TÜV Rheinland Energie und Umwelt GmbH
Test Centre for Energy Appliances

Report no. S 221 2014 S4

Testing of oil pressure atomizing nozzles in accordance with DIN EN 293

Danfoss A/S

TÜV Rheinland Energie und Umwelt GmbH
Test Centre for Energy Appliances

Functional test
Oil pressure atomizing nozzles, EN 293:1992

Manufacturer / Contractor:	Danfoss A/S Nordborgvej 81 6430 Nordborg - Denmark
Product:	Oil pressure atomizing nozzles
Type designation:	0,40 / 0,50 / 0,60 USgal/h
Test subject:	Functional requirements of EN 293
Technical data:	
Nominal throughput Index angle	0,40 / 0,50 / 0,60 USgal/h 45° / 60° / 80° Solid / hollow cone
Test requirements:	EN 293:1992, subclause 6.4 and 6.6
Test cause:	Comparison test of various types of nozzles

Dated in Cologne,
9th December 2014

Test Centre for Energy Appliances
DIN- and DVGW-test laboratory

432/rw
Review

Head of test centre

Dirk Wilczek

Dipl.-Ing. W. Rückwart

Content

1. Task, Cause of Test

TÜV Rheinland, as an independent and impartial test institution, has been commissioned by the company Danfoss to examine 45 oil pressure atomizing nozzles in respect to precision and quality as these are important aspects to ensure well running burners with low oil usage and pollution. Representative samples from various manufacturers shall be tested in accordance with the standard DIN EN 293 for nominal throughput and spray distribution.

The manufacturers Fluidics, OEG, Steinen, Danfoss, Monarch and Delavan have been selected with the aim of including such makes of nozzle in the analysis which are commercially available. The nozzle types and brands selected for the tests are perceived to be some of the most common / relevant in the residential burner markets.
The lower performance range of the nozzles of 0.4 US Gal/h to 0.6 US Gal/h was selected as it makes the highest demands on the production accuracy.
In advance to the tests a test program was developed which represents the basis for execution thereof. The laboratory of the company Danfoss in Nordborg was used for the practical execution of the nozzle tests.
The test program comprises the following activities:

- Neutral procurement of a total of 270 nozzles by TÜV Rheinland from various different retailers in Germany and France in accordance with the test program. 9 types of nozzle of each of the manufacturers stated above were procured and 5 of each type of nozzle were procured.
- Inspection of the test equipment in the test laboratory of the company Danfoss, Nordborg in respect of the suitability for the designated testing in accordance with the test standard
- Flow metering of all 270 nozzles at reference conditions in accordance with the test basis, carried out on the test rig of the company Danfoss (DIN EN 293, point 6.4)
- Symmetry measurement with the sector patternator for a selected spectrum of types of nozzle, carried out on the test rig of the company Danfoss (DIN EN 293, point 6.6)

The process sequence of the examination as well as the measurement results are to be depicted in the report in such a manner that clearly shows whether the test standard is complied with.

2. Description of Test subject

The following nozzles were subjected to the test. 5 samples of each nozzle type were subjected to the throughput test and 3 samples were subjected to the spray distribution test.

	0.40 USgal/h	0.50 USgal/h	0.60 USgal/h
Fluidics	60°SF 80°HF	45°SF 60°SF 60°HF	45°SF 60°SF 60°HF 80°HF
OEG	60°S 80°H	45°S 60°S 60°H	45°S 60°S 60°H 80°H
Steinen	60°ST 80°HT	45°ST 60°ST 60°HT	45°S 60°S 60°H 80°H
Danfoss	60°S 80°H	45°S 60°S 60°H	45°S 60°S 60°H 80°H
Monarch	60°R 80°R *)	45°R 60°R 60°NS	45°R 60°R 60°NS 80°NS
Delavan	60°B 80°A	45°B 60°B 60°A	45°B 60°B 60°A 80°A

*) sample NS was not available on the market – throughput was tested with type R

3. Approval Test

(The practical tests were performed in the laboratory of Danfoss A/S in Nordborg from 25th to 29th August 2014)

3.1 Procurement of nozzles

The nozzles were randomly purchased at wholesalers in Germany and France in a ratio of 4:1. The wholesalers were selected by TÜV Rheinland and represent standard suppliers for the market.

3.2 Inspection of test laboratory

The test laboratory of Danfoss is located in the burner components factory and used for production quality tests since about 50 years.
The environmental conditions are standard conditions for working places (clean air, normal temperature of 20 +/- 5 °C).
The testing equipment is calibrated according to the Quality procedures of Danfoss under IOS 9001-certification. Calibration data were checked in advance to the tests. The following equipment was in use for the test

Throughput test:
- Pressure: 0…30 bar; device no. 94471
- Temperature: 10…50°C; device no 79710

Control measurement for density correction:
- Weight: 0…2000g; device no. 30160
- Time: 0…60 min; device no. 92122

Spray distribution test:
- Pressure: 0…20 bar; device no. 30050
- Temperature: 0…100°C; device no. 77730
- Distance fixture: 64mm; device no. 91136
- Centre fixture: device no. 076793

The test assembly was found in accordance with the requirements of EN 293.

3.3 Practical test

The practical tests were performed by Mr. Preben Nørskov under witness of Mr. Wolf Rückwart (permanently present during the tests).

Time schedule:

25.08.2014	- inspection of laboratory
	- start of throughput measurements
	- start of spray distribution test
26.08.2014	- completion of throughput measurements
	- ongoing spray distribution test
27.08.2014	- verification of calibration data for measuring equipment
	- ongoing spray distribution test
	- exploitation and processing of data
28.08.2014	- ongoing spray distribution test
	- exploitation and processing of data
29.08.2014	- additional throughput measurements (OEG nozzles)
	- completion of spray distribution test
	- exploitation and processing of data

3.3.1 Throughput test

The throughput test was performed by mass flow method under following conditions:
- oil temperature: 20°C
- oil pressure: 10 bar
- oil density: 799 kg/cm³
- oil viscosity: 3,36 cSt

Tolerances according to EN 293 were considered.
For calculation under reference conditions with a density of 840 kg/cm³ a correction factor of 1,0279 was used. The measurement system was validated with reference nozzles in advance to the tests.
5 samples of each of the following types were subjected to the throughput test:

