TEST REPORT

Comparative intensity testing of UV fixture
from Steril-Aire and Sanuvox

Date: February 14, 2011

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1 Background

The purpose of this test was to compare the intensity output from two similar size UVGI fixtures, one from Steril-Aire Inc. and one from Sanuvox Inc.

Both types of fixtures are commonly used in HVAC applications, mounted either upstream or downstream from cooling coils to irradiate and sanitize the coil surfaces.

The test is primarily a product test and as such evaluating the combined performance of the lamp and the fixture with reflector.

The test is not intended to be a complete evaluation of the performance levels but a first test to establish a general knowledge and possibly initiate further studies.

2 Tested UVGI fixtures

2.1 Steril-Aire equipment

The fixture tested is a 42” fixture designed for a double ended UV lamp.

The fixture is made from stainless steel with a reflector plate of anodized aluminum. The reflector has a shiny surface. The power supply is hosted inside the fixture.

The lamp is held at both ends by connection sockets snapped on to steel tabs.

The lamp is a T5 UV lamp with a bi-pin connector at each end. The arch length is measured at 37.25”.

In the testing of the lamp without fixture a single ended 42” lamp was used with an arc length of 38.88”

2.2 Sanuvox equipment

The Sanuvox fixture is a 41.5” fixture designed for a single ended lamp. The fixture is made entirely from anodized aluminum and has a dull reflector surface and reflector is of parabolic or semi-circular shape. The power supply is hosted in a separate enclosure.

The lamp is held at both ends and in the middle by clips in the reflector and a four-pin connector is connecting one end of the lamp to the power supply.

The lamp is a T6 UV lamp and the arch length is measured at approximately 37.5 inches

3 Test equipment

3.1 Test chamber

The UVGI fixtures were tested in a simple test chamber made from plywood with internal measurements of:

Length: 8 feet

Width and height: 4 feet

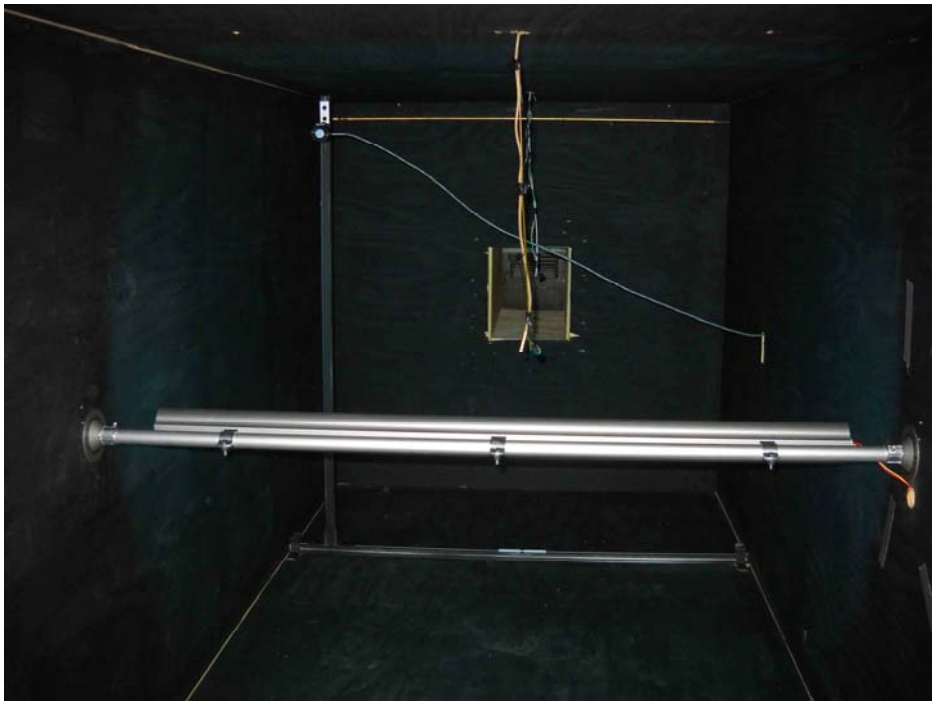
The interior of the chamber was painted matt black to reduce reflections.

One end of the chamber was covered and had a fan supplying a short duct leading into the box. The fan was set up to draw air either entirely from the room, a mixture of room and outside air or 100% outside air. The opposite end of the chamber was left open.

The tested fixture was mounted horizontally 2 feet from the bottom of chamber and 28 inches from the open end (center of lamp) with the lamp facing the closed end.

A UV sensor was placed, facing the lamp, at the same height and at the center of the fixture. The distance from the center of the UV lamp to the sensor was set at 100 cm (1m).

Temperature sensors were placed right behind the sensor and approximately 6” over the center fixture. Each location held a sensor for immediate temperature reading and one for data logging.



View of test chamber with Sanuvox fixture mounted and UV sensor in upper left position.

Fan mount on back side of test chamber.

3.2 Radiometer

The radiometer used for the intensity measurements was a NIST traceable logger model IL1400A from International Light with a UVC sensor. The sensor and radiometer were set to display intensity levels in the mW and µW range.

3.3 Air Velocity reader

The air velocities were recorded with an Airdata Multimeter model ADM-860 by Shortridge Instruments. An air foil rod was used to measure the air velocity near the fixture (approximately 5" above the fixture).

3.4 Amp meter

The currency draw was measured with a electrical tester, Fluke T5-600. The tester could only display readings down 0.1 Amps.

4 Test at 100 cm distance in ambient and air flow conditions

The Steril-Aire fixture was mounted inside the test chamber as described above and turned on for approximately one hour before the first reading.

The first reading was done at ambient conditions (no fan running). The following data were recorded.

- Time of reading
- Temperature at UV sensor
- Temperature above UV fixture
- UV intensity
- Current draw

After the first reading the fans were turned on with a mix of room and outside air. They were left on for approximately 30 minutes before the second reading

The same data were recorded at the second and all consecutive readings with the addition of air velocity. The velocity was measured at three locations approximately 5 inches above the fixture.

At each location five measurements were taken and an average air velocity was calculated as the average of all 15 measurements.

Two more readings were done with 30 minute intervals giving three different sets of data for the test with fans on.

After completion of the testing of the Steril-Aire fixture the Sanuvox fixture was mounted in the same position and left on for approximately 45 minutes prior t the first reading.

The following readings were done with the same approximate intervals as for the Steril-Aire fixture. The recorded data from this test are displayed in the chapter below.

4.1 Steril-Aire data

	Ambient	1 Mixed Air flow	2 Mixed Air flow	3 Mixed Air flow
Inlet Air temp (°F)	66.4	62.6	62.3	61.9
Lamp side Air temp (°F)	77.6	63.2	62.8	62.6
Air velocity (Feet per minute)	0	468	610	595
Current draw (Amps)	0.7	0.7	0.7	0.7
Intensity (µW/cm^2)	285	246	232	241
Relative ambient reading (%)		86%	81%	85%

4.2 Sanuvox data

	Ambient	1 Mixed Air flow	2 Mixed Air flow	3 Mixed Air flow
Inlet Air temp	67.0	62.3	61.4	61.0
Lamp side Air temp	75.4	62.8	62.1	61.6
Air velocity	0	638	518	563
Current draw	0.6	0.6	0.6	0.6
Intensity µW/cm^2	416	402	387	390
Relative ambient reading (%)		97%	93%	94%

4.3 Discussion

4.3.1 Temperatures

The recorded temperature levels were somewhat consistent between the two test runs. In the ambient state both sensors at the fixtures recorded an elevated temperature which was to be expected. During fan operation the temperatures decreased in both cases and the difference between the two sensors were in the range of 0.5 to 1 degree.

The temperature levels during the testing of the Sanuvox fixture were slightly lower than the ones for the Steril-Aire.

Due to the way the air supply was set up it was not possible to reach lower air temperatures than 61 degrees with an outside air temperature in the upper 20's. Lower outside air temperatures or a change in the air supply to draw more outside air is required to reduce the air temperatures.

4.3.2 Intensity levels

It is obvious, even to the naked eye, that the Sanuvox fixture, due to its parabolic reflector, directs more irradiation forward than what the Steril-Aire fixture does. When traced on the side wall of the chamber, the Steril-Aire fixture showed a 270 degree beam of visible light while the Sanuvox showed a 160 degree beam.

The measured intensity levels support that notion and the Sanuvox fixture had an intensity that was approximately 46% higher at ambient conditions. With the fans operating the difference increased to approximately 64%. It is possible that the shape of the parabolic Sanuvox reflector

helps to maintain a higher lamp temperature while the flat Steril-Aire reflector is more prone to lamp cooling through heat transfer from the passing air.

