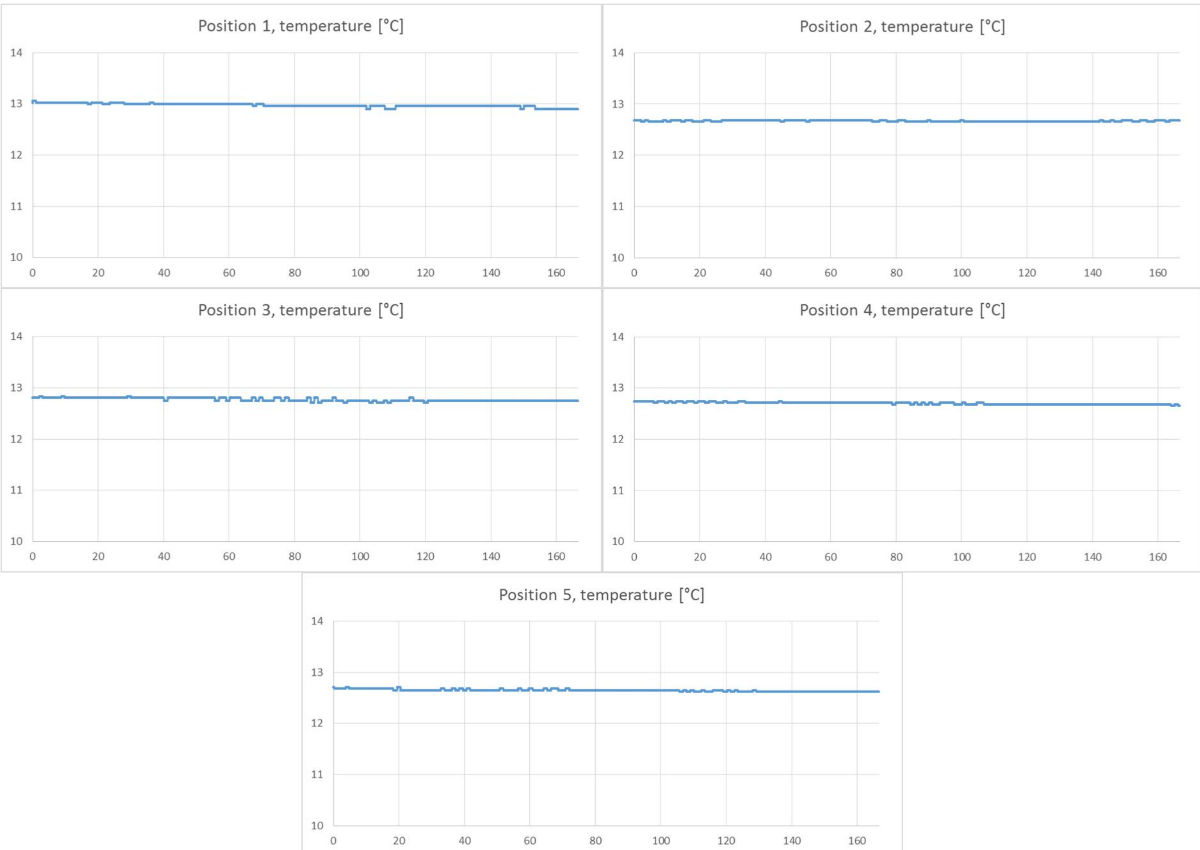

Figure 8. Measured temperature of injected water in the five different experiments.

As can be seen from Figures 6, 7 and 8 the pressure over the spray nozzle as well as the flow rate and temperature of injected water stayed rather constant throughout the measurement series.

5 ANALYZING PARAMETERS

The particle images were analysed with DaVis' ParticleMaster Shadow analysing software. The post-processing for the particle data was done with Excel. As stated before, user must define a global threshold value as well as local low and high threshold values in order for the software to size the particles. In addition there are other options for user to define. For example the maximum ratio of the low level and high level diameters must be given.

The spray was too dense for performing the inversion properly by using normal background light's reference image. The laser pulse was also too unstable for creating unified background light from shot to shot. Thus, a sliding maximum filter having a filter kernel with a 65 pixel radius was used for background light calculation. An example of a shadow image and resulting inverted shadow image is presented in Figure 9.

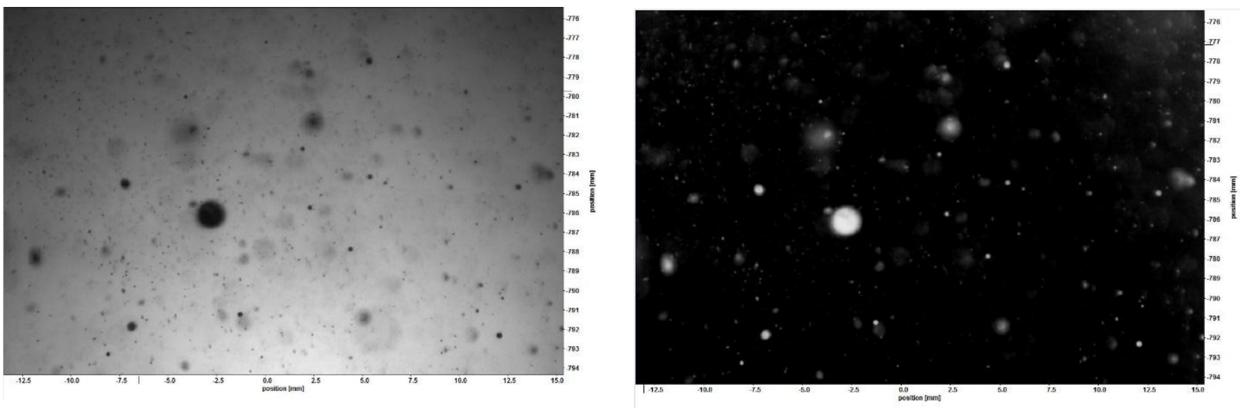

Figure 9. Shadow image on the left and inverted shadow image on the right.

For the global segmentation a threshold of 40 % for the intensity was chosen. An example of global segmentation is presented in Figure 10.