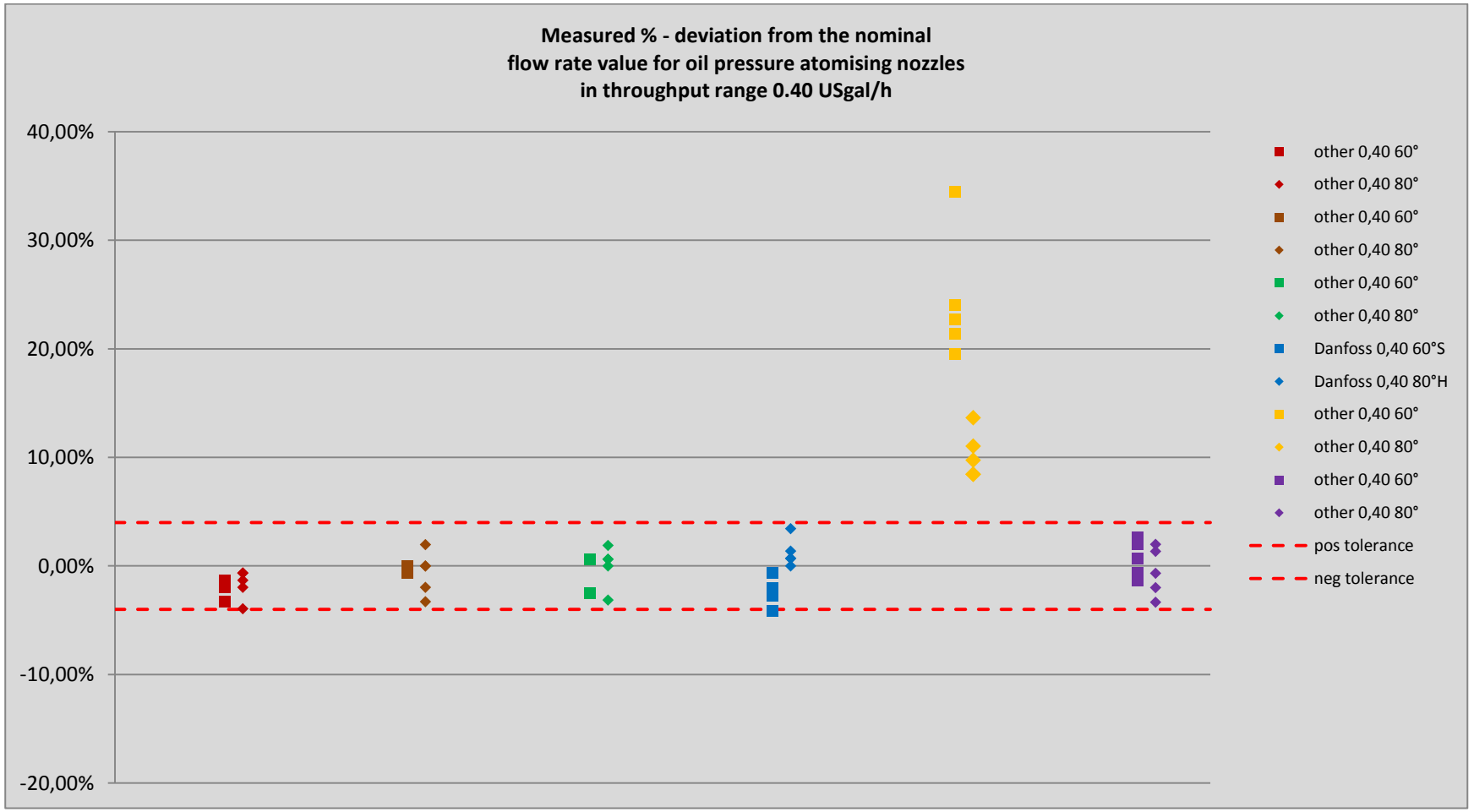
	0.40 USgal/h	0.50 USgal/h	0.60 USgal/h
Fluidics	60°SF 80°HF	45°SF 60°SF 60°HF	45°SF 60°SF 60°HF 80°HF
OEG	60°S 80°H	45°S 60°S 60°H	45°S 60°S 60°H 80°H
Steinen	60°ST **) 80°HT	45°ST **) 60°ST **) 60°HT	45°S 60°S 60°H **) 80°H **)
Danfoss	60°S 80°H	45°S 60°S 60°H	45°S 60°S 60°H 80°H
Monarch	60°R 80°R *)	45°R 60°R 60°NS	45°R 60°R 60°NS 80°NS
Delavan	60°B 80°A	45°B 60°B 60°A	45°B 60°B 60°A 80°A

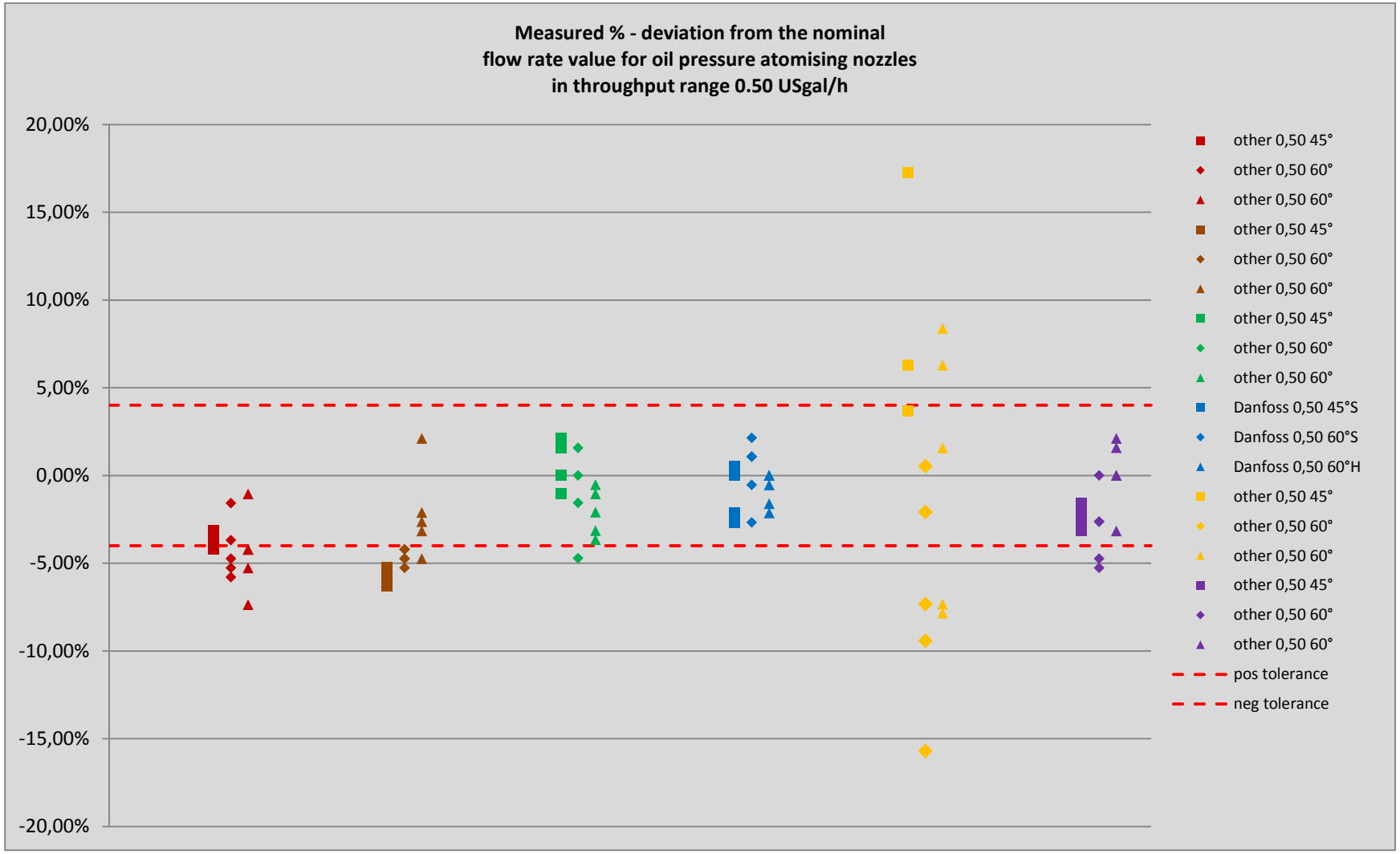
*) sample NS was not available on the market – throughput was tested with type R
**) due to missing quantity only 4 samples were available and tested