An alternative test was later done with both lamps without reflector.

An important aspect of the intensity on a target surface is the possibility to also reach remote parts of e.g. a coil surface. The test above indicates that the Steril-Aire fixture might provide a more even exposure on a larger surface. This was investigated and presented below.

5 Testing at ambient conditions at 100 cm over chamber cross section

A second comparison was done where the sensor was moved to nine different positions covering the cross section of the chamber. The following locations were used:

Upper Left:	5” from the ceiling and 5” from the left wall
Upper Center:	5” from the ceiling and at center of the chamber
Upper Right:	5” from the ceiling and 5” from the right wall
Center Left:	At the lamp level and 5” from the left wall
Center Center:	At the lamp level and at center of chamber
Center Right:	At the lamp level and 5” from the right wall
Lower Left:	5” from the floor and 5” from the left wall
Lower Center:	5” from the floor and at center of chamber
Lower Right:	5” from the floor and 5” from the right wall

The designations are as seen from the lamp position.

The test was performed under ambient conditions.

5.1 Steril-Aire data

The following intensity values were recorded for the Steril-Aire fixture:

	Left	Center	Right
Upper	222	288	224
Center	202	267	204
Lower	225	291	225

Intensities in $\mu W/cm^2$

5.2 Sanuvox data

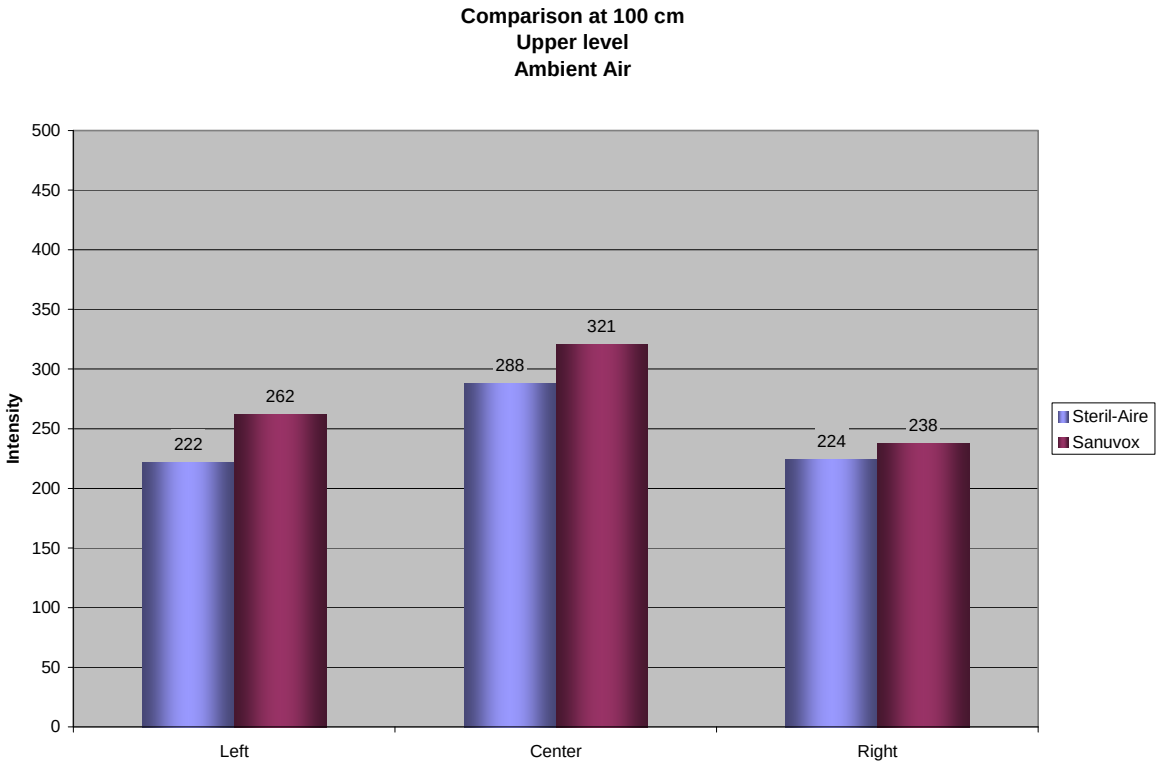
The following intensity values were recorded for the Sanuvox fixture:

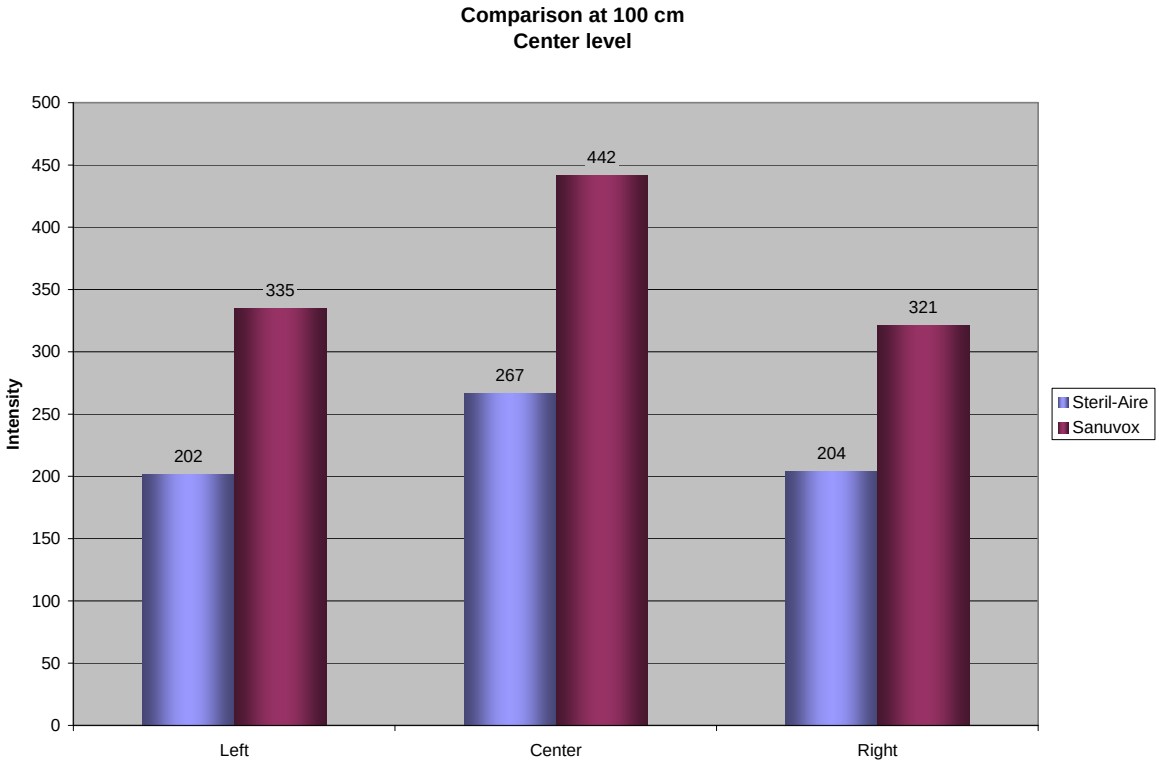
	Left	Center	Right
Upper	262	321	238
Center	335	442	321
Lower	226	290	219