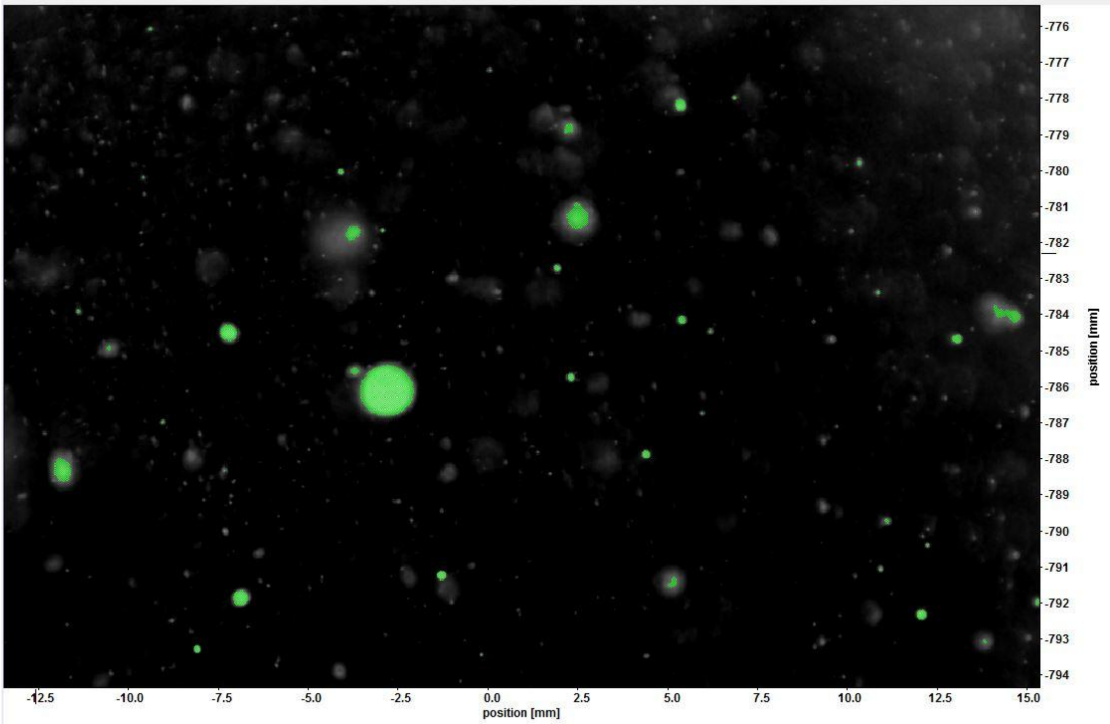

Figure 10. Global segmentation.

As it can be seen from Figure 10 the intensity should be chosen to be low enough to segment even the parts of the out-of-focus particles. The final low and high level thresholding should allow to get rid of the out-of-focus particles. An example of partly segmented out-of-focus particles is shown in Figure 10 in the position (-3.5, -782). For the local low threshold a value of 40 % was chosen and for the high threshold 60 % was chosen. The values were chosen after looking through a sample of result images. The final particle image is shown in Figure 11.

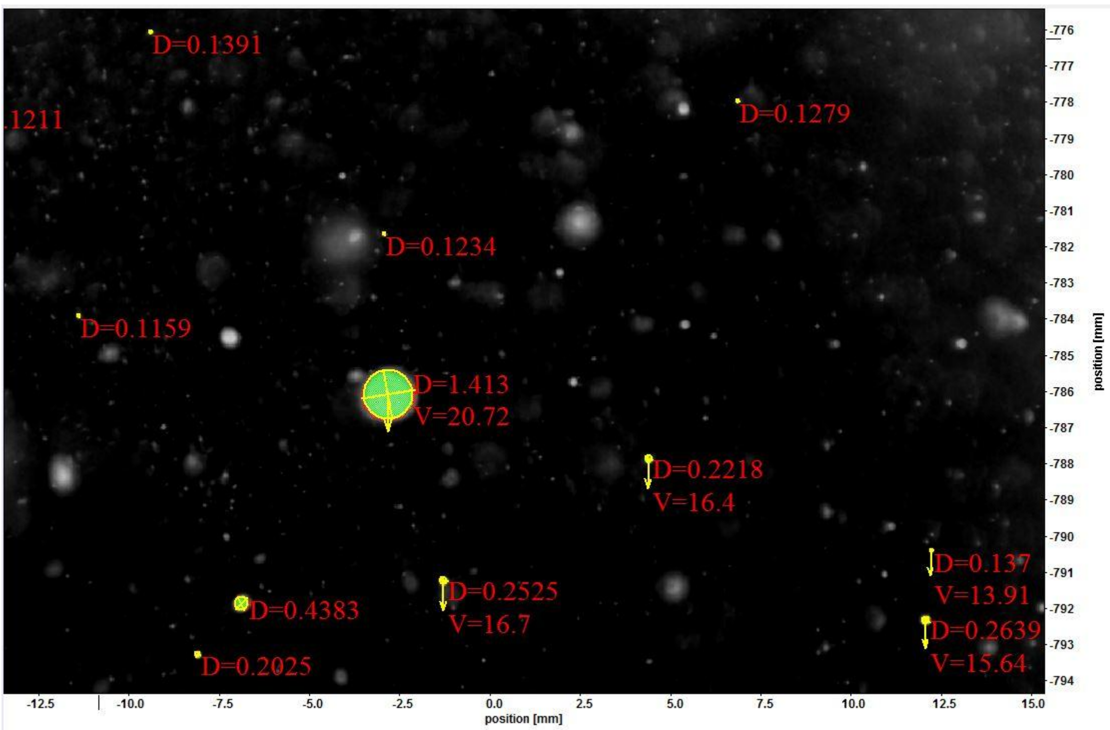

Figure 11. Final result after global segmentation and local threshold values.

As it can be seen from Figure 11 the worst out-of-focus particles has been got rid of in the final particle image. A good example is the particle in the position (-3.5, -782) as it has now been discarded by the low and high threshold values.

From the previous figures it can be seen that it is important to choose correct values for the global and local thresholds to get most of the in-focus particle images to be taken into account in the particle analyses. The downside of the shadowgraphy application is that the user is left with choosing the parameters and there is a lot of interpretation involved before the final result is obtained. Thus making the optical arrangement as simple as possible is crucial. Note that the whole field-of-view is not presented in the figures above.

5.1 SAMPLE SIZE DETERMINATION

The adequate number of measured droplets to reach statistically reliable result is determined by choosing a sample size where the result converges. The effect of sample size on droplet size distribution as well as on average diameter and Sauter mean diameter was investigated.
The average particle diameter is calculated:

$$D_{10} = \frac{\sum_{i=1}^{n} D_i^1}{n}$$

where D_{10} is the average diameter and n is the sample size.

The Sauter mean diameter is the diameter of droplet having the same volume to surface fraction as the entire ensemble of droplets. The Sauter mean diameter is calculated:

$$D_{32} = \frac{\sum_{i=1}^{n} D_i^3}{\sum_{i=1}^{n} D_i^2}$$

Where D_{32} is the Sauter mean diameter.

In the experiments a certain sample number was chosen (N=1000 particle images) to guarantee large enough sample size. With post-processing of the particle data it is possible to make the sample size constant throughout the different series even if multiple measurements are done. In Table 4, the amount of particles that were analysed within the 1000 image series from the different positions in the spray are presented.

Table 4. Number of analysed particles in a 1000 image series

	number of analysed particles [-]
Position 1	98356
Position 2	167414
Position 3	90828
Position 4	167461
Position 5	182668

With the chosen parameters the amount of analysed particles differed from position to positon as expected because the spray is denser the closer it is to the nozzle tip. Interestingly, it seems that the spray is sparser in the centreline. This conclusion can be made if we compare the number of droplets in positions 1, 4 and 5 which are at the same vertical elevation but horizontally either in the middle or 300 mm aside, see Table 2. There is also a clear difference in the number of droplets between the positions 4 and 5. These two numbers should be almost equal assuming that the spray is homogenous at the same horizontal distance from the centreline. This could either indicate that the spray is not homogenous or the difference is due to wrong analysing parameters. In future the density of the droplet flux will be measured with a simple construction made of identical size boxes and placed beneath the spray nozzle. This should give an indication how the droplet flux differs in different parts of the spray.

The values of the average diameter and Sauter mean diameter against the sample size were plotted. Figure 12 shows how the average diameter value for position 1 depends on the sample size.

