




HGI Boss™ PERFORMANCE TESTING

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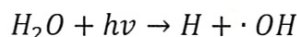
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Executive Summary

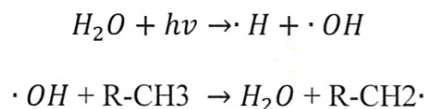
Hydroxyl ($\cdot\text{OH}$) generators are designed to purify the environment in which they are operated. The general principle of operation is the oxidation of ambient water vapor using an ultra-violet (UV) lamp source to produce hydroxyl molecules, $\cdot\text{OH}$, also referred to in the industry and in the literature as hydroxyl radicals or hydroxyls. In ambient air, there are other reaction steps involving oxygen that contribute to the formation of hydroxyls, but the overall result is as shown below.



There are two main categories of hydroxyl generators. Those that use a broad spectrum of ultra-violet radiation to interact with water and oxygen in air; and those that use a single wavelength of ultra-violet light to shine on a photo catalytic surface. The latter method is often referred to as the Photo Catalytic Oxidation (PCO) method. Some generators combine these methods.

The Boss™ device uses the first approach. It produces hydroxyls ($\cdot\text{OH}$) via photolytic decomposition of H_2O in ambient air using a range of high energy ultraviolet radiation. The production reaction occurs in the gas phase, and the resulting gas phase hydroxyl radicals react freely with organic and inorganic compounds and microorganisms in air and on surfaces. The hydroxyl radical reactions produce a series of highly reactive organic free radicals that rapidly react with oxygen and behave themselves as powerful oxidants.¹⁻⁴ This cascade of oxidants is highly reactive and decomposes by a complex series of free radical reactions, some of which involve continued reaction with hydroxyls.

Little if any scientific data is available on the hydroxyl formation rate using either method. This is likely due to the fact that to do so accurately, it is necessary to use a specially designed test chamber. Hydroxyl free radicals are so reactive and short-lived that they cannot be practically measured directly by analytical methods in a laboratory.¹⁻⁵ An industry standard laboratory method for measuring the formation rate of hydroxyls is to measure the rate of removal of a specified amount of a volatile hydrocarbon (shown below as R-CH_3) in an ultra-clean room environment under highly controlled conditions.¹ The hydrocarbon is chosen based on its ability to selectively react with only hydroxyl radicals and not other oxidants, such as ozone, that may be produced by UV photolysis of water vapor.



Upon formation, the hydroxyl rapidly abstracts a hydrogen atom, $\cdot\text{H}$, from the hydrocarbon. The hydroxyl production rate can then be determined indirectly by measuring the increased decay rate of the hydrocarbon concentration while the hydroxyl generator was operating.¹⁻⁵

Because of the high level of reactivity of the hydroxyls, a special reaction chamber made of Teflon must be used to avoid loss of reactant from adsorption and reaction on chamber surfaces. The chamber must also be specially treated to remove all ambient organic and inorganic

molecules using special filters and ventilation. Only then can the selected hydrocarbon reactant concentration changes be accurately measured and attributable solely to the formation and reaction of hydroxyls. Using this methodology, formation rates of hydroxyls as low as a few part per billion (ppb) can be measured.

This experimental method was used to measure the hydroxyl formation rate for the Odorox® Boss™, serial number ODHG001082, (Odorox Environmental LLC, 16525 Westfield, Indiana 46074). The experiment involved the use of n-heptane, which selectively reacts with hydroxyls and not other oxidants that could be produced by the systems. There is abundance of data in the literature describing the kinetics and high rate of reaction of hydroxyls with n-heptane to further enable confirmation that the reactions are due to the presence of hydroxyls.¹⁻⁵

The test chamber was purged and the Boss™ was placed inside. The chamber was sealed and allowed to purge again so that a stable baseline was obtained. A sample of n-heptane was introduced into the system such that an initial vapor phase concentration of 0.13 ppb was obtained. After running the system for two hours in the experimental chamber, the data showed that the Boss™ produced hydroxyls in the hundreds of part per billion (ppb), similar to that found in nature. The hydroxyls reacted rapidly with the n-heptane at a rate consistent with published values.^{1,2,4}

In summary, under highly controlled conditions, the Boss™ system generated hydroxyl radicals which rapidly reacted with n-heptane producing a measurable reduction in the n-heptane concentration consistent with a hydroxyl formation rate in the hundreds of ppb. To provide a perspective on these results, typical concentrations of volatile organics found indoors range from 100 – 750 ppb, with levels commonly reaching 1000 to 4000 ppb.

The hydroxyl reaction rate with n-heptane matched published data, confirming that the reactant was, in fact, the hydroxyl radicals. The average concentration of hydroxyls distributed within the test chamber produced by the Boss™ system was consistent with that found in nature ($\sim 2 \times 10^6$ molecules/cm³), which have been shown to effectively react with and decompose a vast number of organic and inorganic compounds as well as kill bacteria, viruses, and mold.¹⁻⁴

