

The following 23 pages include 1 test performed by LRRI to a fake and intentionally dishonest protocol written by ODOROX /HGI to discredit International Ozone and the Titan 4000 Hydroxyl Generator.

The first report on pages 3 thru 7 was released on July 23rd., 2012. This report shows that the Titan unit was tested at 20% humidity which is 100% against the 60% needed that is written in the owner's manual and screen printed on the front of the unit. This was obviously done to make sure the Titan did not perform well.

The second release of the same report dates July 2nd., 2013 is on pages 9 thru 17. This second release a year later has been changed in many ways. They now identify the Titan model. They removed the statement on using 20% humidity for the testing.

The last 5 pages of this statement are of a report that proves that LRRI was wrong in stating that N-Heptane is not affected by ozone.

There is also a chart on the last page showing that our little Titan 1000 actually oxidized the heck out of N-Heptane with no problem

HGI Industries Falsely Tests Titan Hydroxyl Generator

HGI industries of Boynton Beach Florida, the manufacturer of the Odorox Boss had the Titan Hydroxyl Generator tested under false conditions. These false conditions caused the test results to be skewed and unrepresentative of the product. Below is our rebuttal of their erroneous testing procedures and bogus test results. A link to their test, which by the way is not posted on their site, is included at the end of this rebuttal. I also include links to testing by others that factually disprove HGI's findings.

The opening statement directly following is from HGI's corporate web site.

Mark Mino, President of HGI, commented on these test results.

LRRRI also tested the Titan machine that is marketed by International Ozone as a "hydroxyl generator". After extensive testing, LRRRI detected no measurement of hydroxyls at all, and concluded that if the Titan was producing any hydroxyls, they were too few to be measured. This research confirms the observations of contractors in the field who are unable to remove odors from surfaces and contents with this product. It is very important for the restoration industry and insurance professionals to understand the significant differences in these technologies."

Falsification #1 – HGI identifies their specific model (Boss) and RGF's specific model (IOX Pro 300) but does not identify the Titan Hydroxyl Generator tested. International Ozone has learned that HGI tested the Titan 1000 which is a small homeowner unit intended for use in one room at a time, for lite odors, and is no way a professional restoration piece of equipment. The model that should have been tested would have been the Titan 4000.

Falsification #2 – If HGI or LRRRI had tested our Titan 4000 and read the Titan owner's manual they would have known that this machine requires 60%+ humidity for optimal performance. The screen printed instructions on the face of the unit clearly states, "60%+ Humidity Necessary for Optimal Performance". The testing was performed at 20% humidity. Everyone in the restoration industry knows this is a very dry environment. 20% humidity is hard to achieve and HGI & LRRRI had to artificially manipulate the testing environment to achieve that low humidity. True hydroxyl generators must have water vapor in the air to bust the hydrogen out of for the machine to make OH (hydroxyls).

Falsification #3 – The following statement is taken directly from their test procedures:

"The goal of the studies was to determine the concentration of HO being produced by each system by measuring its rate of reaction with n-heptane, a volatile organic compound known to react selectively with hydroxyl radicals and not ozone."

The linked report, *Non-thermal plasma n-heptane decomposition enhanced by supplementary addition of active species* by S. Pekárek, following this rebuttal proves ozone oxidizes N-Heptane.

An extract from this report states – "ozone and other active species produced were supplied into the main discharge. In this way we were able to increase the n-heptane decomposition efficiency from 47 % to 53 %"

HGI's own test (link following) shows that the Boss and the RGF unit both produce ozone. Low humidity environments are perfect for ozone production and ozone oxidation of contaminants. True hydroxyl generators will not produce hydroxyls in 20% humidity. Because of the low humidity under which the test was performed, no or very small amounts of hydroxyls would have been produced and thus the Titan Hydroxyl Generator would not have affected the N-Heptane.

Conclusion: If HGI had tested the International Ozone machine, in accordance with our specifications and recommendations, the results would have been entirely different. If they had tested the correct model, our Titan 4000, with the correct level of humidity, the findings would have supported our suggested uses and claims.

NOTE: See link below to UL Ozone Test of the Boss which demonstrates the Boss's production of ozone at a level 23.2 times greater than considered safe in occupied areas.