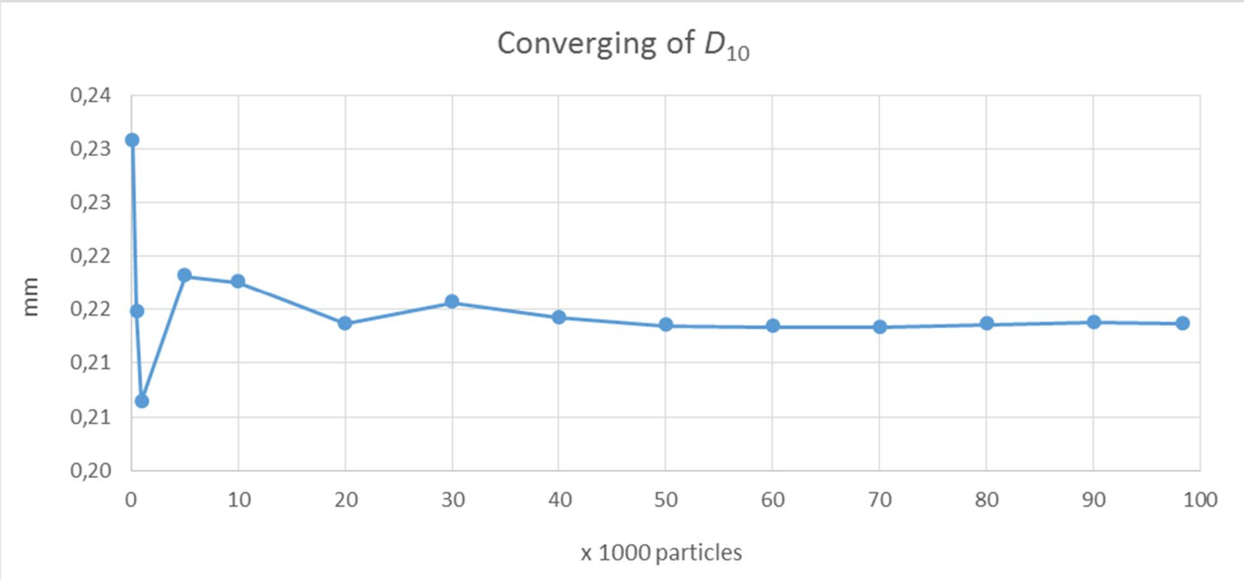

Figure 12. The average droplet diameter against the sample size in position 1.

It can be seen from Figure 12 that after the sample size is bigger than 50000 particles the average diameter stays almost constant. The convergence of the Sauter mean diameter can be seen from Figure 13.

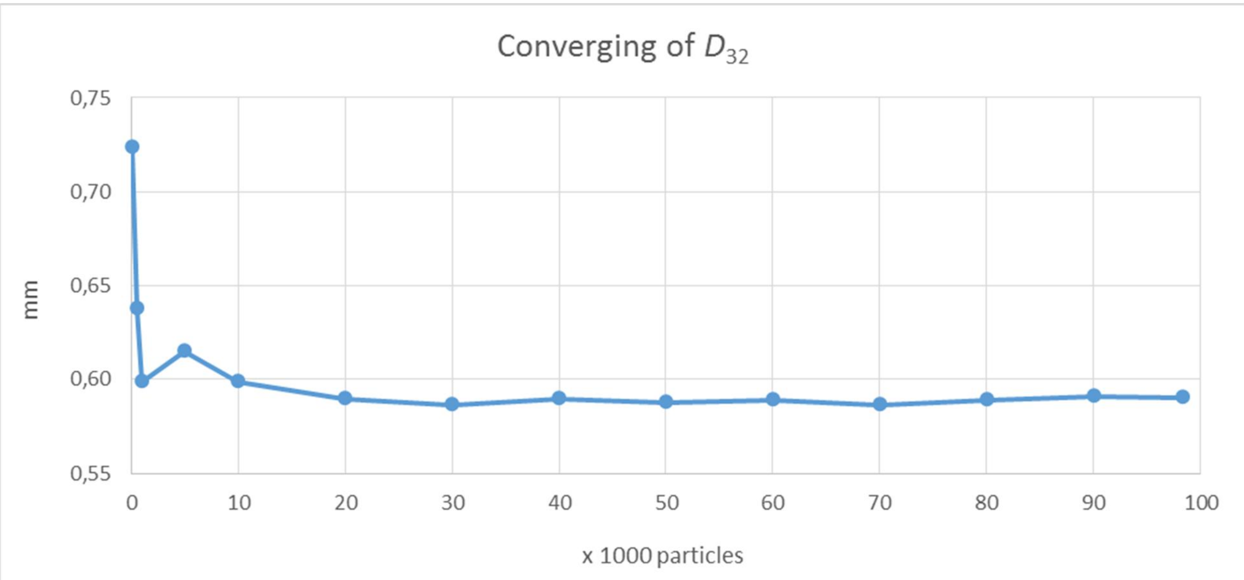

Figure 13. The Sauter mean diameter of the droplets against the sample size in position 1.

From Figure 13 it can be seen that if the sample size is bigger than 20000 particles the value of the Sauter mean diameter is almost constant. In Figure 14 the normalized droplet size distribution with the whole sample and with sample sizes of 20000 particles and 50000 particles is presented.

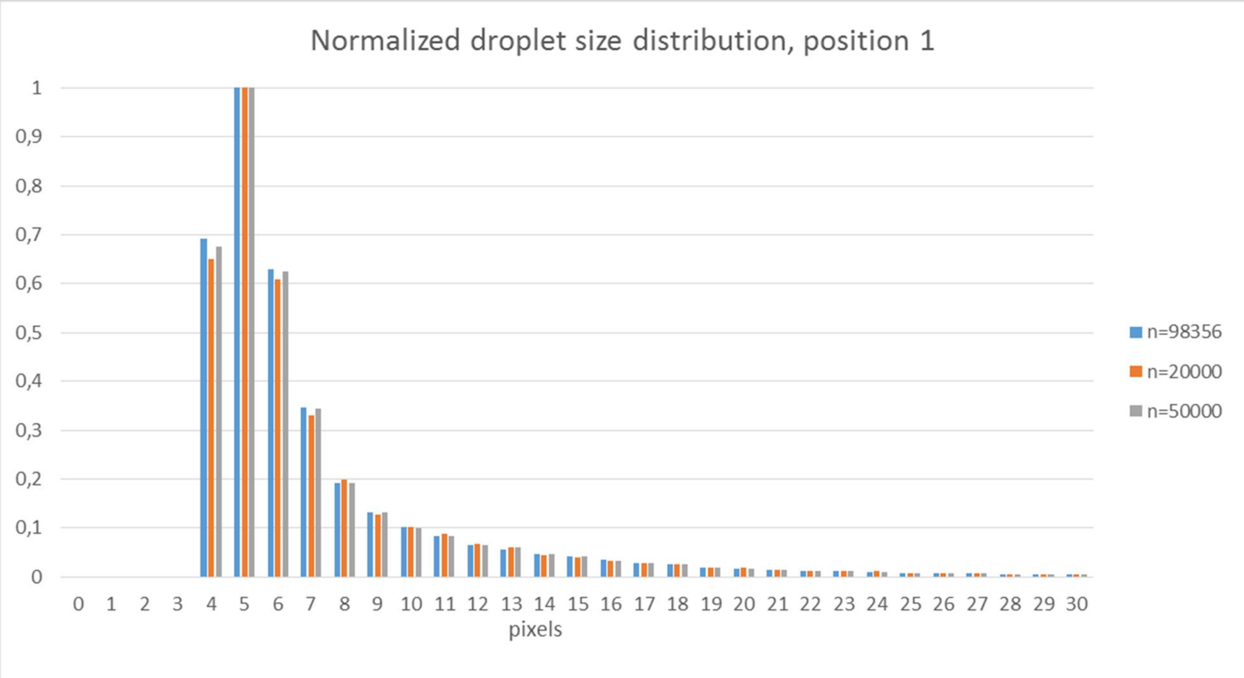

Figure 14. Normalized droplet size distribution with different sample sizes presented with bins which are multiples of the scaling factor.