Materials and Methods

The experiments described here were conducted in a 120 cubic meters (120,000 liters) Teflon chamber. The walls and floor are made of inert “water-clear” Teflon film. A high-volume ventilation fan connected to a HEPA filter removes PM from ambient air during large-volume flushing of the chamber. A clean air generator scrubs moisture, VOCs and PM from air before it enters the chamber. The chamber contents are monitored continuously via sample lines that pass through the floor of the chamber and into the laboratory. Gas chromatography was conducted on the purged chamber and showed little background compounds that could interfere with the tests. The experiments were conducted at night so no sunlight would cause photochemical oxidation of the test mixtures. For all experiments, the Boss™ generator was placed inside the chamber in the middle of the floor; a heavy duty electrical power extension cord passed through a small opening in the floor to the outside to allow for remote powering and operation. Power and operation was confirmed by visual observation of the green power light and hearing the blower. Two mixing fans one each at both ends of the chamber, were turned on to assure complete mixing. All experiments were conducted with addition of a low concentration of an inert non-reactive dilution tracer of carbon tetrachloride (2.5 micro-liters in the chamber). Since several continuous monitoring instruments are sampling from the chamber continuously, the chamber contents are diluted about 1-2 percent per hour, which is considered low. The measurement of the dilution tracer shows this steady slow decrease in concentration. Any compounds that are not reacting would decrease in relative concentration equal to this dilution rate, and any chemical reactivity with OH and ozone would cause a larger decrease in concentration. All other air pollutant measurements are compared and corrected using these dilution measurements.

Results

Hydrocarbon Removal (Heptane Treatment)

0.13 ppmV of n-heptane was injected into the chamber and monitored to establish initial test conditions and demonstrate stability before operation of the hydroxyl generators. All data presented in this report are corrected for dilution using the monitored tracer (carbon tetrachloride). The background air was measured with gas chromatography and mass spectrometry and was observed to be clean.

The Boss™ unit was powered and operated using High Processor and High Fan settings at 1939 (7:39 PM). It was operated for 2 hours. During this time the n-heptane was monitored and showed a decrease in concentration of 18 percent with the decay rate shown as a regression, slope in ppm per hour (Figure 1). After the instrument was turned-off, the heptane was monitored showing that a relatively stable concentration was observed and it can be concluded that the instrument was responsible for the observed decay when it was operational.

Heptane Treatment with Boss™ OH Generator Oct 17, 2011

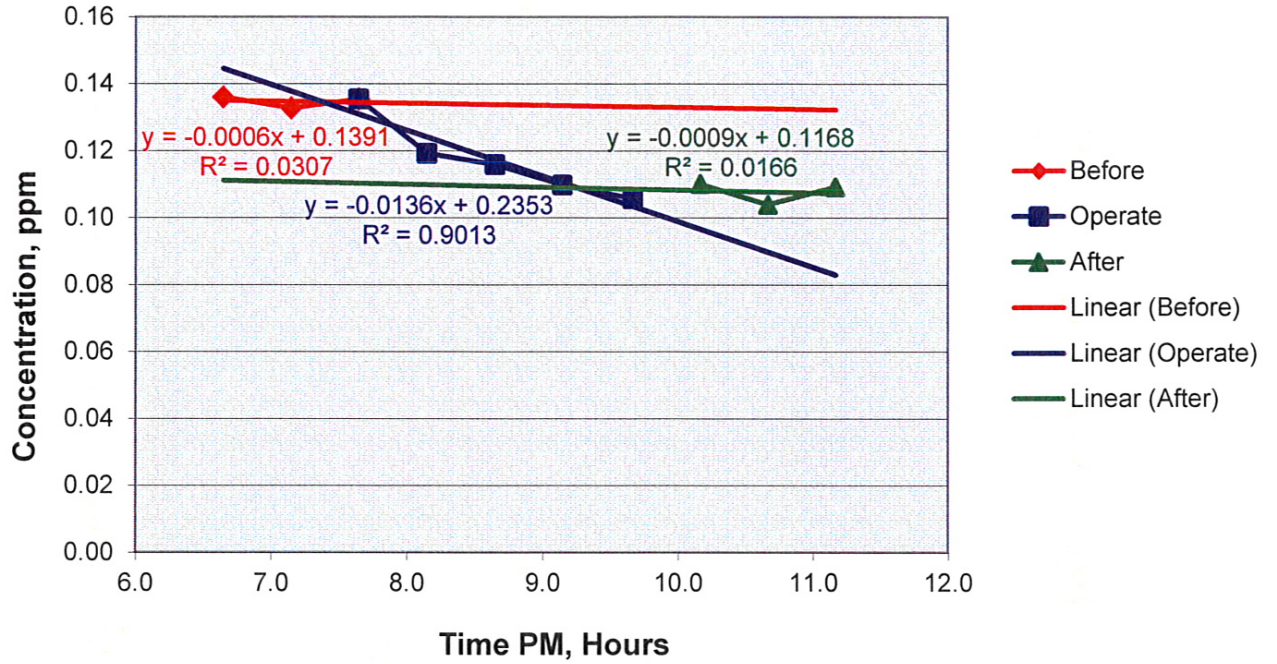


Figure 1 Heptane treatment, Boss™ hydroxyl generator.

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Appendix

Test Condition Summary for the Hydroxyl Generator Experiments

Operating Conditions

Boss Heptane Treatment Oct 17, 2011

venting stopped at 1800

mixing fans on

1829 inject 95ul heptane for 0.13 ppmV; 4 ul CCl4

1839 sundown

1939 start Boss Hi Processor; Hi Fan

1947 Ctemp 298.1K; Dewpoint 11.9C

2139 Stop Boss

Heptane Decay

Time Hours	ppm Before	ppm Operate	ppm After
6:39 PM	0.1360		
7:09 PM	0.1327		
7:39 PM	0.1354		
7:39 PM		0.1354	
8:09 PM		0.1192	
8:39 PM		0.1159	
9:09 PM		0.1098	
9:40 PM		0.1057	
10:10 PM			0.1100
10:40 PM			0.1039
11:10 PM			0.1091