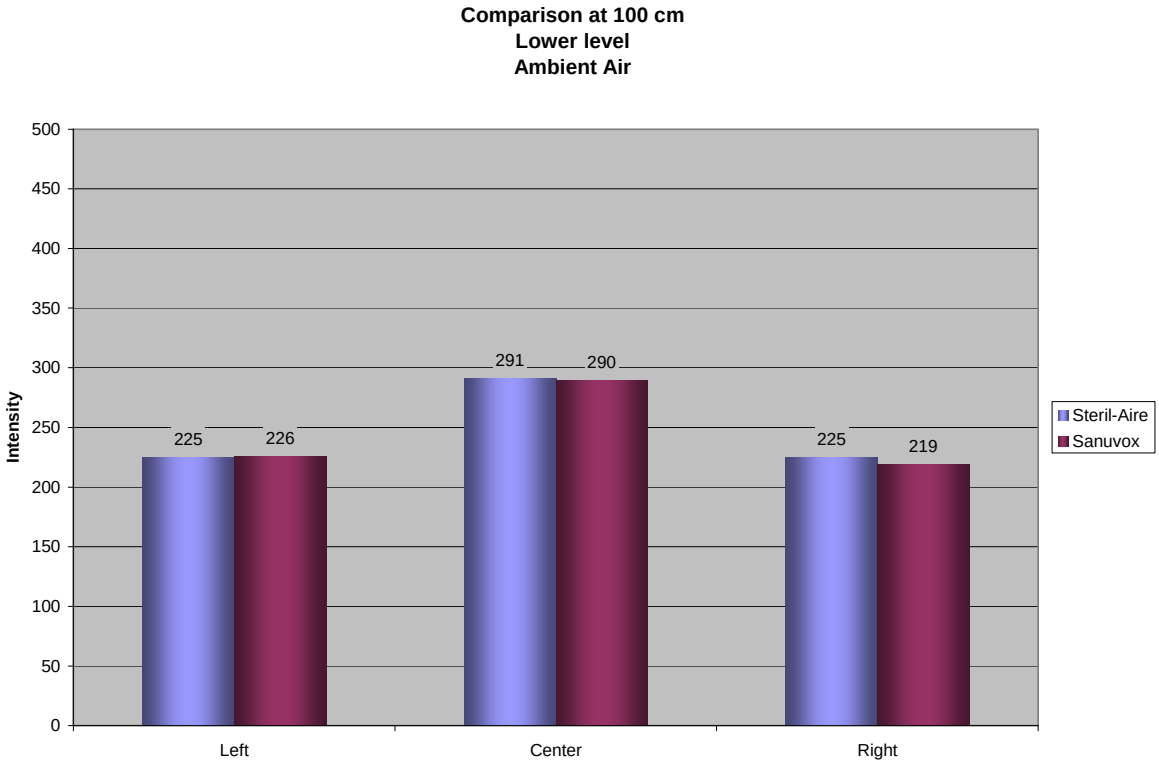
Intensities in $\mu W/cm^2$

5.3 Comparison

The following graphs show a comparison for each level.






Comparison at 100 cm
Lower level
Ambient Air
Intensity
500
450
400
350
300
250
200
150
100
50
0
225
226
291
290
225
219
Left
Center
Right
Steril-Aire
Sanuvox

Relative intensity Sanuvox to Steril-Aire

	Average
Upper	112%
Center	163%
Lower	99%

The Sanuvox fixture gave a higher intensity reading on the upper and center level and an equal intensity on the lower. The high intensity on the center level is to a great extent due to the parabolic shape of the reflector which throws the irradiation forward to a greater extent than the flat Steril-Aire reflector.

It was also found that if the Sanuvox reflector is not installed perfectly level, the intensity on the upper and lower areas differ from each other. This is most likely why the upper level shows a somewhat higher intensity than the lower.

6 Testing at ambient conditions at 10" over chamber cross section

This test was conducted in exactly the same way as the previous test but the sensor was moved to a position approximately 10 inches from the lamp plane. The test simulates a typical UV installation where the fixtures are mounted at the outer edge of the drain pan. The typical distance from lamp to coil is 6 to 14 inches.

6.1 Steril-Aire data

The following intensity values were recorded for the Steril-Aire fixture:

	Left	Center	Right
Upper	213	355	218
Center	800	1724	809
Lower	200	335	205

Intensities in $\mu W/cm^2$

6.2 Sanuvox data

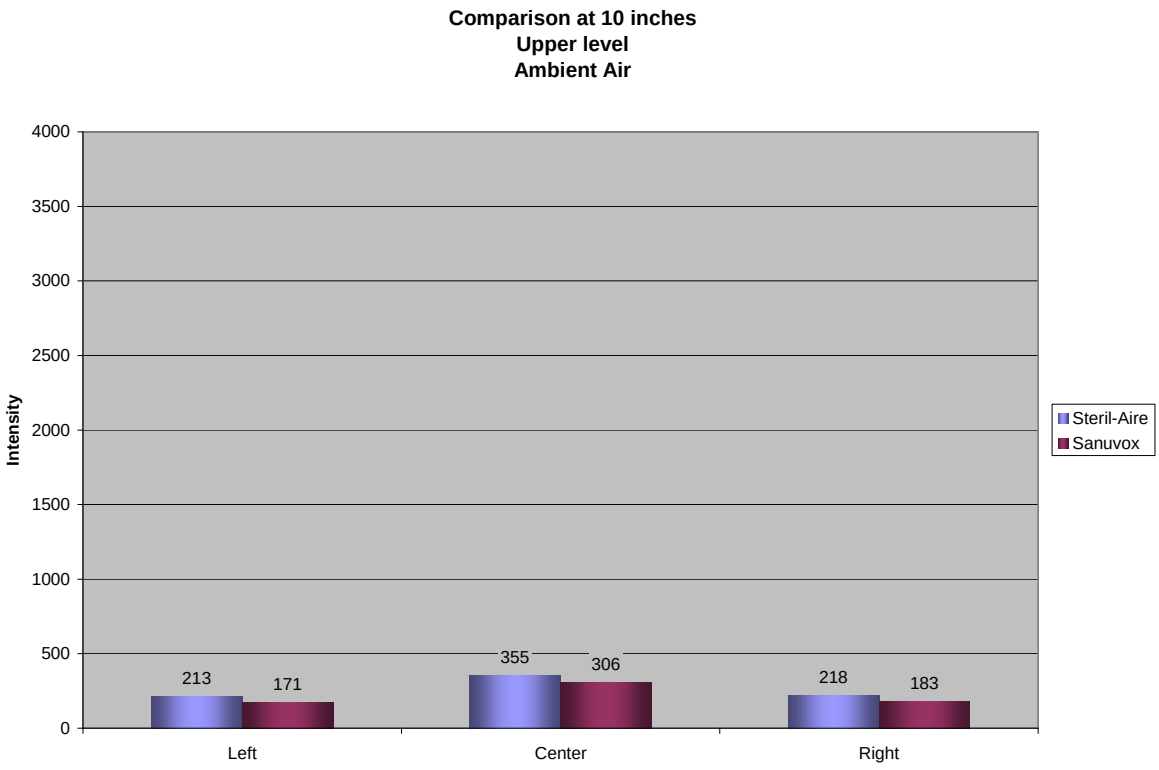
The following intensity values were recorded for the Sanuvox fixture:

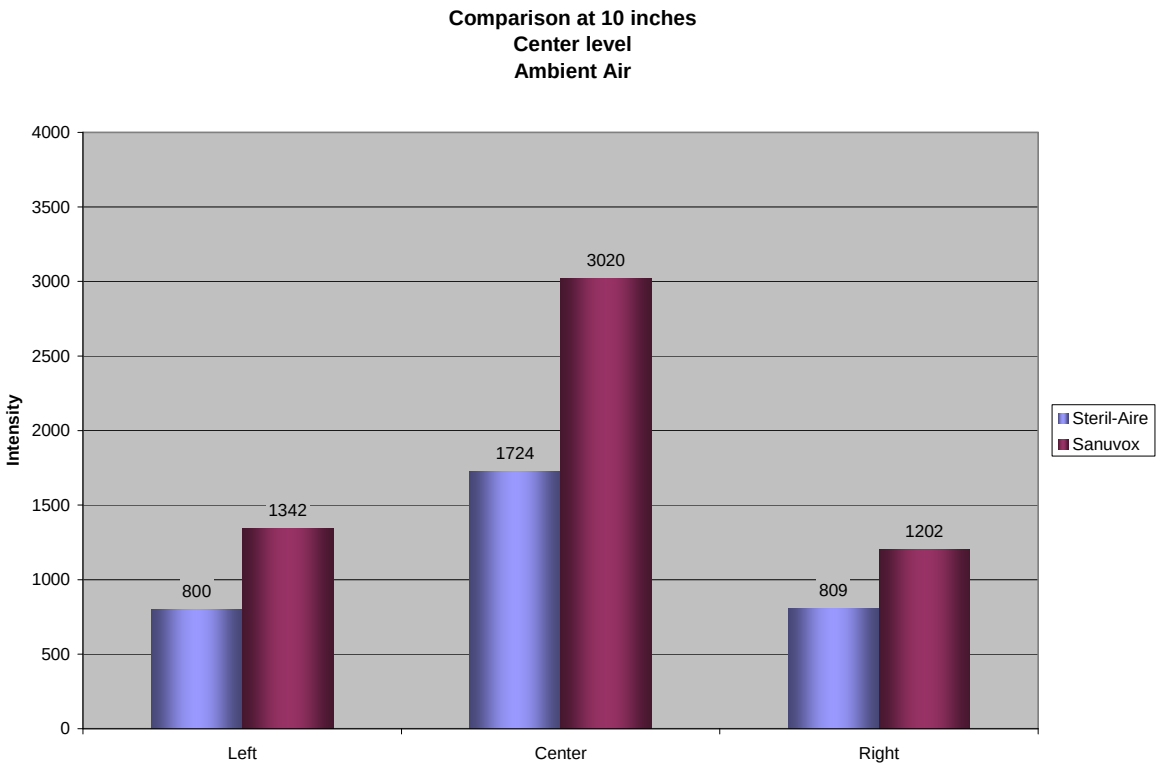
	Left	Center	Right
Upper	171	306	183
Center	1342	3020	1202
Lower	164	285	173