The bins were chosen to be multiples of the pixels (within the first 30 pixels, one pixel being 0.0303623 mm as according to scaling factor). The majority of the particles are in the size range of 4-5 pixels (0.121449 mm – 0.151812 mm). Three pixels is the lowest limit for the software to be able to analyse the droplet. Thus, the size distribution is cut from the beginning. Taking into account the convergence of the average and Sauter mean diameters and the droplet size distribution the valid sample size seems to be around 50000 particles, although the sample size of 20000 particles represents the whole sample almost as well. The sample size of 50000 particles gave similar results also in other positions.

The measuring frequency was chosen to be low so that every shadowgraphy image is an independent event. This means that all the droplets in image n are out of image n+1. Because the measurement area is vertically 50 mm long it takes 0.005 seconds for a droplet having a vertical velocity of 10 m/s to travel through the measurement area. This is equivalent to the measuring frequency of 200 Hz. In the tests the measurement frequency was chosen to be 6 Hz. This is also the highest possible measurement frequency of the system.

6 RESULTS

6.1 POSITION 1

For position 1 the centre point of the measurement area was chosen to be 800 mm beneath the nozzle tip and 1900 mm above the ground elevation in vertical direction and at the centreline in horizontal direction. The particle size distribution with a 0.01 mm bin size is presented in the Figure 15.

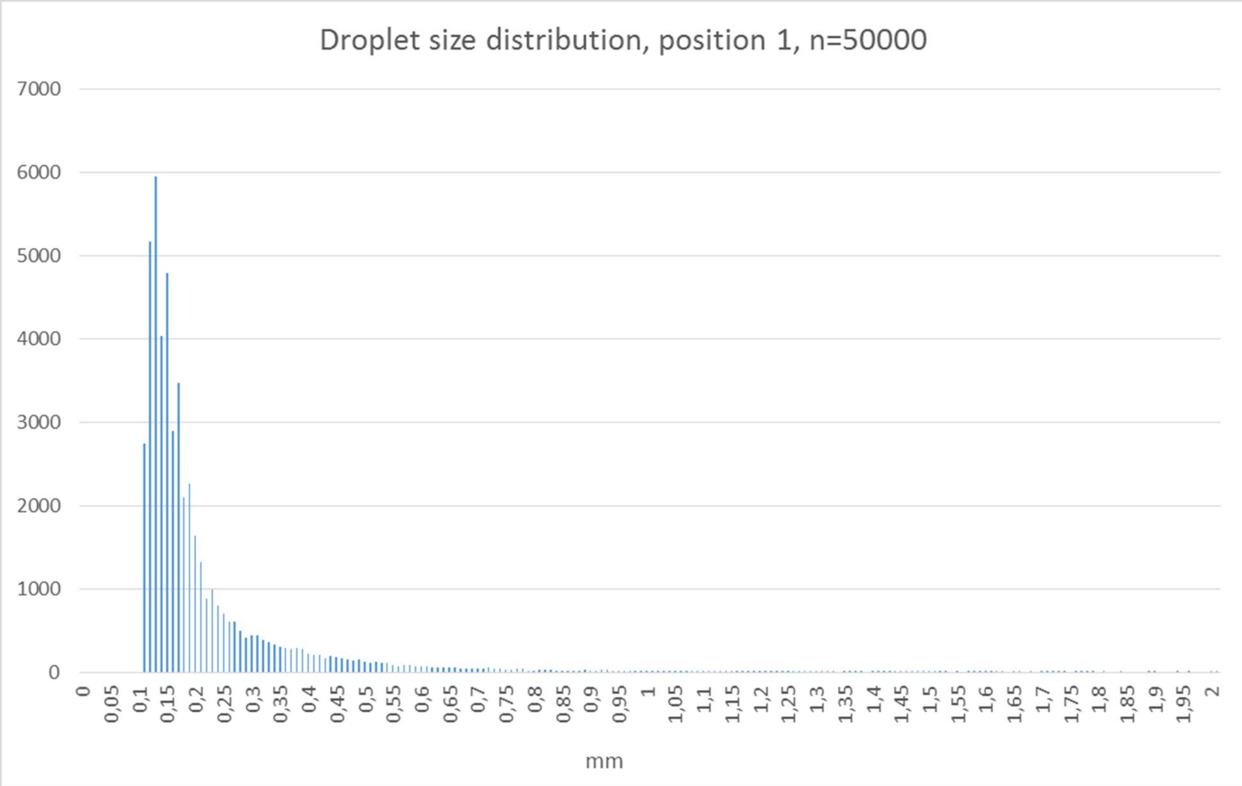

Figure 15. Droplet size distribution with the whole sample in position 1.

The majority of the sized particles are below 0.80 mm. The droplet size distribution from 0 to 0.80 mm is presented in more detail in Figure 16.