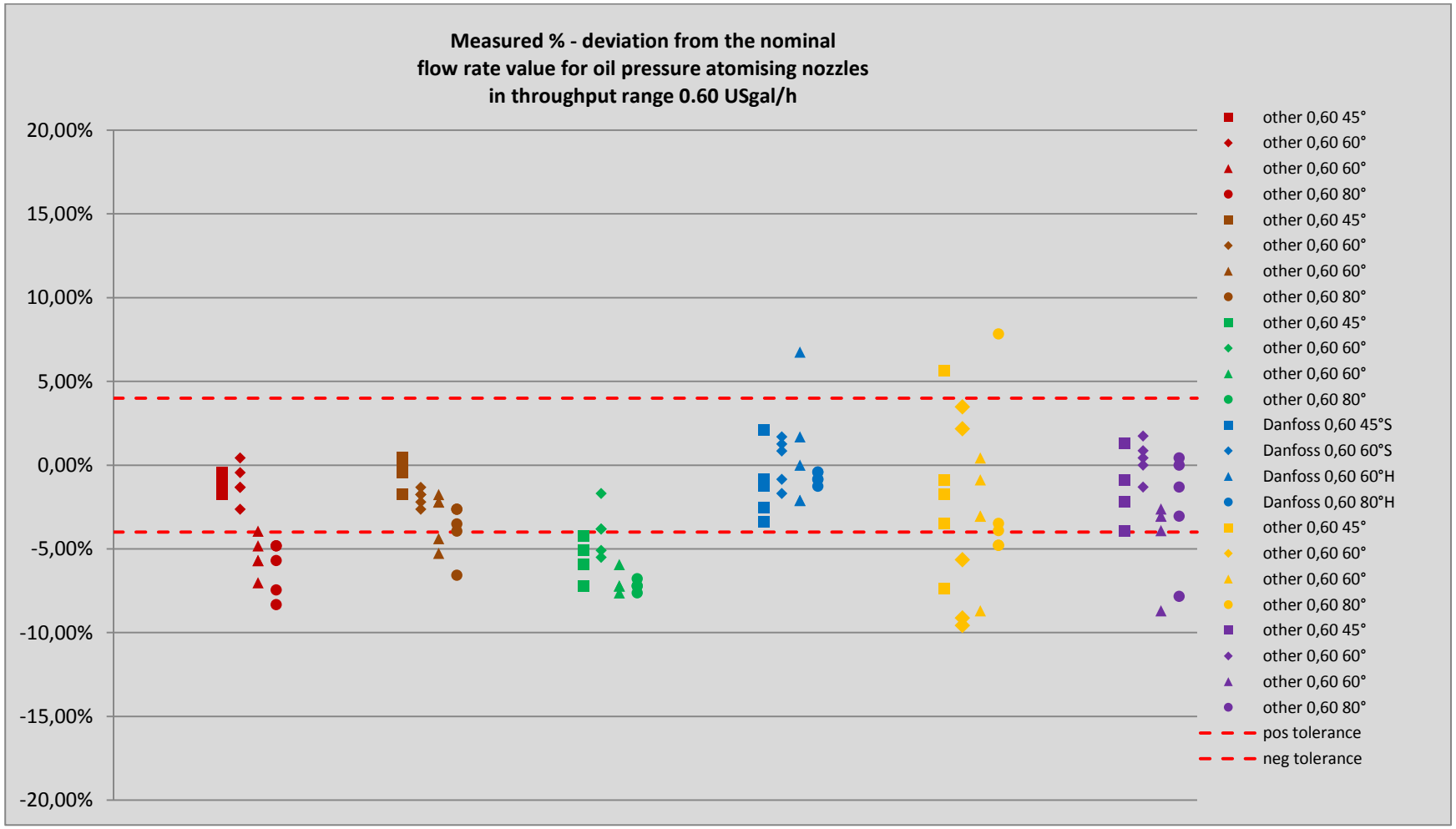
The measured values were compared to 0% deviation from the nominal throughput. The following table gives an overview on highest negative and positive deviations and average absolute deviation of different types of tested nozzles (if no positive deviation was measured the maximal value is listed)