Link to HGI Test - http://internationalozone.com/Comparison-UVSystems_7-12%20Text%20Boxes.pdf

Link to N-Heptane Report - <http://internationalozone.com/n-heptane%20and%20ozone.pdf>

Report by Jacoby - <http://internationalozone.com/William%20Jacoby%20-%20Photocatalytic%20Oxidation.pdf>

Link to UL Boss Ozone Test - <http://internationalozone.com/UL%20Odorox%20Report%20Total.pdf>



Comparison of Photo Catalytic UV and Multiple Wavelength UV Irradiation Air Cleansing Technology

The latest generation of air and surface decontamination/cleaning systems now uses UV irradiation to generate powerful oxidants to eliminate odor, decompose volatile organic compounds (VOCs) and kill microorganisms. Some have focused on imitating nature and generating the same type and levels of oxidants in air by decomposing water vapor and oxygen in ambient air with UV irradiation. Other methods use artificial approaches. The goal is similar; to try and generate hydroxyl radicals ($\text{HO}\cdot$ /or/ $\cdot\text{OH}$), nature's principal atmospheric oxidant for cleansing our atmosphere and biosphere of excessive levels of volatile organic/inorganic compounds and microorganisms.

Atmospheric hydroxyl radicals are nature's most effective and fast acting oxidant. Only atomic fluorine is more powerful and it is not found in nature. For example, hydroxyl radicals oxidize VOCs about one million times faster than ozone and have much broader reactivity. The implication is that, any time hydroxyl radicals are proven to be produced, they will dominate chemical and microbiological reactions. If ozone and hydroxyls are generated together, the hydroxyls react so fast, it is as if the ozone were not present. ← Something somebody made up.

The key to designing safe and effective hydroxyl radical oxidative air cleaners is to literally imitate the action of the Sun's interaction with water vapor to produce hydroxyl radicals at the same rate and levels as found in nature. This ensures that the by-products are also "natural". We have evolved and adapted well to the presence of these hydroxyls and by-products in our air. Modern living causes levels of VOCs to accumulate significantly indoors, where natural outdoor hydroxyl radicals cannot reach. Hydroxyl radicals react so quickly – within 50 milliseconds – they are usually consumed basically where they are formed. UV air cleansing systems have the potential to restore nature's balance indoors and greatly improve the quality and safety of indoor environments.

There are three main categories of air cleansing systems. The first type, called multiple wavelength UV systems, uses a range of different wavelengths of UV energy designed to produce the hydroxyl radical from water vapor and oxygen in air. This approach imitates nature in that no other chemicals or devices are used. The second type, called photo catalytic oxidation (PCO), uses a single wavelength of lower energy UV energy that selectively interacts with a catalyst coated surface to theoretically produce hydroxyl radicals. The third type combines both methods. HGI Odorox[®] systems use the multiple wavelength UV method. They use 185nm to 254nm. 185nm is ozone producing.

HGI commissioned the Lovelace Respiratory Research Institute (LRRI), an facility with distinguished expertise in atmospheric oxidative cleaning chemistry, to evaluate these three methods to determine how effective they were in producing hydroxyl radicals and what kind of by-products were produced. The goal was to produce quantitative data for each system under identical conditions, data that is not available in the literature. These studies have been further analyzed and interpreted by a leading physical chemist and industry expert in atmospheric hydroxyl radical chemistry and spectroscopic analysis, Dr. David Crosley. They had 20% humidity for this test. Where did they get their water vapor?

Identified their model, Boss. Identified RGF model, Pro 300. Didn't identify the Titan model because they tested the Titan 1000. A homeowner unit intended for one room at a time of lite odors. Not a fire/flood restoration piece of equipment.

LRRI tested three different machines⁴, each representative of one of the three different methods of air cleansing. The systems were:

- Odorox[®] Boss[™] Multiple wavelength UV system (Manufactured by HGI Industries Inc.)
- Titan Photocatalytic Oxidation (PCO) system (Manufactured by International Ozone Technology Group Inc.)
- Perfex IOX Pro 300 (RGF Rapid Recovery System[®]) Combination system (Manufactured by HGI Industries Inc.)