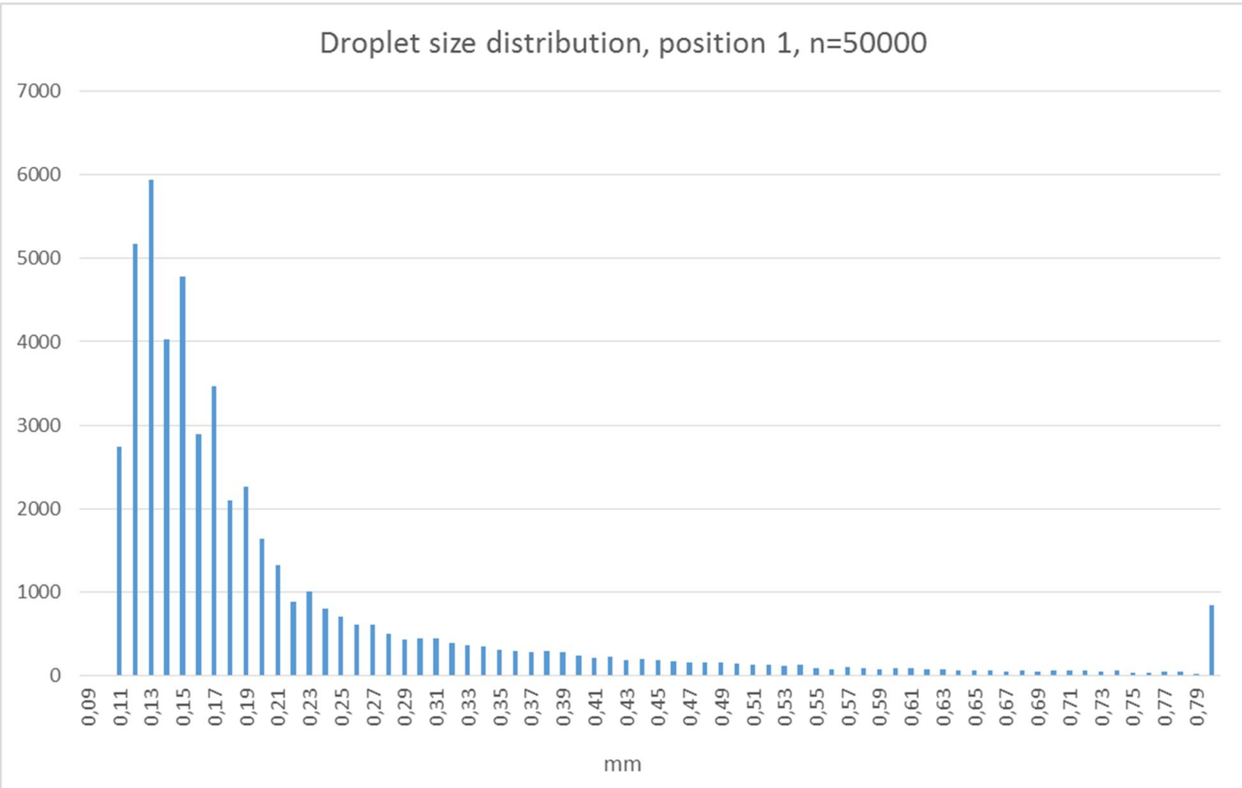

Figure 16. Droplet size distribution from 0 to 0.80 mm in position 1.

The last bin is the sum of all the droplet diameters larger than 0.80 mm. The shape of the droplet size distribution is not smooth even with the whole sample as the ratio of the size of the pixel to the droplet diameter is too large. Thus, it is better to choose the bin size as multiples of pixels. The same droplet size distribution with bins as multiples of pixel size is presented in Figure 17.

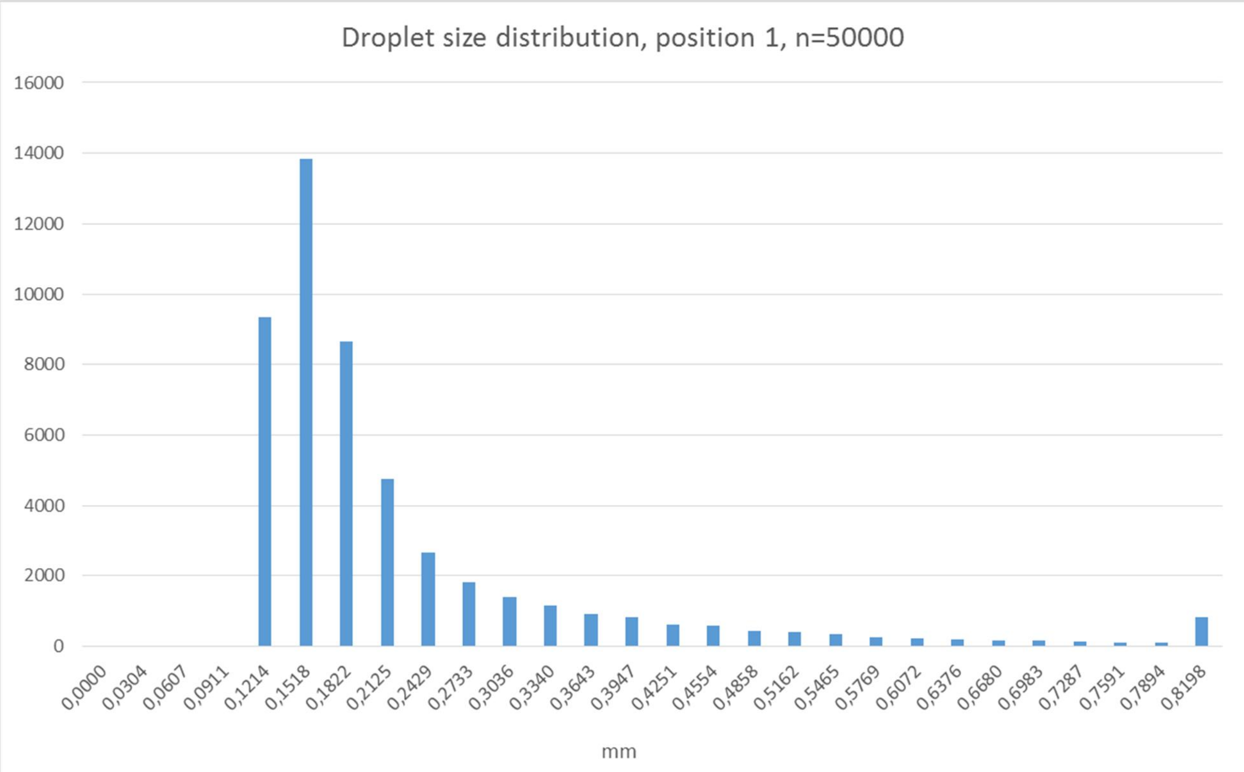

Figure 17. Droplet size distribution in position 1 presented with bins which are multiples of the scaling factor.

The distribution looks smoother now when the bin size has been chosen according to the pixel size. This indicates that the majority of the droplets are too small compared to the scaling factor. There are 9358 droplets in the bin of 3-4 pixels which is the lowest limit for a droplet with the scaling factor used in the experiments.

In Table 5, the average diameter and Sauter mean diameter values for position 1 with the whole sample and with the sample size of 50000 particles are presented.

Table 5. Average diameter and Sauter mean diameter for position 1 for different sample sizes

	D_{10} [mm]	D_{32} [mm]	stdev
n = 98356	0.214	0.590	0.163
n = 50000	0.213	0.587	0.162

6.2 POSITION 2

For position 2 the centre point of the measurement area was chosen to be 400 mm beneath the nozzle tip and 1500 mm above the ground elevation in vertical direction and at the centreline in horizontal direction. The droplet size distribution is presented in Figure 18.