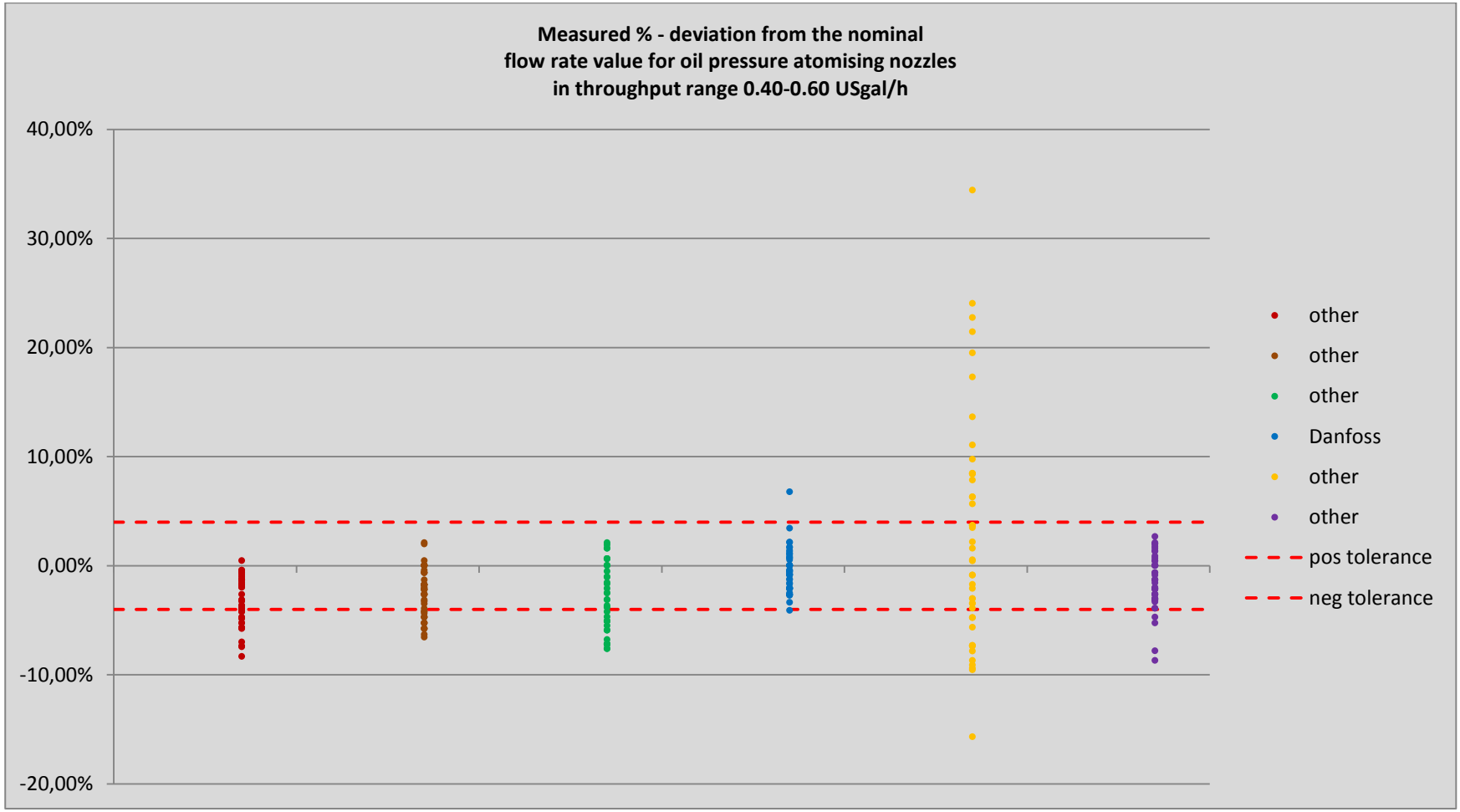
		Other	Other	Other	Danfoss	Other	Other
0.40 USgal/h	neg	-3,95	-3,29	-3,14	-4,11	8,44	-3,33
	pos	-0,66	1,97	1,89	3,42	34,42	2,67
	avg	1,84	0,92	1,40	1,78	17,34	1,67
0.50 USgal/h	neg	-7,37	-6,32	-4,71	-2,67	-15,71	-5,26
	pos	-1,05	2,11	2,09	2,14	17,28	2,11
	avg	4,11	4,46	1,77	1,32	6,74	2,25
0.60 USgal/h	neg	-8,33	-6,58	-7,63	-3,38	-9,57	-8,70
	pos	0,44	0,44	-1,69	6,75	7,83	1,74
	avg	3,53	2,46	5,79	1,65	4,50	2,43
Overall	neg	-8,33	-6,58	-7,63	-4,11	-15,71	-8,7
	pos	0,44	2,11	2,09	6,75	34,42	2,67
	avg	**3,35**	**2,78**	**3,50**	**1,57**	**8,10**	**2,20**

The following diagrams are showing the calculated deviations from all measurements.


Measured % - deviation from the nominal
flow rate value for oil pressure atomising nozzles
in throughput range 0.40 USgal/h
40,00%
30,00%
20,00%
10,00%
0,00%
-10,00%
-20,00%
other 0,40 60°
other 0,40 80°
other 0,40 60°
other 0,40 80°
other 0,40 60°
other 0,40 80°
Danfoss 0,40 60°S
Danfoss 0,40 80°H
other 0,40 60°
other 0,40 80°
other 0,40 60°
other 0,40 80°
pos tolerance
neg tolerance


Measured % - deviation from the nominal
flow rate value for oil pressure atomising nozzles
in throughput range 0.50 USgal/h
20,00%
15,00%
10,00%
5,00%
0,00%
-5,00%
-10,00%
-15,00%
-20,00%
other 0,50 45°
other 0,50 60°
other 0,50 60°
other 0,50 45°
other 0,50 60°
other 0,50 60°
other 0,50 45°
other 0,50 60°
other 0,50 60°
Danfoss 0,50 45°S
Danfoss 0,50 60°S
Danfoss 0,50 60°H
other 0,50 45°
other 0,50 60°
other 0,50 60°
other 0,50 45°
other 0,50 60°
other 0,50 60°
pos tolerance
neg tolerance


Measured % - deviation from the nominal
flow rate value for oil pressure atomising nozzles
in throughput range 0.60 USgal/h
20,00%
15,00%
10,00%
5,00%
0,00%
-5,00%
-10,00%
-15,00%
-20,00%
other 0,60 45°
other 0,60 60°
other 0,60 60°
other 0,60 80°
other 0,60 45°
other 0,60 60°
other 0,60 60°
other 0,60 80°
other 0,60 45°
other 0,60 60°
other 0,60 60°
other 0,60 80°
Danfoss 0,60 45°S
Danfoss 0,60 60°S
Danfoss 0,60 60°H
Danfoss 0,60 80°H
other 0,60 45°
other 0,60 60°
other 0,60 60°
other 0,60 80°
other 0,60 45°
other 0,60 60°
other 0,60 60°
other 0,60 80°
pos tolerance
neg tolerance


Measured % - deviation from the nominal
flow rate value for oil pressure atomising nozzles
in throughput range 0.40-0.60 USgal/h
40,00%
30,00%
20,00%
10,00%
0,00%
-10,00%
-20,00%
other
other
other
Danfoss
other
other
pos tolerance
neg tolerance

3.3.2 Spray distribution test

The spray distribution index describes the uniform distribution of fuel into a burning chamber.

The picture below shows the different spray characteristics.

Nozzle type hollow

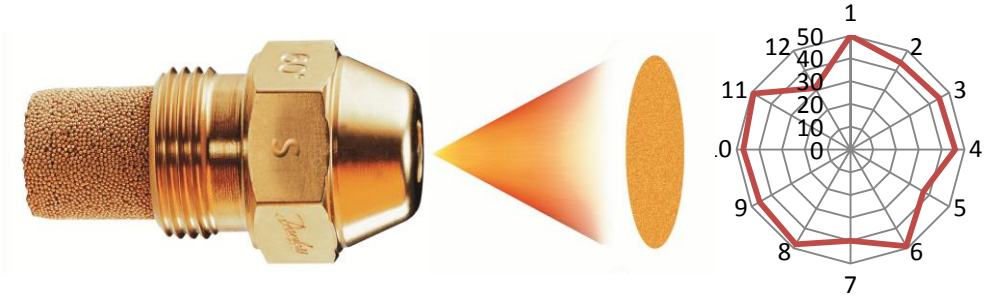
Nozzle type solid

The spray distribution test was performed under following conditions:

- oil temperature: 20°C
- oil pressure: 10 bar
- oil density: 800 kg/cm³
- oil viscosity: 3,39 cSt

Tolerances according to EN 293 were considered.