Where did they get water at 20% RH?

They identify the uv wavelength they use in their patent application. 185nm to 254nm. 185nm is ozone producing.

Multiple wavelength UV systems, like the Odorox[®] Boss[™] unit, use a range of UV wavelengths below 350 nm, similar to that found in nature, to form hydroxyl radicals. At these wavelengths there is enough energy to produce hydroxyl radicals directly from dissociation of H₂O and by several pathways involving the decomposition of oxygen and ozone in air. Free hydroxyl radicals react with VOCs in air and also with microorganisms. They oxidize and decompose VOCs producing a complex mixture of intermediate oxidation products that continue to decompose until they yield carbon dioxide and water.^{4,5} Hydroxyls kill microorganisms by reacting with the proteins and other chemicals in cellular membranes resulting in cell leakage and death, a process called lysing. High energy oxygen species are formed during the photolysis process and deliberately decomposed by exposure to selected wavelengths of UV energy to form additional hydroxyl radicals. This formation and decomposition process is exactly what happens in nature. There is some level of residual ozone that reaches a steady state concentration that typically remains within ambient levels in normally ventilated spaces. The key difference among vendors is the amount of ozone produced and destroyed.

The Odorox produces a lot and destroys very little per Underwriters Laboratories test.

PCO systems, like the Titan, rely on the use of semiconductor catalyst coated surfaces inside the photolysis chamber to theoretically generate hydroxyl radicals and other oxidants. Typically titanium dioxide is used. The UV irradiation is absorbed by the catalyst, which produces a reactive electron "hole" and a free electron. The "hole" presumably removes an electron from water to form the hydroxyl radical, while the free electron reacts with oxygen to form superoxide. These reactive oxygen species react rapidly with organic compounds and other species adsorbed on the catalyst surface. This mechanism does not produce any "free" oxidants at a distance from the catalyst.^{1,2,3} The photocatalytic method uses a longer, lower energy wavelength of UV energy above 350 nm so that little to no ozone is formed. Developed for the space shuttle, the approach was designed to generate sufficient oxidants to treat small volumes of air with low concentrations of VOCs. Nowhere in the patent or scientific literature for these systems is there definitive proof or measurement of what oxidants are formed. It is presumed that the oxidants are the hydroxyl radical and the superoxide radical.

Combination systems, like the IOX Pro 300 system, use both a catalyst coated surface inside the photolysis chamber and multiple wavelengths of UV light over a broad range from 360 nm and below. It is presumed that hydroxyl radicals can be formed on the catalyst as well as in the atmosphere. Ozone is also produced and decomposed in this type of system. There is no data in the literature about how many hydroxyl radicals are produced or how the catalyst affects the formation of by-products.

Lots of testing and thousands of units being used everyday in the field prove this statement wrong.

20% humidity is dry - No water vapor at all in the air. True hydroxyl generators must have 60%+ humidity to work. If they had tested the correct Titan unit it is screen printed right on the front of the unit and also written in the owner's manual.

Each system was tested under identical conditions inside a Teflon room of 120,000 liters (120 cubic meters) designed for atmospheric studies. Using Teflon minimizes adhesion of organic compounds to the test chamber walls, which is important when testing very low parts-per-billion (ppb) levels of compounds. The environment inside the chamber was controlled to minimize organic contaminants to a constant level of 7 ppb using HEPA and charcoal filters. Testing was done at night to eliminate the introduction of ambient UV radiation into the chamber. As each system ran, a slow purge of purified ambient air with an average relative humidity of 20-30% passed through the room and exited to a gas chromatograph-mass spectrometer that measured very low ppb levels of chemicals. Inside the chamber were various meters for measuring a variety of chemicals including ozone, NO, NO₂, etc.. The goal of the studies⁴ was to determine the concentration of HO• being produced by each system by measuring its rate of reaction with n-heptane, a volatile organic compound known to react selectively with hydroxyl radicals and not ozone or other oxidants. The kinetics of the reactions of hydroxyl radicals with n-heptane are well understood and published so that a comparison could be made to confirm that hydroxyl radicals were the only reactive species.⁶ The experiment also measured the formation of ozone and formaldehyde which are common by-products of incomplete combustion/decomposition. Each system was run for two hours in the presence of 130 ppb of n-heptane. During the run the concentrations of n-heptane, ozone and formaldehyde were measured. The results were reported by LRRI⁴ and further analyzed by Dr. Crosley⁵.