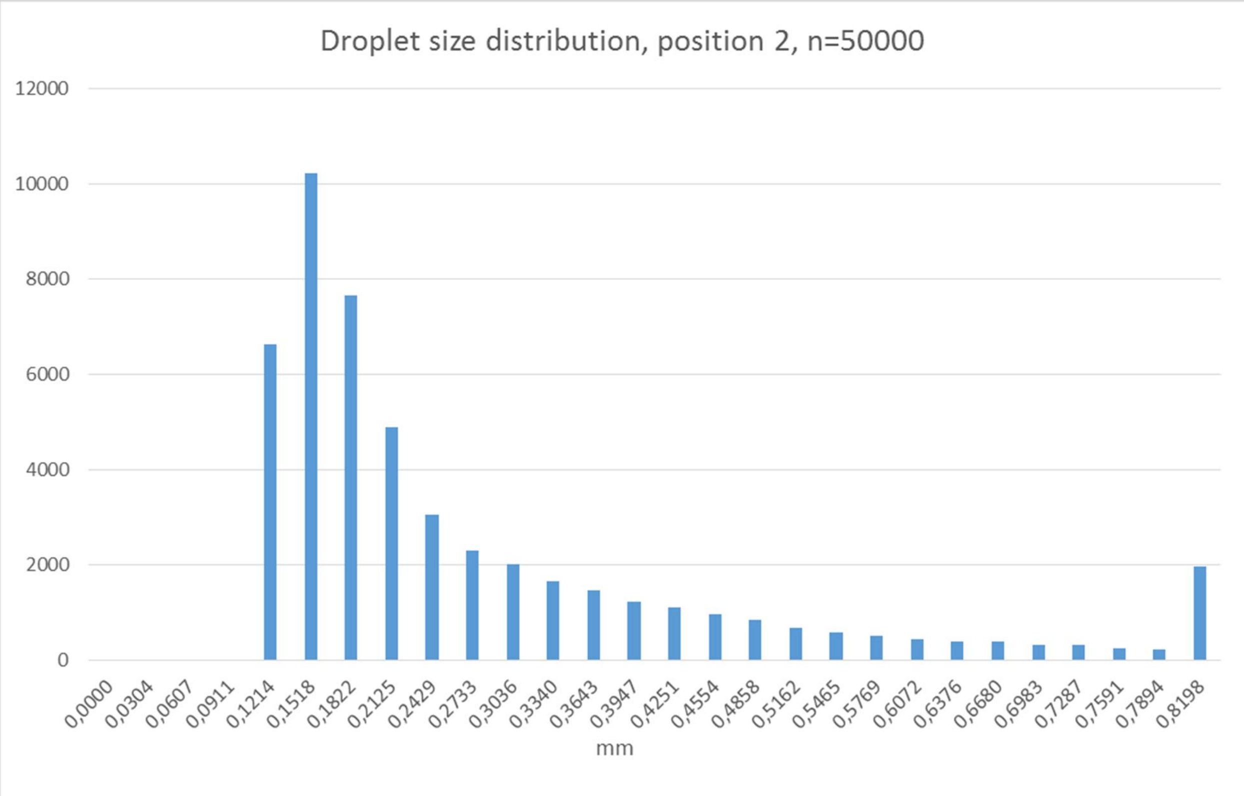

Figure 18. Droplet size distribution in position 2 presented with bins which are multiples of the scaling factor.

Similarly to position 1 the distribution is cut at the low end because of the scaling factor. In Table 6, the D_{10} and D_{32} with the sample size of 50000 particles are presented.

Table 6. Average diameter and Sauter mean diameter for position 2

	D_{10} [mm]	D_{32} [mm]	stdev
n = 50000	0.272	0.733	0.221

6.3 POSITION 3

For position 3 the centre point of the measurement area was chosen to be 1200 mm beneath the nozzle tip and 2300 mm above the ground elevation in vertical direction and at the centreline in horizontal direction. The droplet size distribution is presented in Figure 19. In Table 7, the D_{10} and D_{32} with the sample size of 50000 particles are presented.

Table 7. Average diameter and Sauter mean diameter for position 3

	D_{10} [mm]	D_{32} [mm]	stdev
n = 50000	0.193	0.494	0.130

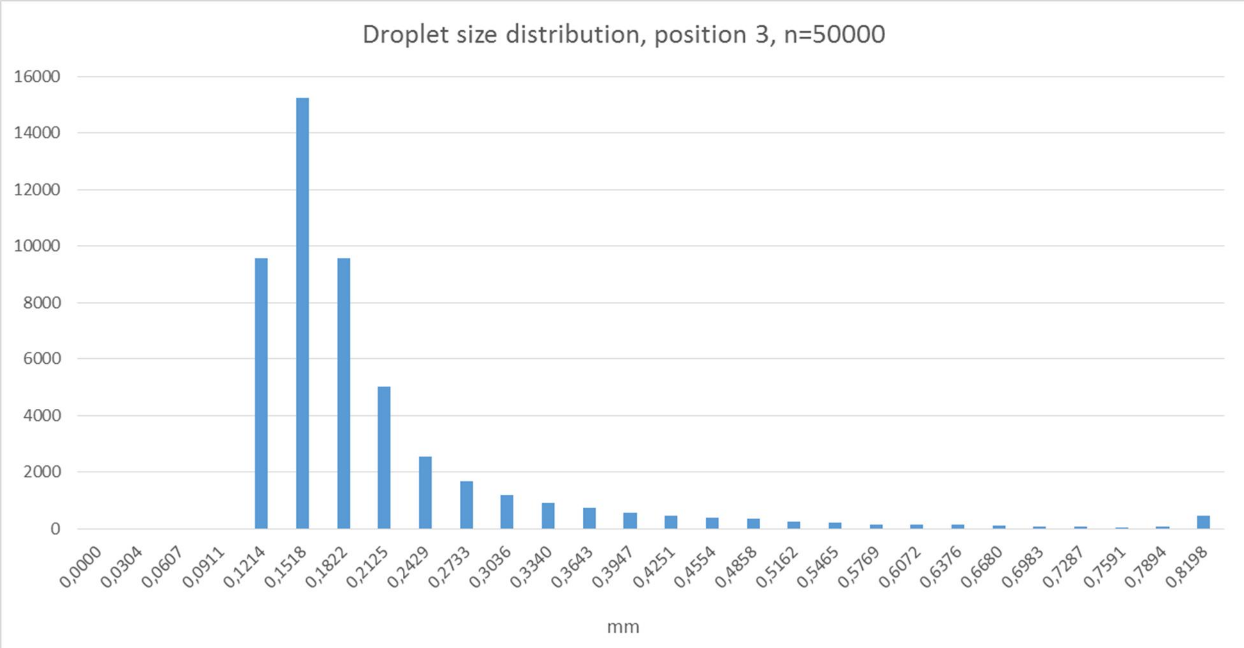

Figure 19. Droplet size distribution in position 3 presented with bins which are multiples of the scaling factor.

6.4 POSITION 4

Vertically position 4 was at the same elevation as position 1 but horizontally 300 mm on the right side of the centreline of the nozzle. The droplet size distribution is presented in Figure 20.