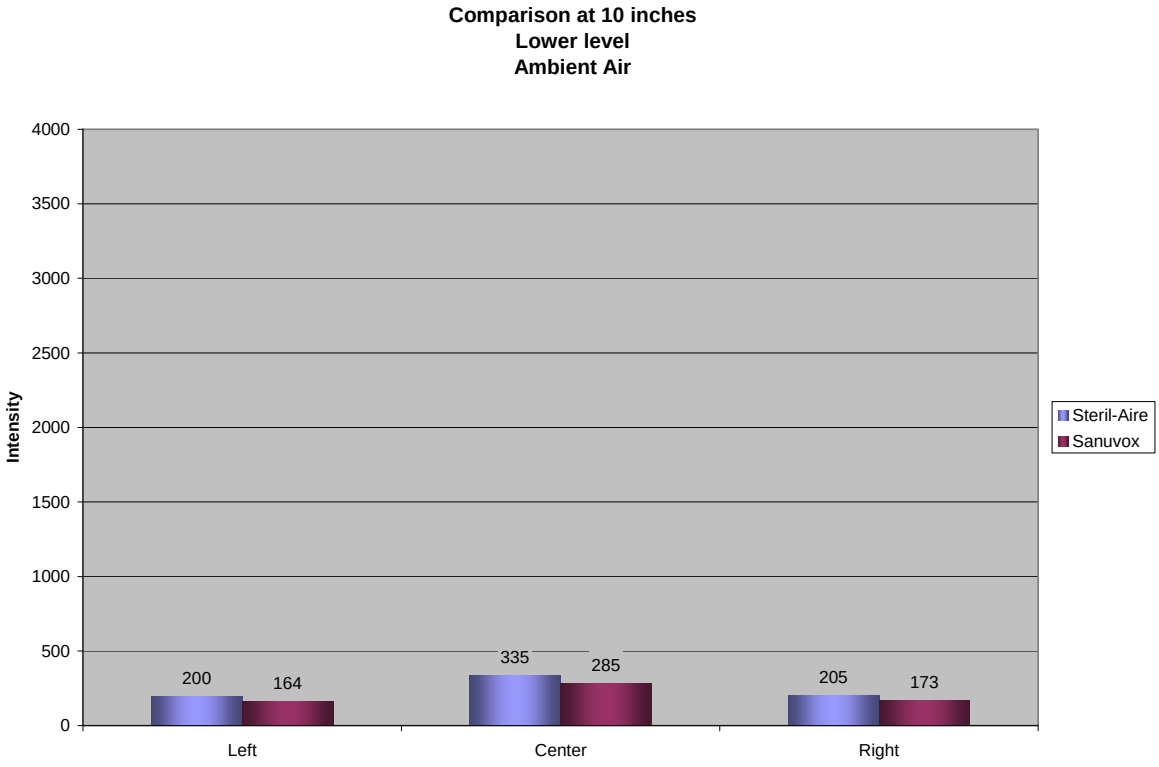
Intensities in $\mu W/cm^2$

6.3 Comparison

The following graphs show a comparison for each level. Note that the scale is different from the results at 100 cm to enable display of the highest readings.







Relative intensity Sanuvox to Steril-Aire

	Average
Upper	84%
Center	164%
Lower	84%

The Sanuvox fixture showed the same relation to the Steril-Aire fixture for the center level also at 10 inches. At upper and lower levels the Steril-Aire fixture showed the higher intensity which is logical considering its greater angle if irradiation. The Sanuvox fixture was checked with a level to ensure vertical placement of the upper and lower edge of the reflector. Even a slight tilt of the fixture up or down changed the intensity at the upper and lower levels considerably.

7 Testing in moving air at 100 cm over chamber cross section

The test is a repetition of the test above (Chapter 5) but this time with the fans in operation. The fan operating conditions were basically the same as described in Chapter 4 but with the difference that only room air was used. The setup used in chapter 4 did not produce significantly lower air temperatures compared to room temperatures.

7.1 Steril-Aire data

The following intensity values were recorded for the Steril-Aire fixture:

	Left	Center	Right
Upper	252	286	221
Center	210	274	217
Lower	244	301	219

Intensities in $\mu W/cm^2$

7.2 Sanuvox data

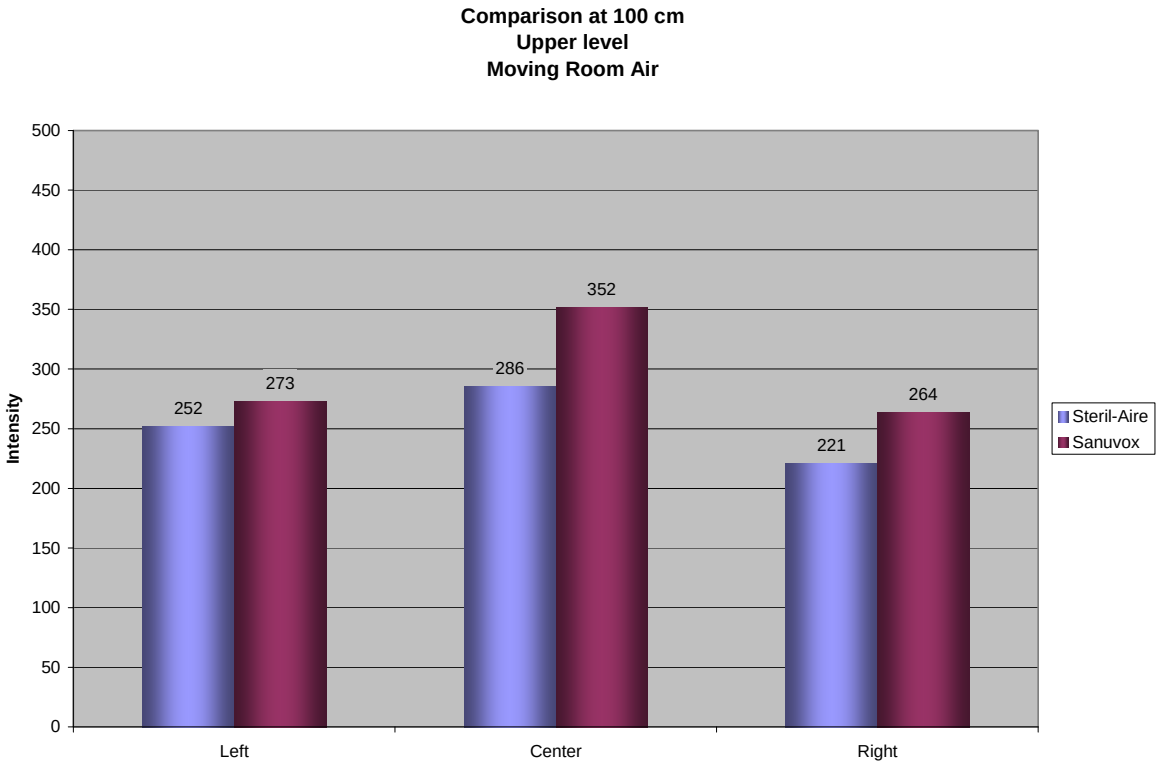
The following intensity values were recorded for the Sanuvox fixture:

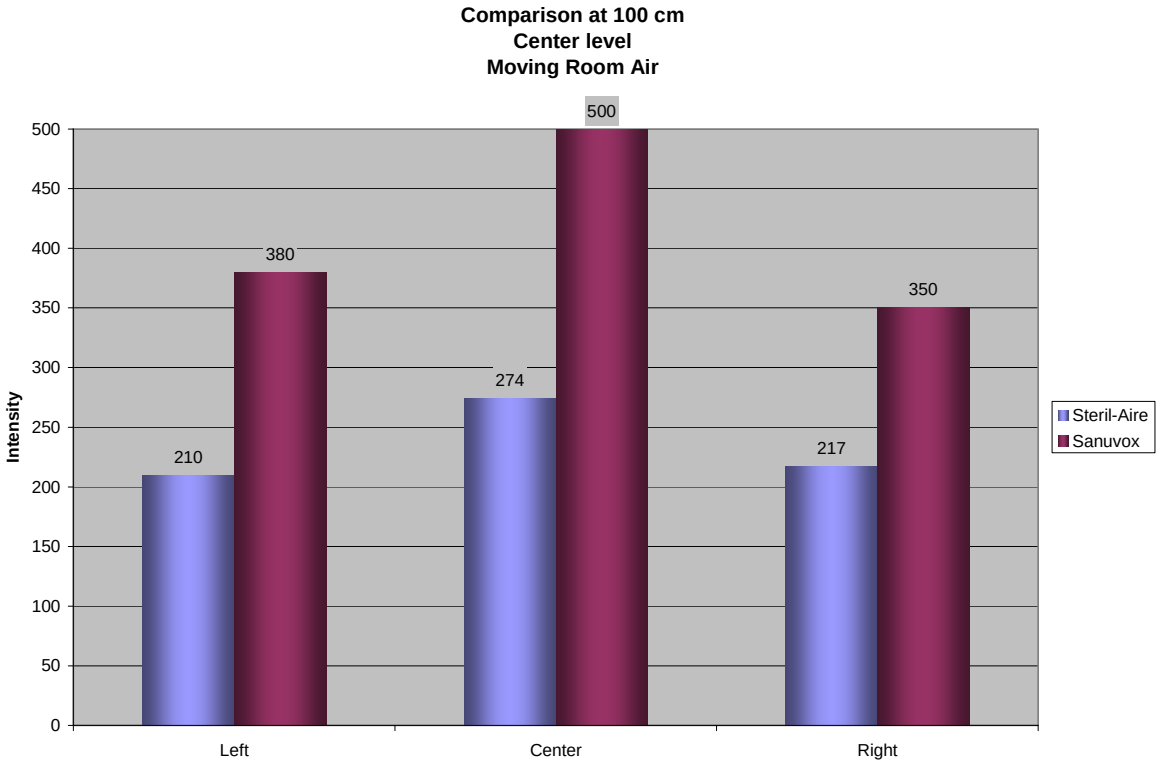
	Left	Center	Right
Upper	273	352	264
Center	380	500	350
Lower	270	338	256

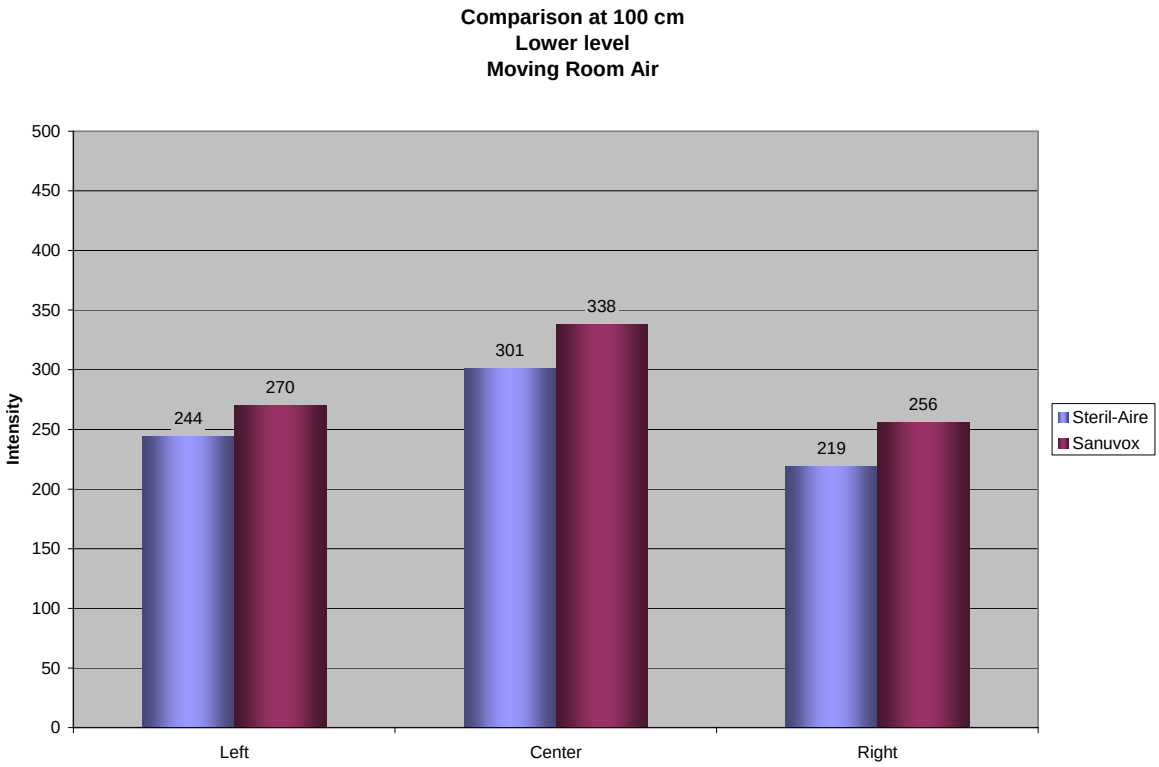
Intensities in $\mu W/cm^2$

7.3 Comparison

The following graphs show a comparison for each level.







Relative intensity Sanuvox to Steril-Aire

	Average
Upper	117%
Center	175%
Lower	113%

Relative intensity moving air to ambient air conditions (average moving air/average ambient air)

	Steril-Aire	Sanuvox
Upper	103%	108%
Center	104%	112%
Lower	103%	118%

The pattern is the same as for the testing at ambient conditions with the difference that the Sanuvox fixture is increasing slightly more, when exposed to moving room air, than what the Steril-Aire fixture does.

8 Testing in moving air at 10 inches over chamber cross section

This is a repetition of the test presented in chapter 6 with the same air flow arrangements as described in chapter 7.

8.1 Steril-Aire data

The following intensity values were recorded for the Steril-Aire fixture:

	Left	Center	Right
Upper	259	397	223
Center	942	1672	692
Lower	218	337	192

Intensities in $\mu W/cm^2$

8.2 Sanuvox data

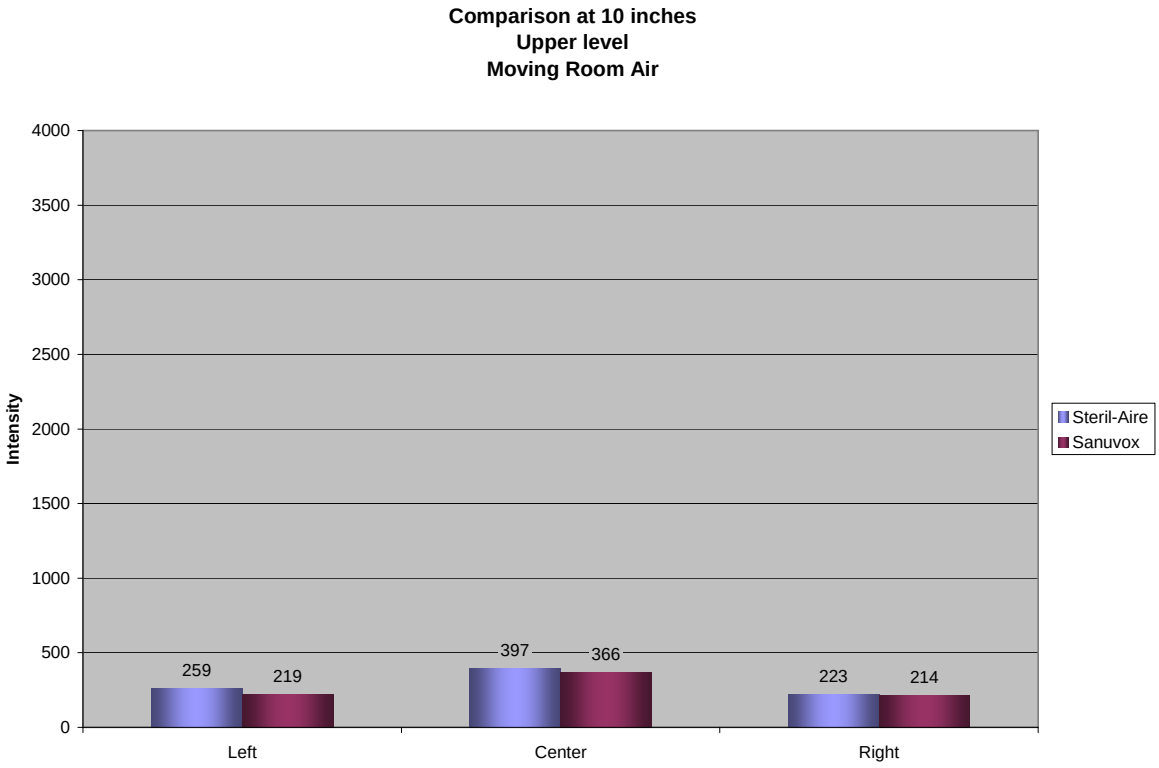
The following intensity values were recorded for the Sanuvox fixture:

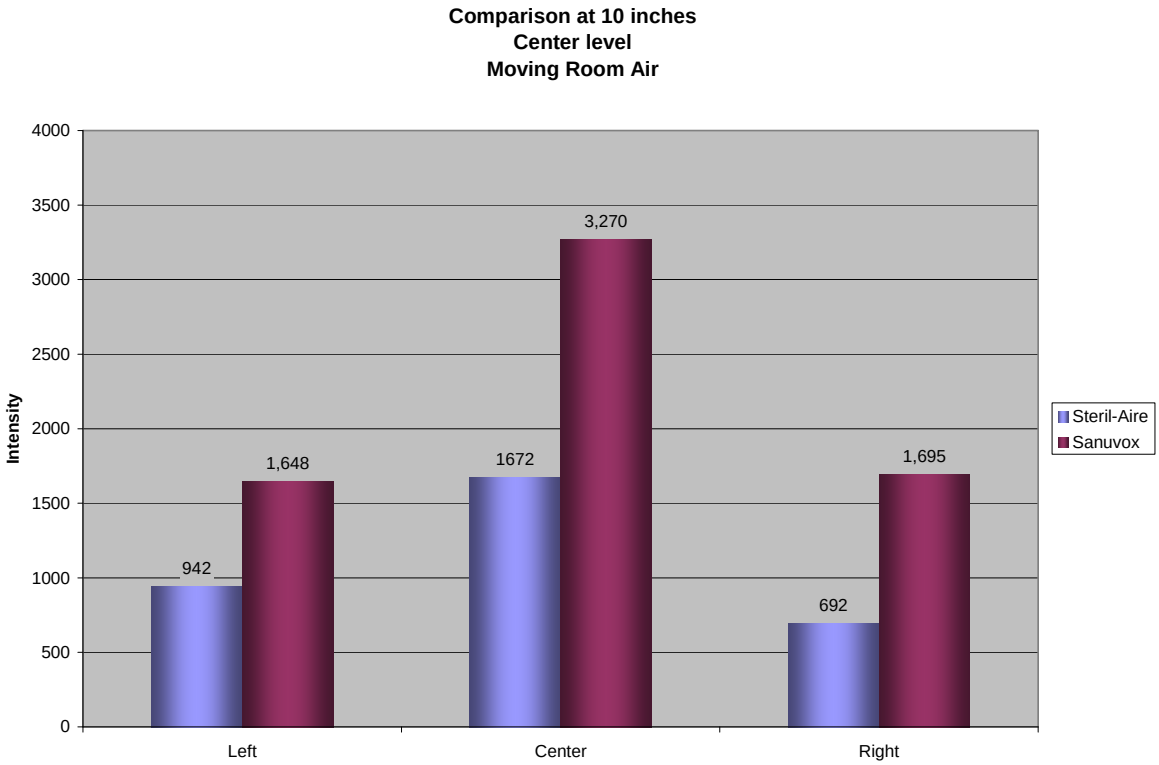
	Left	Center	Right
Upper	219	366	214
Center	1648	3270	1695
Lower	186	324	184

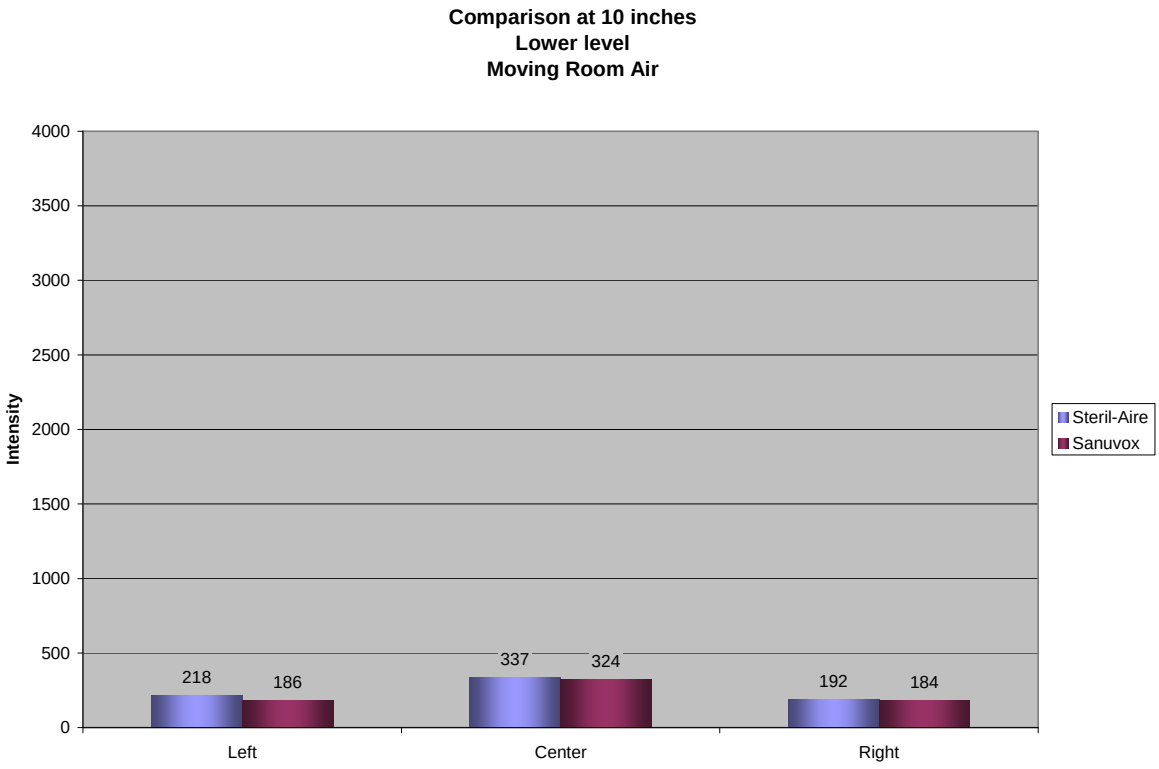
Intensities in $\mu W/cm^2$

8.3 Comparison

The following graphs show a comparison for each level.







Relative intensity Sanuvox to Steril-Aire

	Average
Upper	91%
Center	200%
Lower	93%

Relative intensity moving air to ambient air conditions (average moving air/average ambient air)

	Steril-Aire	Sanuvox
Upper	112%	121%
Center	99%	119%
Lower	101%	112%

The Steril-Aire fixture is, due to its wider irradiation angle, spreading more UV to the upper and lower levels as before. The improved intensity of the Sanuvox fixture at moving air conditions has however reduced the difference. At the center level the difference has increased to the advantage of the Sanuvox equipment. This is also visible when the relative intensity to ambient conditions is calculated for each fixture (see above).

It is again clear that the parabolic reflector of the Sanuvox fixture is improving the lamp output to a greater extent than the flat Steril-Aire reflector.

9 Testing in moving cold air at 100 cm over chamber cross section

The previous test (chapter 7) was repeated after reconstruction of the air supply enabling 100% outside air to be blown into the test chamber. At time of testing the outside temperature was recorded in the range of 28-32°F. The air temperature just before the sensor was recorded to be 50-51°F which is more realistic than previous air temperatures. This test was only performed at 100 cm.