*

System	n-Heptane removal percent (%)	Ozone net formation rate* ppb/min ± 0.4	Formaldehyde net formation rate* ppb/min ± 0.001
Boss™	18 ± 2	3.2	0.033
RGF/ IOX Pro 300	18 ± 2	10.9	0
Titan	0 ± 6	0	0

See report "Non-thermal plasma n-heptane decomposition enhanced by supplementary addition of active species. Ozone oxidized (eats) n-heptane.

Did not identify Titan model.

(Note: In normal use environments ozone and formaldehyde levels plateau to lower steady state levels due to loss factors, such as, continued reaction with HO• and other free radicals, chemical reactions with ambient VOCs, adsorption, ventilation, etc.)

If they don't like the finding they put in a disclaimer.

The data for the Boss™ and IOX Pro 300 multiple wavelength UV systems indicate that:

- Both produced about the same concentration of hydroxyl radicals (within the limits of error)
- They generated sufficiently high concentrations of hydroxyl radicals so that measurements of their reaction with the target VOCs n-heptane could be made. In the two hour test period 18 percent of the n-heptane was consumed
- The fact that the oxidant produced was the hydroxyl radical was based on the rate of reactions matching the published kinetics data for hydroxyl radicals – a definitive result determined by Dr. Crosley which corresponded well with published kinetics data by Finlayson and Pitts^{5,6}

- The hydroxyl radical formation rate was similar to that found in nature of $1 \times 10^6 \text{ cm}^3/\text{sec}$ presuming the oxidant and by-products were uniformly distributed throughout the treatment space
- Negligible amounts of formaldehyde were produced
- The rate of reaction of the hydroxyls generated with the representative of VOCs; n-heptane was calculated from the data to be 22-45 milliseconds, which is extremely fast compared to any other oxidation reaction. This would enable rapid decomposition of both initial VOCs and their oxidation by-product
- The use of both multiple wavelength UV light and a catalyst in the IOX Pro 300 system
 - Did not result in a higher level of hydroxyl radical formation
 - Resulted in a higher ozone formation rate - 3.4 times higher than the Boss™ unit.

The data for the Titan system indicate that it did not produce sufficient hydroxyl radicals to result in a measurable change in the n-heptane concentration. The value was so low that it was reported as zero with a 91 percent statistical probability of as much as 1ppb based on the error bars for the measurement. There was no measured ozone or formaldehyde formation. Based on this negative result, an additional run was made using 130 ppb of 2-methyl furan, which is known to be at least twice as reactive as n-heptane with the hydroxyl radical. After two hours no measurable decrease in the 2-methyl furan concentration was noted either. The results were not considered quantitatively because the possible change was so low as to be within the error limits of the GC-mass spectrometer measurement capability.

Wrong model tested - No humidity - no hydroxyls.

These results are consistent with published data about PCO systems which report that they have significant limitations with regard to remediation^{1,2,3}

See report - Photocatalytic Oxidation by William Jacoby.

- PCO system oxidative capacity is limited by catalyst surface area. Typically the amount of VOCs that could be adsorbed onto the catalyst would be in the high parts per trillion and low parts per billion. This is much lower than the concentrations of VOCs that are measured in ambient air, which range from the high ppb to low parts-per-million (ppm) range.
- Since reaction of any oxidative species generated by a PCO system would occur with adsorbed VOCs, only throughput air is treated – not external surfaces. Whatever oxidants are produced would immediately react with adsorbed VOCs, so there are no “free” hydroxyls or other oxidants that could circulate outside of the treatment chamber. PCO systems have proven to work best at low air speeds confirming that reactions are occurring predominantly on the catalyst surface. (High speeds are 340 CFM and low speeds would be half to one third of that rate – or even lower.) This limits their use when trying to treat large areas.
- Humidity inhibits the rate of reaction as water vapor competes for catalyst active sites.
- Catalysts are subject to deactivation due to catalyst surface contamination. TiO2 is self cleaning.
- Oxidation is incomplete, producing an effluent that has 3.4 to 4.6 times more formaldehyde and acetaldehyde. Mathematical modeling studies indicate that there would continue to be a three-fold increase in the steady state concentrations of these (and other) incomplete oxidation products given the flow rates and capacity of this technology³. Their own testing shows this to be untrue.