The measurement is done according to EN 293 with a distribution measurement into a circular container divided into 12 sectors. The index is calculated by the minimum amount of oil collected in one of the sectors divided by the average of collected oil in each sector.
A perfect uniform distribution would be shown in the diagram as a circle at the maximum range of 50 (ml) with a maximum index of 1,0.



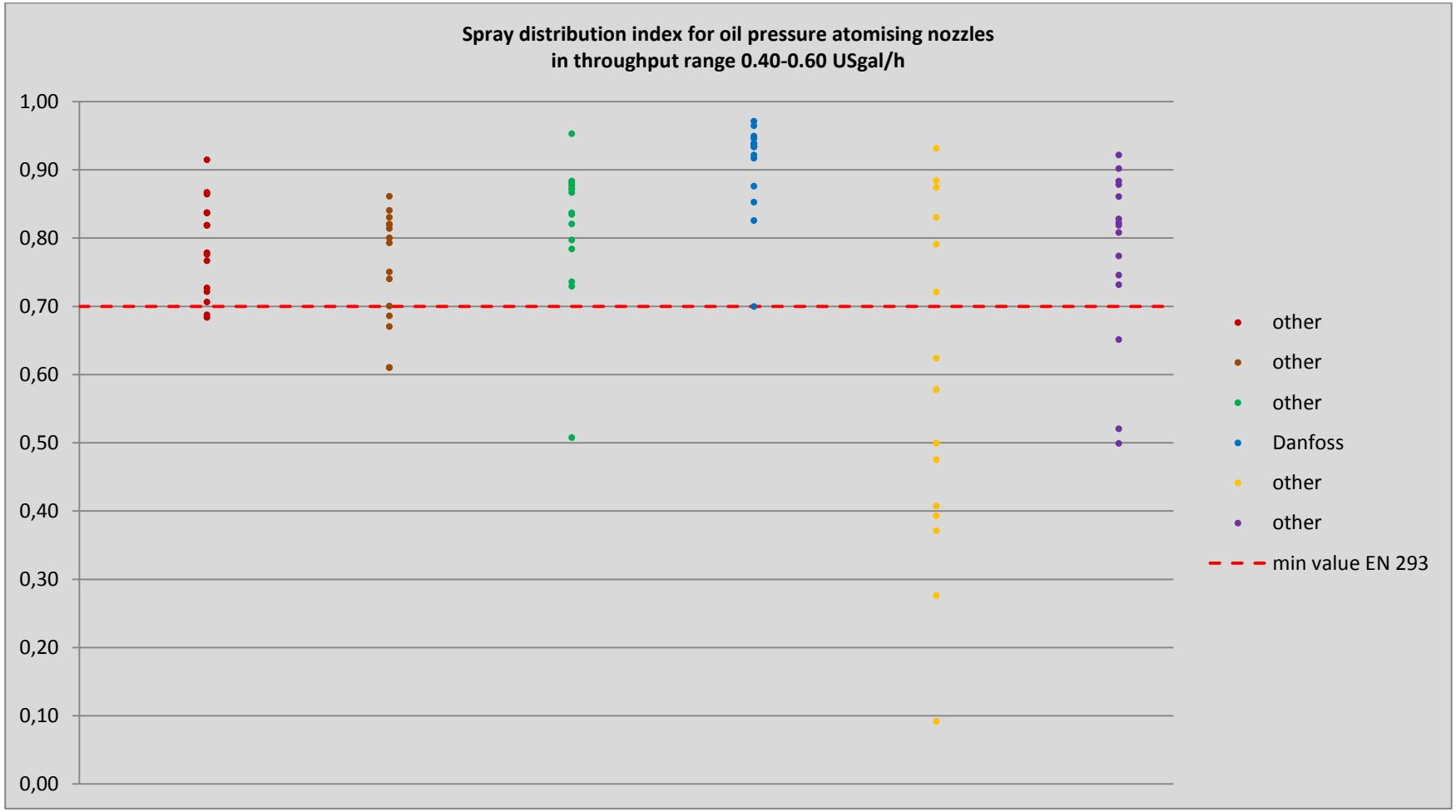
3 samples of each of the following types were subjected to the spray disitribution test:

	0.40 USgal/h	0.50 USgal/h	0.60 USgal/h
Other	60°	45° 60°	45° 80°
Other	60°	45° 60°	45° 80°
Other	60°	45° 60°	45° 80°
Danfoss	60°S	45°S 60°S	45°S 80°H
Other	60°	45° 60°	45° 80°
Other	60°	45° 60°	45° 80°

Result table (distribution index)
The table shows the overall average distribution index for each tested series of nozzles. The average was builded from 3 tested samples of type 0,40 and each 6 sample of types 0,50 and 0,60.
The standard EN 293 gives a limit of minimum 0,7 for the spray distribution index.

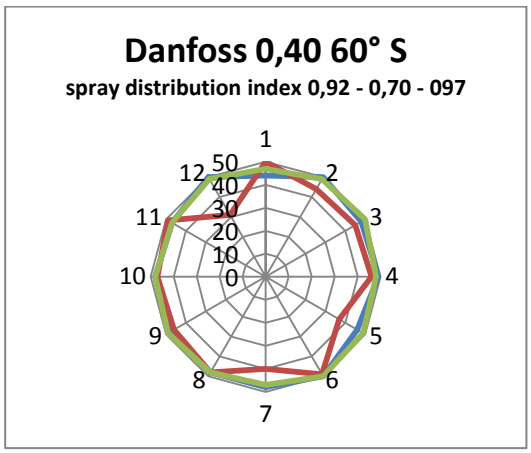
	Other	Other	Other	Danfoss	Other	Other
0.40 USgal/h	0,81	0,81	0,82	0,86	0,72	0,62
0.50 USgal/h	0,79	0,75	0,77	0,90	0,41	0,80
0.60 USgal/h	0,77	0,73	0,86	0,94	0,69	0,84
Overall avg.	0,79	0,76	0,82	0,91	0,58	0,78

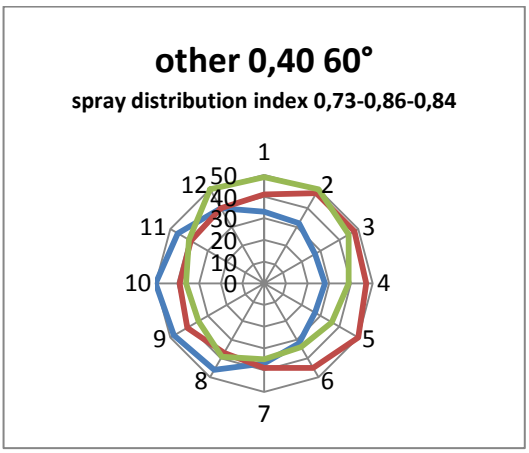
The following diagram shows an overview of the index calculated for each tested nozzle.