9.1 Steril-Aire data

The following intensity values were recorded for the Steril-Aire fixture:

	Left	Center	Right
Upper	168	206	144
Center	143	190	157
Lower	168	198	144

Intensities in $\mu W/cm^2$

9.2 Sanuvox data

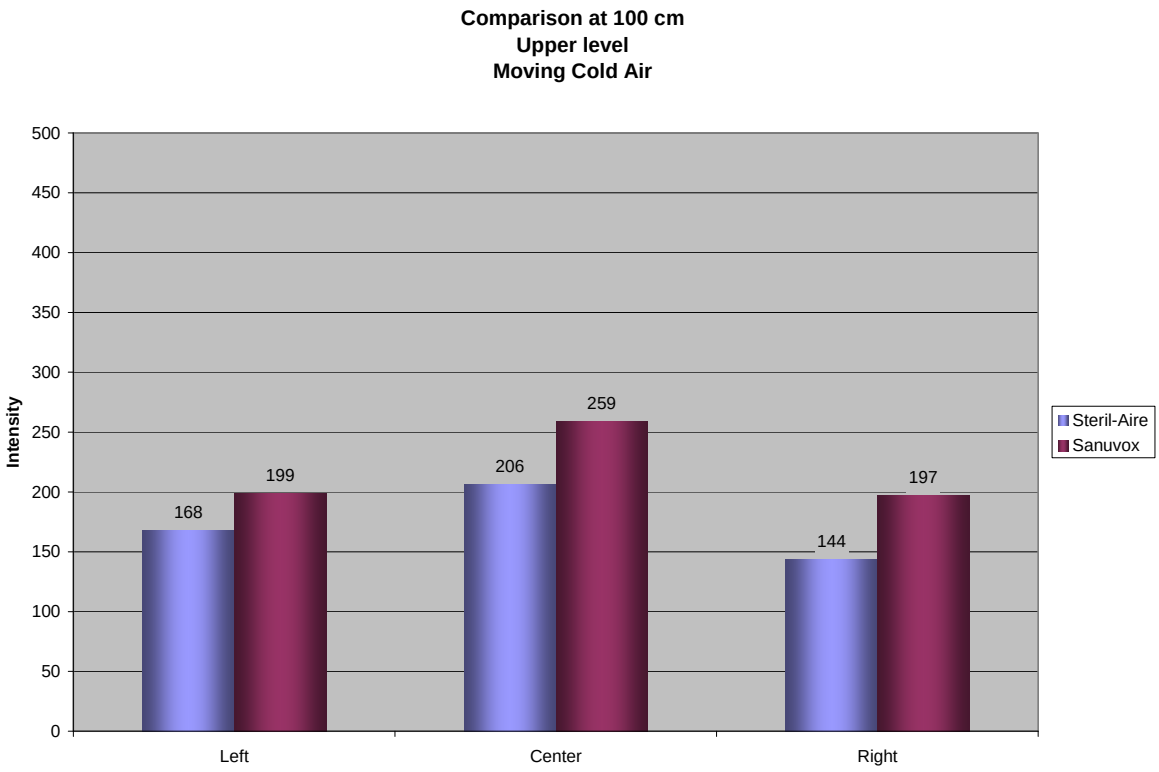
The following intensity values were recorded for the Sanuvox fixture:

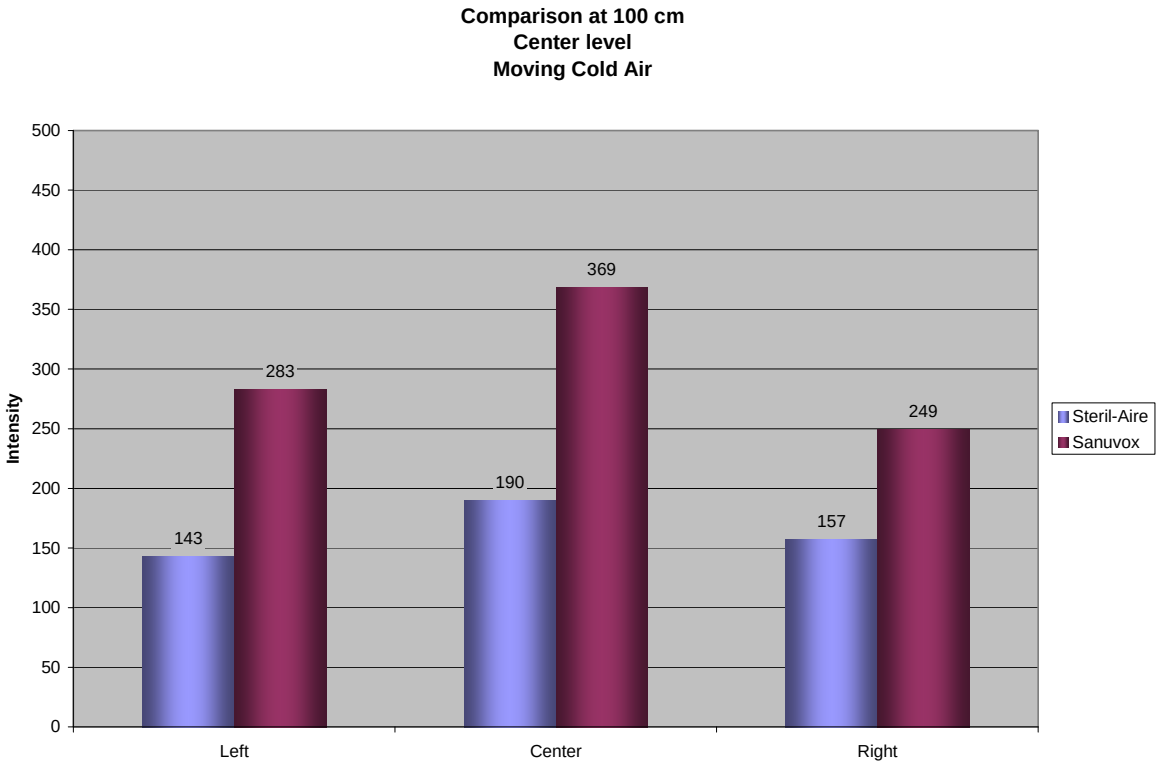
	Left	Center	Right
Upper	199	259	197
Center	283	369	249
Lower	202	232	178

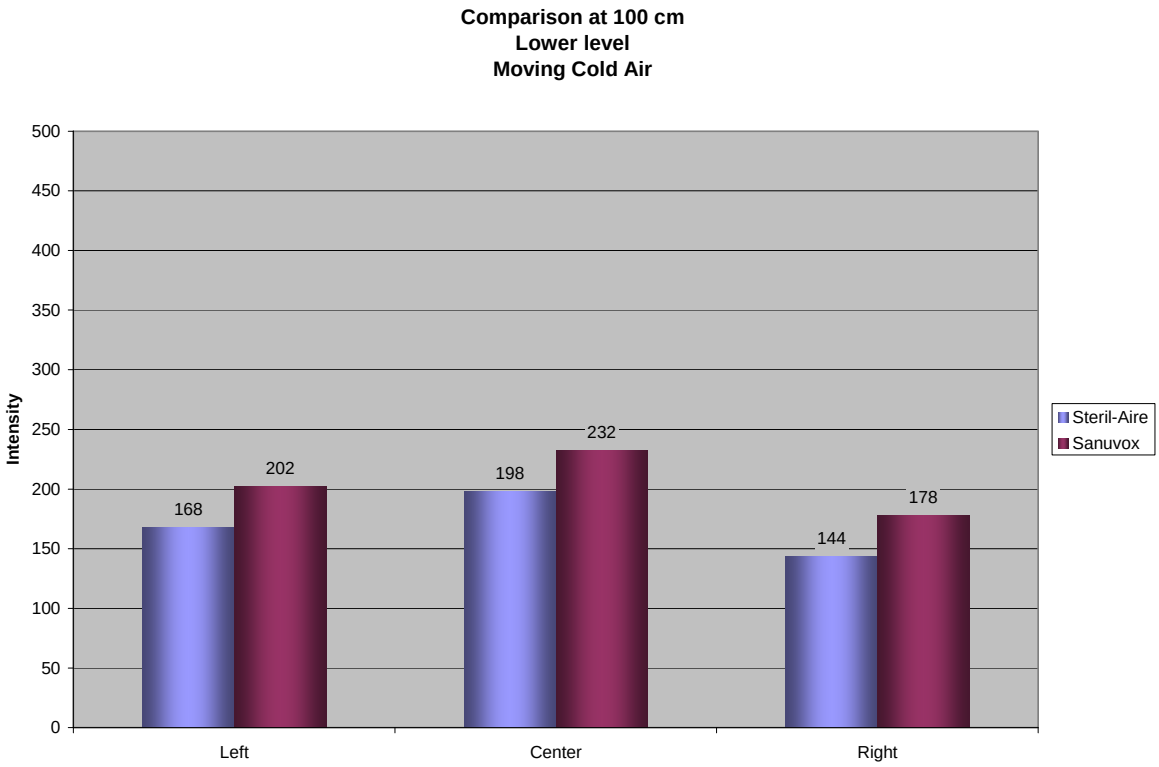
Intensities in $\mu W/cm^2$

9.3 Comparison

The following graphs show a comparison for each level.