This is disproved by thousands of units working in the field.

Our Titan 4000 works great at 5,000cfm.

True hydroxyl generators have to have high humidity.

In summary the LRR I studies and analysis by Dr. Crosley indicate that:

- The use of multiple wavelength UV light is an effective means of producing hydroxyl radicals in both the Boss™ and IOX Pro 300 systems.
- Including a catalyst with multiple wavelength UV irradiation did not increase the amount of HO• produced in the IOX Pro 300 system.
- Different multiple wavelength UV systems may produce the same levels of hydroxyls – as was found in this test - while producing very different levels of ozone and potentially a different distribution of oxidized organic compounds.
- PCO systems, as exemplified by the Titan, are fundamentally different from multi UV systems and do not have the capacity to generate a high enough concentration of HO• to decompose VOCs in the range of 130 ppb, which is typical of what would be required for remediation applications.

They do not publish their multiple UV wavelengths here but they do in their patent applications. 185nm - 254nm. 185nm is ozone producing. These are the same lamps used in every ozone generator ever produced.

If they had tested the correct model with the correct amount of humidity they wouldn't even publish this report.

It is evident that each vendor should measure and validate the performance claims of their systems since oxidant and by-product levels were significantly different among the systems tested.

References

1. Bill Jacoby, "Photocatalytic Oxidation", Penn State University, College of Engineering, 2000.
 Please see following report - Photocatalytic Oxidation by William Jacoby. He loves our technology.
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4. Lovelace Respiratory Research Institute "HGI Hydroxyl Generator Performance Testing Final Report (Draft), June 2012.
5. Dr. David Crosley HGI LRR I Data Analysis Reports 1-7 May 2011- March 2012.
6. B. J. Finlayson Pitts and J.N. Pitts, Jr., *The Chemistry of the Upper and Lower Atmosphere*, Academic Press, San Diego 1999.

HGI logo and Odorox are trademarks or registered trademarks of HGI Industries Inc., Boynton Beach, Florida, USA.
Rapid Recovery System is a trademark or registered trademark of RGF Environmental Group Inc, West Palm Beach, Florida, USA.

The following 9 pages are a rewrite of the original LRRI report which was dated July 23, 2012. This rewrite was released by ODOROX / HGI one year later dated July 2, 2013.

Everything that International Ozone pointed out in the first report that was wrong or in error has been changed in this rewritten report released a year later.

The Titan 4000 model number is now identified.

The 20% humidity used during the testing has been removed from this rewritten report.

On the 5th. page 1st. paragraph LRRI identified the Titan 4000 was running by_ ***“confirmed by visual observation of the GREEN POWER LIGHT and hearing the BLOWER”***

The second test with Methal-Furan was supposedly done after the n-heptane test but is dated 4 months before the n-heptane test.

This all adds up to being very suspicious.




Model Number was added to this rewritten version of this report.

INTERNATIONAL OZONE Titan 4000 PERFORMANCE TESTING

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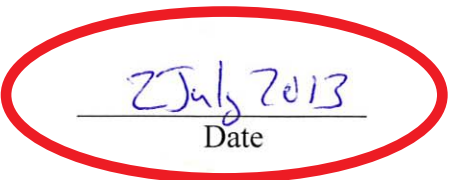

2 July 2013
Date

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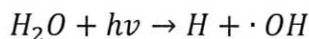
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Executive Summary

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 International Ozone Titan 4000 air cleansing system is labeled and marketed as a hydroxyl generator. The Titan 4000 oxidizes compounds on the surface of a titanium dioxide (TiO_2) coated mesh which is illuminated by ultraviolet lamps, and all the reactions take place on the catalyst surface. Water and O_2 from the ambient atmosphere are adsorbed on the TiO_2 surface, which the reactant encounters upon flowing through the device. Hydroxyl radicals and super oxide ions (O_2^-) are produced directly on the catalyst surface after irradiation with 385 nm light. These oxidants react with organic reactants that are also adsorbed on the surface. Thus all of the reaction for the Titan 4000 system occurs on the TiO_2 catalyst surface, and no reactive hydroxyl radicals are ever ejected into the room or even into the gas phase portion of the reaction chamber according to the scientific literature.⁵ This method is innately limited by the available surface area of the catalyst, which diminishes over time due to carbonization and contamination. It was intended to treat small volumes of air.