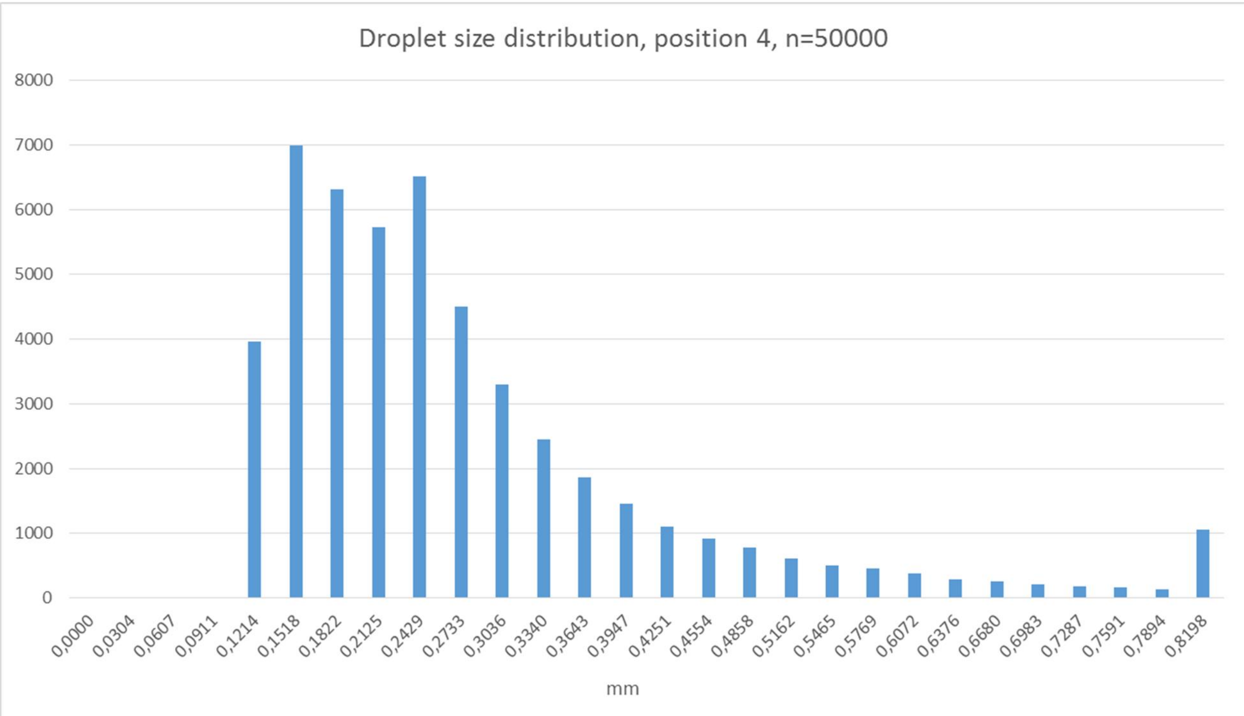

Figure 20. Droplet size distribution in position 4 presented with bins which are multiples of the scaling factor.

From Figure 20 one can see that the shape of the droplet size distribution in position 4 looks drastically different than the distributions in the centreline positions presented in the previous chapters. The D_{10} and D_{32} with the sample size of 50000 particles are presented in Table 8.

Table 8. Average diameter and Sauter mean diameter for position 4

	D_{10} [mm]	D_{32} [mm]	stdev
n = 50000	0.266	0.548	0.168

6.5 POSITION 5

Vertically position 5 was at the same elevation as position 1 but horizontally 300 mm on the left side of the centreline of the nozzle. The droplet size distribution is presented in Figure 21.

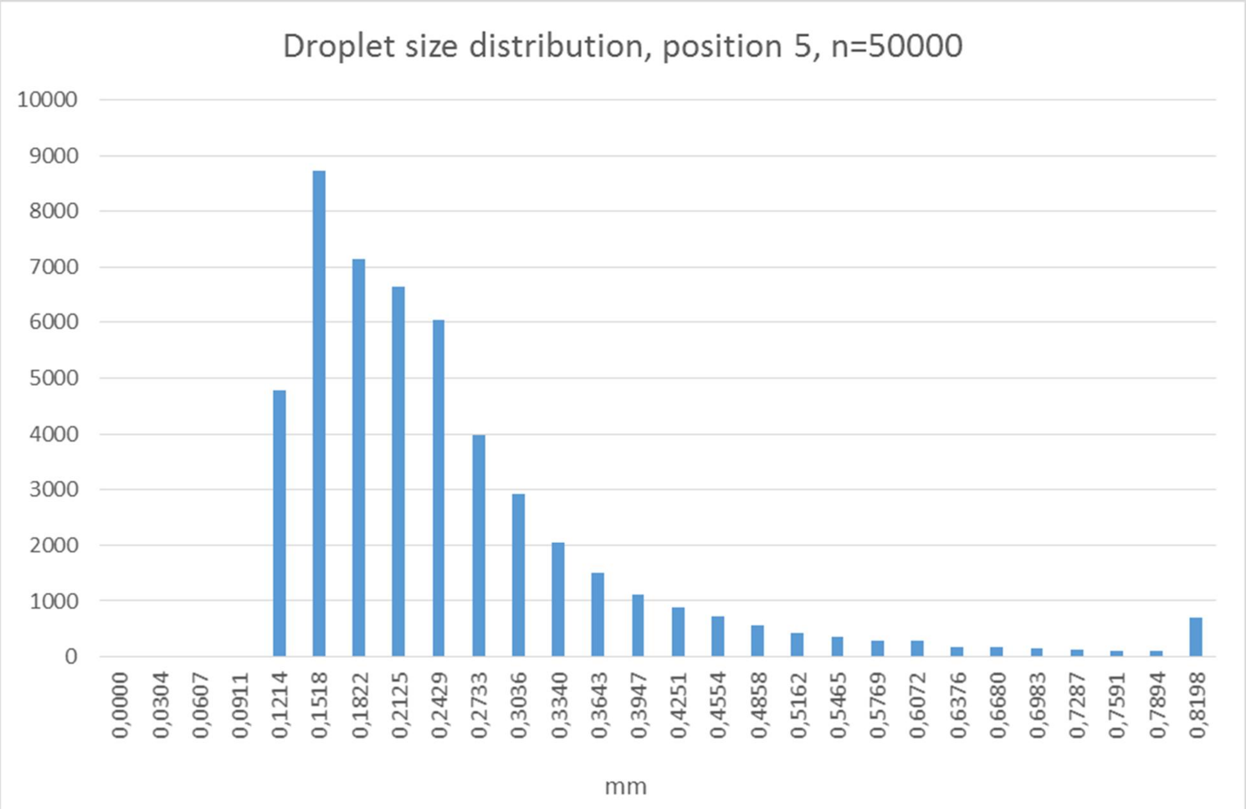

Figure 21. Droplet size distribution in position 5 presented with bins which are multiples of the scaling factor.

Also in position 5 the distribution is broader than in the centerline positions. In Table 9, the D_{10} and D_{32} with the sample size of 50000 particles are presented.

Table 9. Average diameter and Sauter mean diameter for position 5

	D_{10} [mm]	D_{32} [mm]	stdev
n = 50000	0.241	0.563	0.151

6.6 SUMMARIZED RESULTS FROM DIFFERENT POSITIONS

The average diameters and Sauter mean diameters from all the measurement positions with an equal sample size (n=50000) are presented in Table 10 and the droplet size distributions in Figure 22.