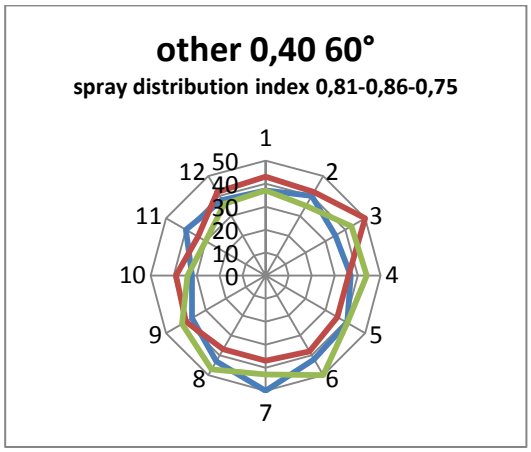

Spray distribution index for oil pressure atomising nozzles
in throughput range 0.40-0.60 USgal/h
1,00
0,90
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
other
other
other
Danfoss
other
other
min value EN 293

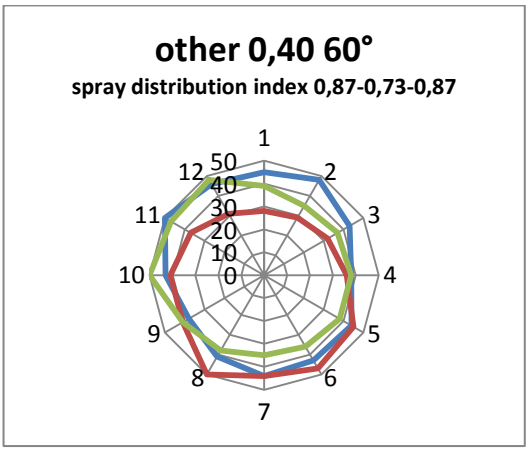
The following diagrams are showing the spray distribution and the spray distribution index of each tested nozzle.

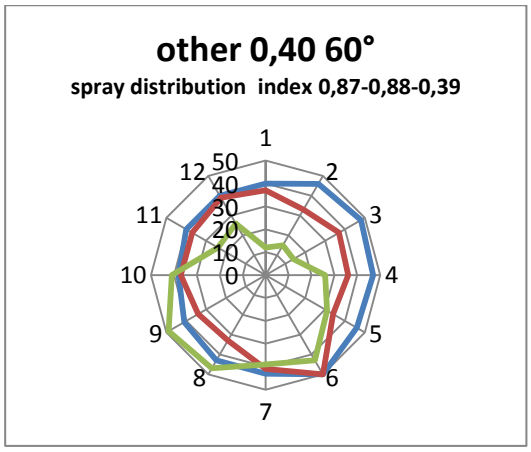
Nozzles 0,40 USgal/h 60° solid cone

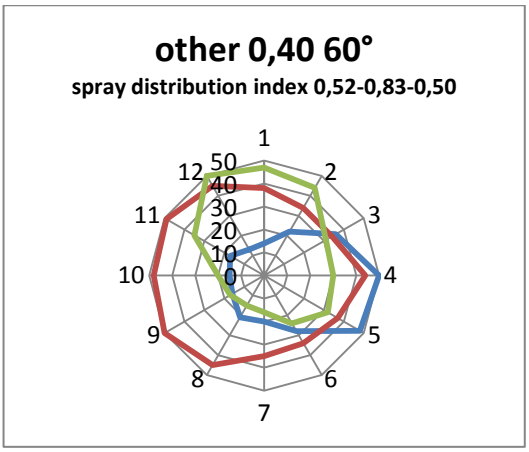






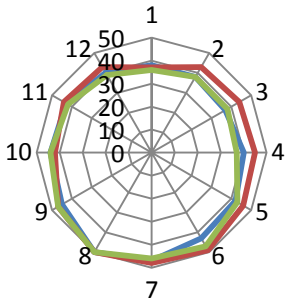




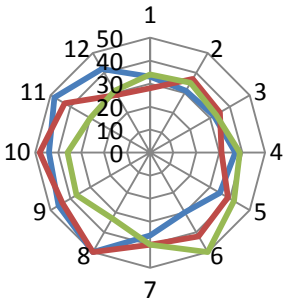


Nozzles 0,50 USgal/h 45° solid cone

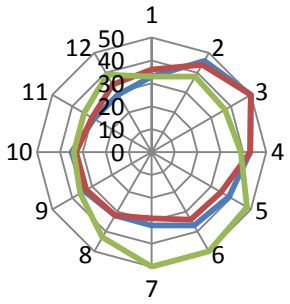
Danfoss 0,50 45° S
spray distribution index 0,88-0,83-0,85



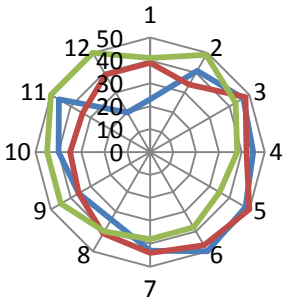
other 0,50 45°
spray distribution index 0,78-0,72-0,82



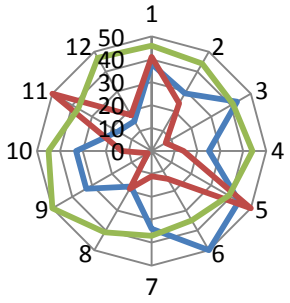
other 0,50 45°
spray distribution index 0,79-0,80-0,82



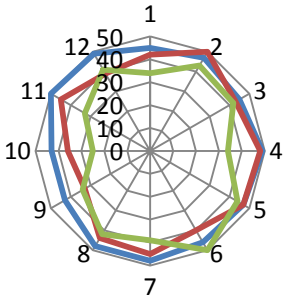
other 0,50 45°
spray distribution index 0,51-0,83-0,82



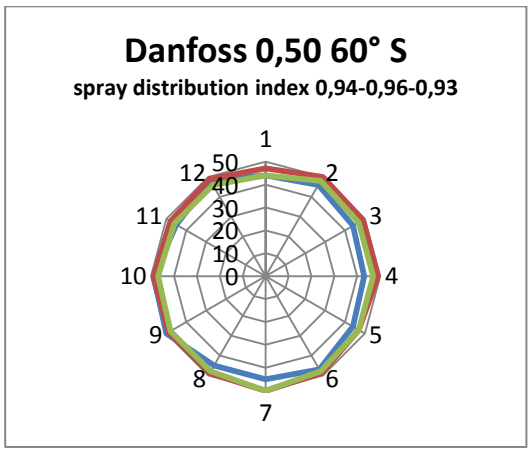
other 0,50 45°
spray distribution index 0,47-0,09-0,83