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 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.

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) have been routinely measured.

Serial Number was added in the rewritten report

This experimental method was used to measure the hydroxyl formation rate for the Titan 4000, serial number TZ-12291 (International Ozone, Lantana, Florida 33462). The experiments involved the use of n-heptane, and 2-methyl-furan which selectively react with hydroxyls and not other oxidants that could be produced by the system. There is an abundance of data in the literature describing the kinetics and high rates of reaction of hydroxyls with these hydrocarbons to further enable confirmation that the reactions are due to the presence of hydroxyls.¹⁻⁵

The test chamber was purged and the Titan 4000 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. The Titan 4000 was run for two hours, during which time the concentration of n-heptane was measured every few seconds by a gas chromatograph-mass spectrometer (GC-MS). No reduction in the concentration of n-heptane was measured, indicating that no measurable amount of hydroxyls was being formed. If any hydroxyls were formed they were below the 2-3 ppb sensitivity level of the GC-MS.

In an effort to determine if even low ppb of hydroxyls were being produced by the Titan 4000 system, the test was repeated using 2-methyl furan, a hydrocarbon that reacts twice as fast with hydroxyls as n-heptane and would therefore be twice as sensitive. Again, there was no verifiable concentration of hydroxyls produced by the Titan system during two hours of operation.

In summary, under highly controlled conditions, there was no evidence that the Titan 4000 was producing hydroxyls using published analytical methods capable of measuring hydroxyl concentrations as low as 2-5 ppb.

As stated in the first report this test was run at 20% humidity, The Titan 4000 owner's manual and the screen printing on the front of the machine clearly states that 60%+ humidity is necessary for the unit to perform at its best.

Materials and Methods

The experiments described here were conducted in a 120 cubic meter (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 particulate material from ambient air during large-volume flushing of the chamber. A clean air generator scrubs moisture, VOCs and particulate material 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 Titan 4000 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

If you look at the pictures at the bottom of the page of the Titan 4000 with the 20" 5,000 CFM fan and 4 very bright UV Lamps and the Odorox Boss with its GREENPOWER ON LIGHT and SMALL BLOWER. I think LRRRI got mixed up on which unit they were testing.

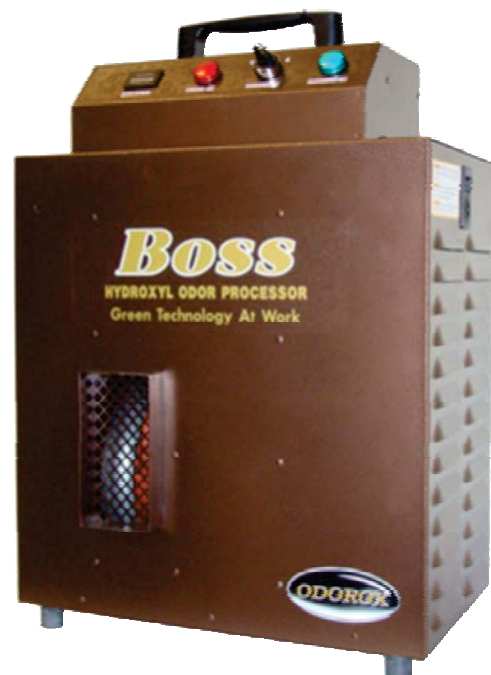
powering and operation. Power and operation was confirmed by visual observation of the green power light and hearing the blower. Two mixing fans, one each at both ends of the chamber, were turned on to assure complete mixing. All experiments were conducted with addition of a low concentration of an inert 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 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)

A sample of n-heptane was injected into the chamber such that the concentration was 0.13 ppmV. The n-heptane concentration was 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, i.e. there were no organic compounds present above 1-2 ppb.