Table 10. Average diameter and Sauter mean diameter for different measurement positions

	D_{10} [mm]	D_{32} [mm]
Position 1	0.213	0.587
Position 2	0.272	0.733
Position 3	0.193	0.494
Position 4	0.266	0.548
Position 5	0.241	0.563

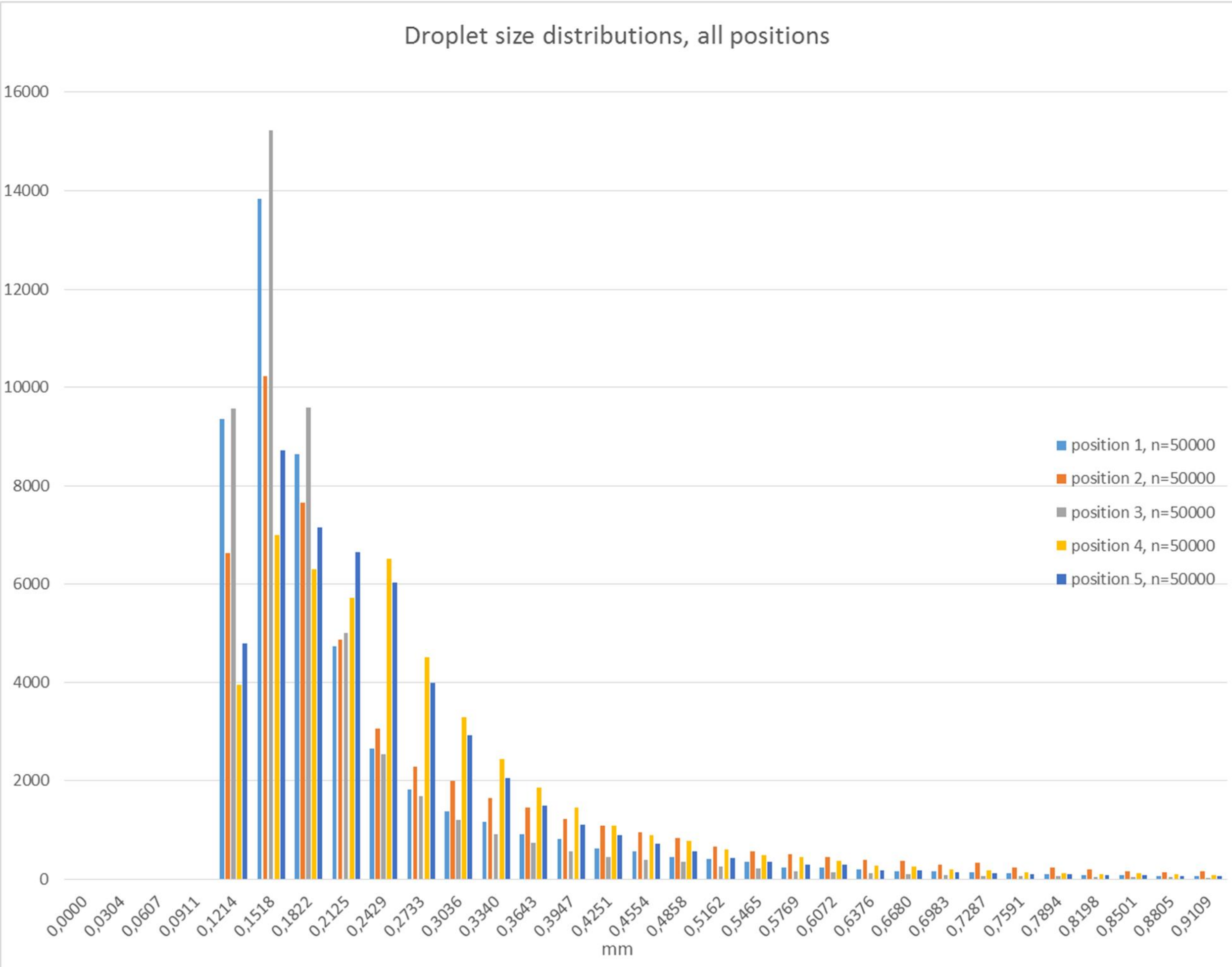

Figure 22. Droplet size distributions in all measurement positions presented with bins which are multiples of the scaling factor.

In the centreline positions 1, 2 and 3 the peak is clear in the 4-5 pixel bin range compared to the broader distributions of the positions 4 and 5.

7 SUMMARY AND DISCUSSION

This report summarizes the measurement results of single spray nozzle tests carried out in a testing station specifically built for this purpose at LUT in 2015. Water was injected through a spray nozzle and the developed droplet distribution was measured with the shadowgraphy application of the PIV system.

The main objective of the tests was to get experience from the use of the shadowgraphy application in order to be able to evaluate its suitability for demanding measurements of different characteristics of spray nozzles. The need for such measurements in Nuclear Engineering Laboratory at LUT emerged when studies focusing on spray operation in nuclear power plant containments were included in the research plan of the INSTAB project of the SAFIR2018 programme.

Five different measurement positions were selected underneath of the spray jet to be used in the tests. The interest was to find out if it has any effect on the droplet size distribution when the measurement area is shifted vertically and horizontally.

In the three positions, which were on the centreline axis, the droplet size distributions looked alike. In the two positions, which were horizontally 300 mm away from the centreline axis, the droplet size distributions seemed to be drastically different than the distributions in the centreline positions. The majority of the droplets were in the size range of 0.2-0.8 mm in the centreline positions whereas the droplet distribution was broader in the other two positions. However, this result is somewhat uncertain because the size distribution had to be cut from the beginning due to the too large scaling factor of the used measurement system.

As it can be seen from the measured droplet size distributions the scaling factor for these tests was too large in order to get a full range of different droplet sizes. In forthcoming spray nozzle tests the camera should always be placed as close to measurement area as possible to get the scaling factor to be as small as possible. The effect of a smaller scaling factor on droplet diameter distribution is being tested.

There are many user-defined parameters in the shadowgraphy application which are needed in processing of the particle images. Emphasis should be put to making the experimental arrangement as simple as possible. The user-defined threshold values for global and local segmentation are selected with a trial-and-error method. From the particle images it then can be interpreted whether the values are acceptable or not. Furthermore, this part of the analysing work can take a lot of time.

The improved testing station functioned well in these tests and it will give a possibility to measure different kind of spray nozzles in future.

8 REFERENCES

[1] ParticleMaster Shadow user manual, LaVision, 2013.

[2] Page 5 in http://www.spray.com/cat70m/cat70mpdf/ssco_cat70m_b.pdf.

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Abstract
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This report summarizes the measurement results of single spray nozzle tests carried out in a testing station specifically built for this purpose at Lappeenranta University of Technology (LUT) in 2015. Water was injected through a spray nozzle and the developed droplet distribution was measured with the shadowgraphy application of the PIV system.

The main objective of the tests was to get experience from the use of the shadowgraphy application in order to be able to evaluate its suitability for demanding measurements of different characteristics of spray nozzles. The need for such measurements in Nuclear Engineering Laboratory at LUT emerged when studies focusing on spray operation in nuclear power plant containments were included in the research plan of the INSTAB project of the SAFIR2018 programme.

Five different measurement positions were selected underneath of the spray jet to be used in the tests. The interest was to find out if it has any effect on the droplet size distribution when the measurement area is shifted vertically and horizontally. The majority of the droplets were in the size range of 0.2-0.8 mm in the centreline positions whereas the droplet distribution was broader in the two other positions, which were 300 mm away of the centreline axis.

There are many user-defined parameters in the shadowgraphy application which are used for processing of the particle images. The selection of these parameters has a strong effect on the measurement results and therefore emphasis should be put to making the experimental arrangement as simple as possible.

The measured droplet size distributions revealed that the scaling factor of the used application was too large for these tests in order to get a full range of different droplet sizes. In future spray nozzle tests the camera of the PIV system should always be placed as close to the measurement area as possible in order to get the scaling factor to be as small as possible.

Key words containment spray, shadowgraphy, full cone nozzle

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