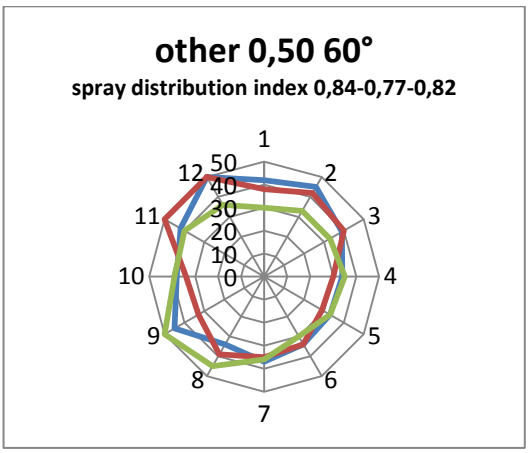


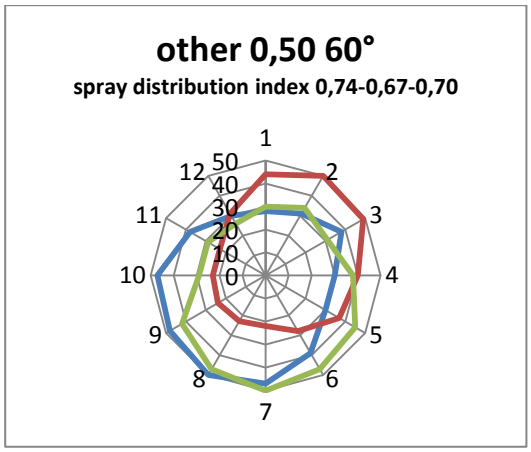
other 0,50 45°
spray distribution index 0,92-0,77-0,65