Relative intensity Sanuvox to Steril-Aire

	Average
Upper	126%
Center	184%
Lower	120%

Relative intensity moving air to ambient air and moving room air conditions
(average cold moving air/average ambient air and average cold moving air/average moving room air)

	Steril-Aire		Sanuvox	
	Cold to ambient	Cold to room	Cold to ambient	Cold to room
Upper	71%	68%	80%	74%
Center	73%	70%	82%	73%
Lower	69%	67%	83%	71%

The cold air conditions reduce the intensity of the Steril-Aire fixture more than the Sanuvox and the comparison shows a significant advantage for the Sanuvox fixture over the Steril-Aire fixture.

10 Comparison at maximum and minimum intensity points

The recorded intensity over a coil is usually lowest at the coil corners and highest at the middle. In the performed testing the four outer locations of the sensor (upper and lower left and right) corresponds to the minimum points while the center/center location corresponds to the assumed maximum point.

The table below shows the Max and Min intensities for each test condition as a relative number to the Steril-Aire fixture at ambient conditions. The Min values are the average values of the four min points. All data are from the 100 cm testing.

	Steril-Aire			Sanuvox		
	Ambient	Room air flow	Cold air flow	Ambient	Room air flow	Cold air flow
Max	100%	103%	71%	166%	187%	138%
Min	100%	104%	70%	105%	119%	87%

At the 100 cm (39") distance from the sensor the Sanuvox outperforms the Steril-Aire fixture in all conditions.

11 Test of lamp without reflector

A comparative test was conducted with the lamp mounted without reflector under ambient and air-flow conditions. The objective was to investigate the lamp output without support from the fixture design.

The lamps were mounted in clips on vertical aluminum supports, painted matt black to avoid reflections. For practical reasons a single ended Steril-Aire lamp was used instead of the double ended used in the fixture. The single ended lamp has a slightly longer arc length compared to the double ended. The distance from the center of the lamp to the sensor was 100 cm and the sensor was placed at the midpoint of the glass. The temperature approximately 5 inches above the lamp was recorded to ensure somewhat similar test conditions.

11.1 Results

	Steril-Aire		**Sanuvox**	
	Air temp @ lamp °F	Intensity µW/cm^2	Air temp @ lamp °F	Intensity µW/cm^2
Ambient	75.4	126	76.1	226
Room Air flow	71.1	321	70.4	264
Outside Air flow	51.7	213	50.8	165

At ambient temperature the Sanuvox lamp generated a higher intensity than the Steril-Aire lamp. Both lamps increased the intensity output with the room temperature air flow but the Steril Aire lamp increased its output more than the Sanuvox lamp and showed a higher intensity than the Sanuvox lamp. The increase in intensity indicates that the lamps burn hotter than the optimum

temperature at ambient conditions. The air flow at room temperature brings the lamp temperature closer to optimum generating a higher UV output.

In the cold air flow both lamps drop in intensity. The Steril-Aire lamp was still higher than during ambient conditions while the Sanuvox lamp dropped below the output at ambient conditions. The lamp temperature is now below the optimum temperature causing the intensity to drop.

From this test it is obvious that the Steril-Aire lamp has a different temperature-output curve than the Sanuvox lamp and can handle cold air flows better than the Sanuvox lamp.

11.2 UV Output calculation

Based on the data above the UV output was calculated using the formula below:

Formula

$$\Theta = \frac{\pi^2 * H * E * L}{\arctan(L/2H) + 0.5 * \sin(2 * \arctan(L/2H))} * 10^{-6}$$

H = Distance from lamp plane to sensor
E = Recorded irradiance
L = Arc length of the lamp

The following UV outputs in Watts were calculated:

	Steril-Aire	Sanuvox
Ambient	14.4	25.5
Room Air flow	36.6	29.8
Outside Air flow	24.3	18.6

12 General Discussion

This comparative test is a first attempt to evaluate the product performance and determine if there are similarities between the fixtures that enable an easy replacement of Steril-Aire equipment with Sanuvox fixtures.

There is an obvious difference in the general design of the fixtures that lend each fixture advantages and disadvantages to the other depending on what performance aspect is reviewed.

A general description of the two products would be that the Steril-Aire lamp is handling HVAC conditions better but the Sanuvox fixture is compensating for this and giving the combined product a higher UV output in HVAC conditions.

The integration of ballast and fixture in the Steril-Aire design allows for mounting on a rack with integrated wiring and one final power connection to the general power source while the separation of ballast and fixture necessitates separate wiring from each Sanuvox fixture.

The same design difference allows the Sanuvox ballasts to be located outside of the harsh air handler environment.

The difference in reflector design gives the Sanuvox fixture a higher intensity at lamp level independent on the distance to the exposed surface. The disadvantage is that the reflector also restricts irradiation in the upper and lower regions, especially at shorter distances commonly seen in air handlers.

The Steril-Aire fixture has an advantage with its wider beam of irradiation.

In any given UV system design it is the lowest intensity on a surface like a coil that determines the efficacy. Very high intensity levels at the lamp are always impressive but are usually of lesser value if the lowest values are insufficient.

The greater angle of irradiance for the Steril-Aire reflector also makes it more suitable for treatment of fly by since it gives a considerably longer “kill length” that the Sanuvox fixture.

It should however be possible to angle the Sanuvox fixtures so that a higher intensity level reaches the upper and lower section of, for example, a cooling coil or the increase the “kill length”.

The table below is a compilation of aspects indicating which fixture has an advantage over the other. No importance has been given to the individual performance factors. The check sign indicates what specific fixture has a perceived advantage over the other. If there is no perceived advantage, both fixtures received a check mark.

Both products must be considered to work well as long as their specific design and installation aspects are considered.

		Steril-Aire	**Sanuvox**
1	Number of available fixture sizes		✓
2	Intensity at lamp level		✓
3	Width of irradiance field	✓	
4	Overall intensity at long distance		✓
5	Overall intensity at short distance	✓	
6	Power consumption		✓
7	Sensitivity to proper mounting	✓	
8	Perceived ruggedness against realignment of fixtures at operation	✓	
9	Protection of lamp glass from physical impact		✓
10	Anticipated air restriction when mounted downstream from coil facing air flow	✓	
11	Maximum fixture length	✓	✓
12	Moisture protection of connections	✓	
13	Ease of service		✓
14	Space requirements outside air handler	✓	

		Steril-Aire	Sanuvox
15	Possibility to apply Vigilair control panel and door sensors	✓	✓
16	Possibility to apply heat transfer formula calculations	✓	

Comments

2 The shape of the reflector concentrates more irradiance at lamp level.

3 The flat Steril-Aire reflector gives a considerably wider angle of irradiance which is helpful in air treatment (fly-by efficacy).

4 The same reason as for 3.

5 This disadvantage for Sanuvox can be overcome by either the general placement of fixtures in an array or by angling upper and lower fixtures to produce a more even intensity field.

6 The Sanuvox fixture showed a slightly lower current draw than the Steril-Aire fixture.

7 The mounting of the Sanuvox fixture with two clamps to a tubular structure is simple but there is a risk that the fixture can tilt up or down if hit after installation. The angle of the fixture is affecting the irradiation beam and if a fixture is knocked out of alignment the intensity levels are out of control.

8 Due to its design the Sanuvox fixture is likely to more sensitive to realignment if subjected to physical force. It is not uncommon that service technicians bump into lamp fixtures when doing other service inside the air handler.

9 The Sanuvox lamp is placed inside the edges of the reflector and thus better protected from impact (see 8).

10 The Sanuvox fixture restricts, due to its shape, air flow to a higher degree than the Steril-Aire fixture.

11 Steril-Aire's new 62" fixture has been included in the comparison.

12 Neither fixture has a good moisture protection but the Steril-Aire fixtures can use "Boot" to cover the connection points. Sanuvox does not yet have that available.

13 The mounting of Sanuvox ballasts outside the air handler makes any service of them a lot easier.

14 The mounting of Sanuvox ballasts outside the air handler requires more space on the outside of the air handler.

15 The shape of the Sanuvox ballast makes it more difficult to apply the reflection formula for heat transfer to calculate the irradiance in a certain point.

16 The more complex reflection from the Sanuvox fixture makes calculations using the Radiant Heat Transfer formula more complex. In the Vigilair design software we use the formulas for direct irradiation and reflection from a flat surface (the Steril-Aire reflector).
A modification of the software to enable use of Sanuvox fixtures would require significant alterations of the software.