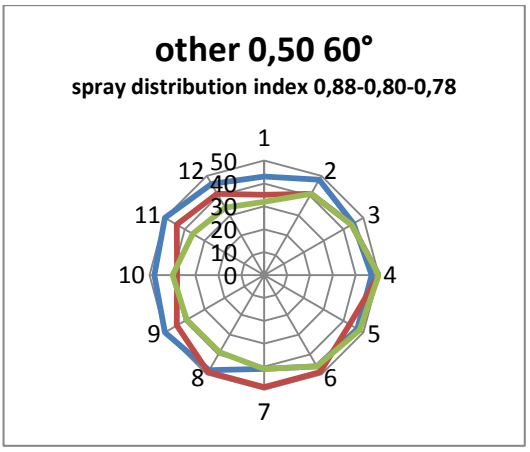


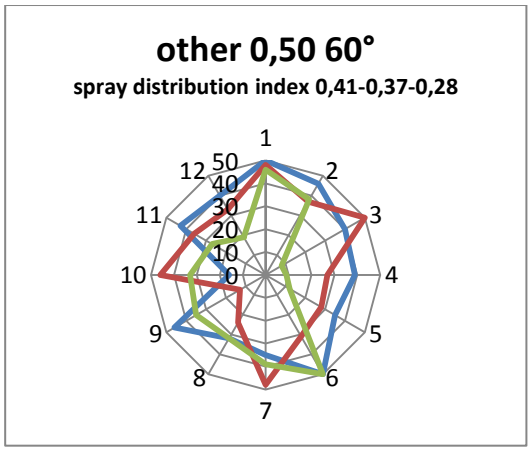
Nozzles 0,50 USgal/h 60° solid cone

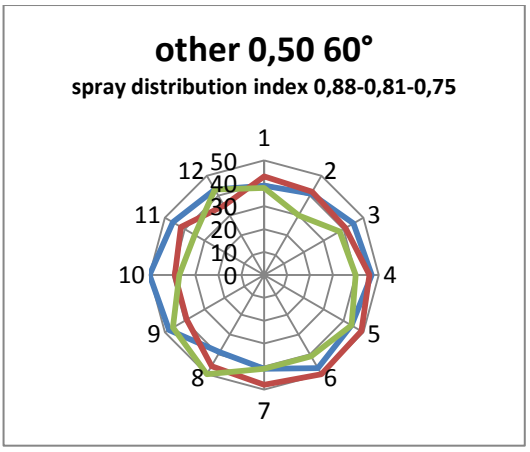




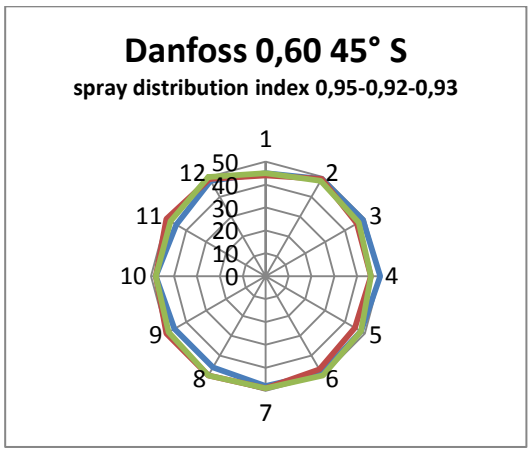


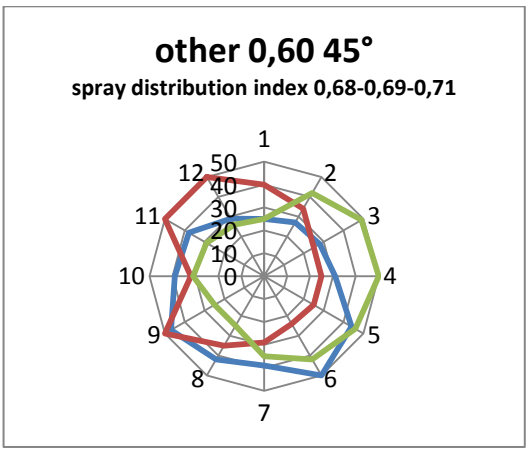


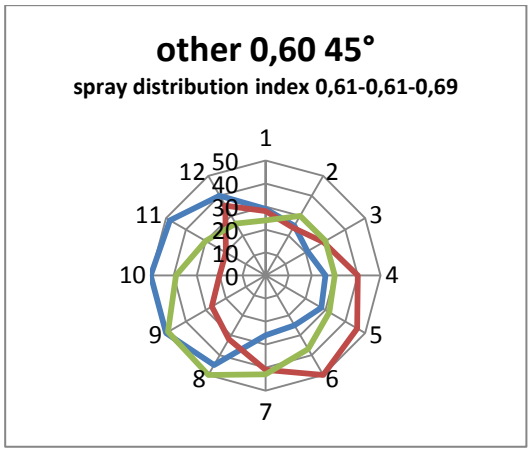


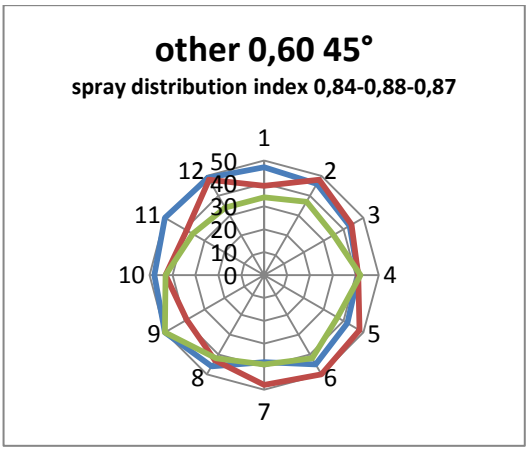


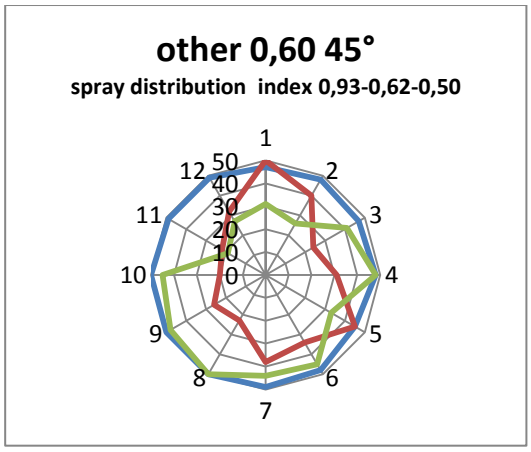
Nozzles 0,60 USgal/h 45° solid cone

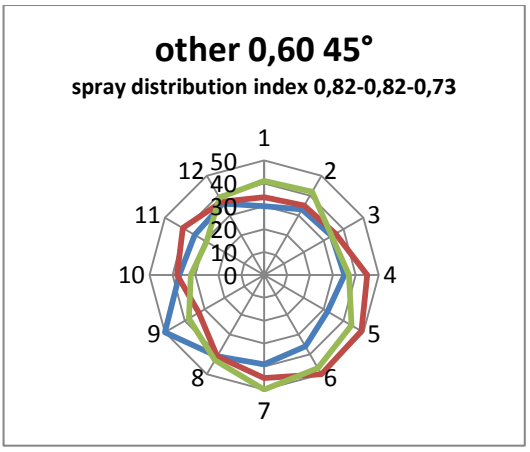






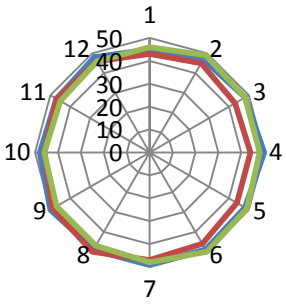




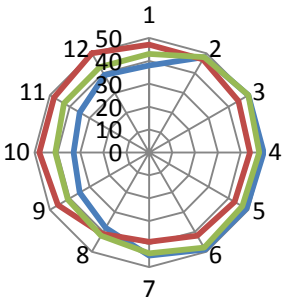


Nozzles 0,60 USgal/h 80° hollow cone

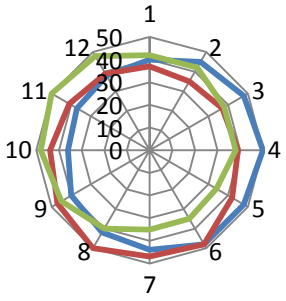
Danfoss 0,60 80° H
spray distribution index 0,93-0,94-0,95



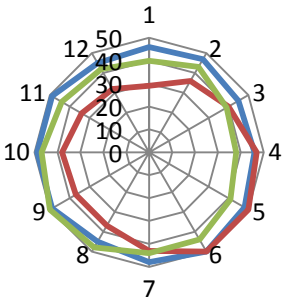
other 0,60 80°
spray distribution index 0,78-0,87-0,91



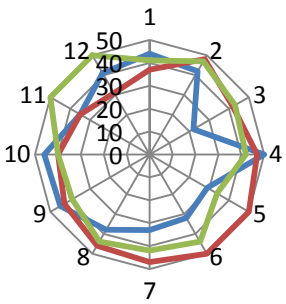
other 0,60 80°
spray distribution index 0,84-0,83-0,82



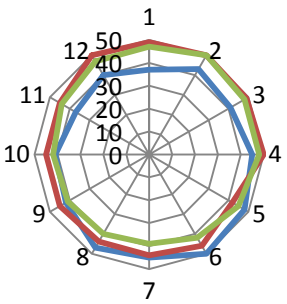
other 0,60 80°
spray distribution index 0,95-0,74-0,88



other 0,60 80°
spray distribution index 0,58-0,72-0,79



other 0,60 80°
spray distribution index 0,86-0,90-0,88



4 Summary

It has been noticed that the differences in the quality of the oil atomizing nozzles fluctuate considerably with regard to nominal flow rate (throughput) and spray symmetry. This statement does not only apply to products from one and the same manufacturer, but also to comparable types of nozzles from different manufacturers. The deviation margin is considerable and also exceeds thereby, in a negative manner, the permissible limits specified in the test standard. Below tables show the deviations found out of the measurements.

Nominal flow rate
This table gives the cumulative no. of tested nozzles inside the listed deviation ranges and the total no. of nozzles found above 4% deviation from the nominal throughput.

deviation	Other	Other	Other	Danfoss	Other	Other
< 1%	6	10	8	18	4	12
<= 2%	19	18	15	28	6	23
<= 3%	20	27	19	41	8	33
<= 4%	27	31	24	43	17	41
> 4%	**18 (40 %)**	**14 (31 %)**	**16 (40 %)**	**2 (4 %)**	**28 (62 %)**	**4 (9 %)**

Spray distribution index
This table gives the cumulative no. of tested nozzles inside the listed index ranges and the total no. of nozzles found below the minimum index 0,7 required by EN 293.

spray distribution index	Other	Other	Other	Danfoss	Other	Other
> 0,9	1	0	1	11	1	1
<= 0,9	14	15	14	4	14	14
<= 0,8	8	9	5	1	11	6
<= 0,7	2	5	1	1	9	3
< 0,7	**2 (13 %)**	**4 (27 %)**	**1 (7 %)**	**0 (0 %)**	**9 (60 %)**	**3 (20 %)**

A total number of 265 nozzles were tested against the requirements of EN 293 for nominal throughput and 90 samples against the requirement of the spray distribution index. At all 82 of the tested samples (31 %) failed the tolerance of 4% for nominal throughput as required by the standard and 19 of the tested samples (21 %) failed the minimum value of 0,7 for spray distribution index as required by the standard..

At all 34% of the tested nozzles were found not in accordance with the requirements of the standard EN 293.

From a technical point of view the following reasons come into question as possible causes:

- differing levels of development of the manufacturing technology at various manufacturers
- different production machinery of the manufacturers
- different processes and procedures during quality control of the current production lines

The testing of the examined nozzle spectrum of oil pressure atomizing nozzles with a relatively small throughput has clearly shown by using the example of the company Danfoss that consistently good atomization properties such as nominal flow rate (output) and spray symmetry (complying with the test standard), can be attained by all means.

End of report