The Titan unit was powered on at 1929 (7:29 PM) and was operated for 2 hours. During this time the n-heptane concentration was monitored and showed no decrease in concentration with the decay rate shown as a regression slope in ppm per hour (Figure 1). It can be concluded that there was no observable n-heptane decay when the unit was operational.



This LRRRI report is available on ODOROX's website at:
<http://www.odoroxhg.com/odorox-hydroxyl-vs-titan-pco>
You can read about the Titan GREEN LIGHT and BLOWER SOUND there.

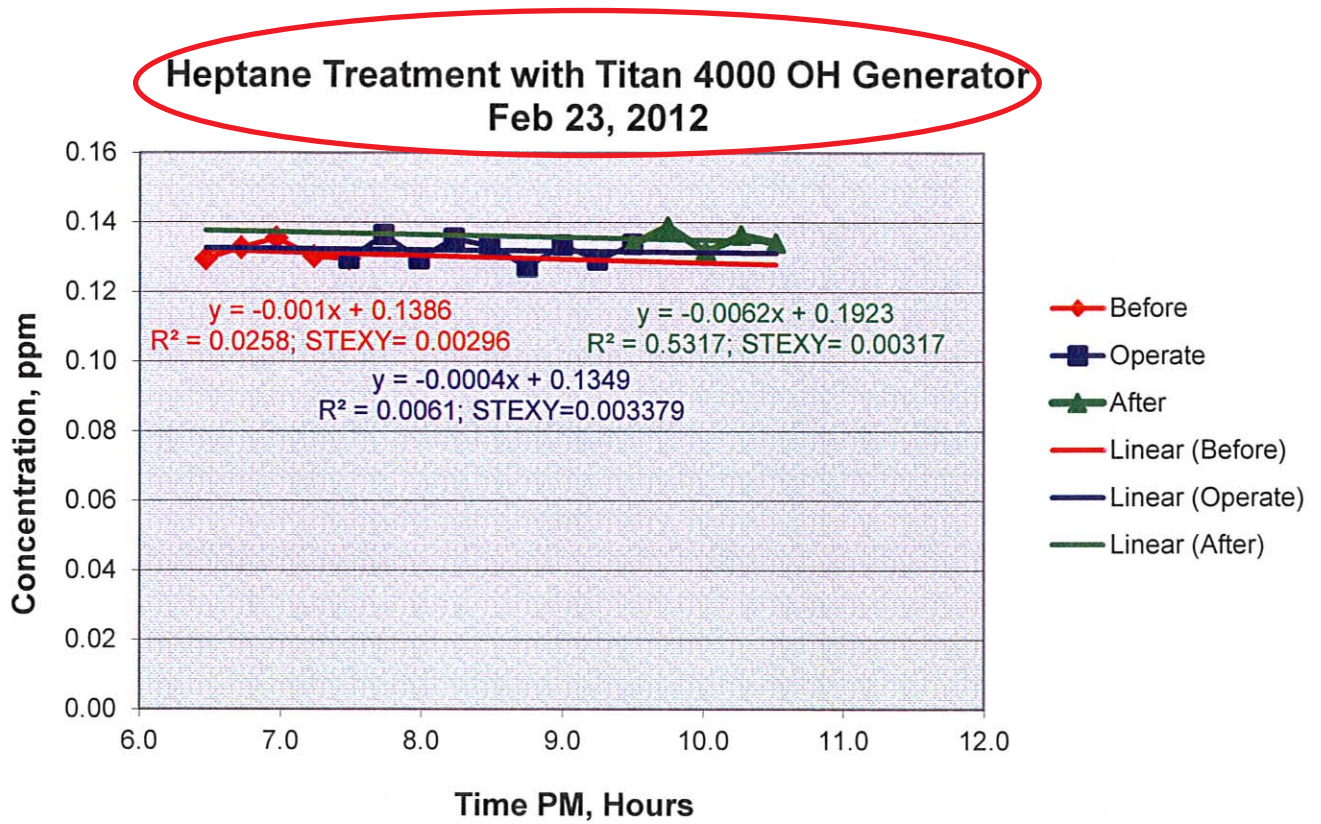


Figure 1 Heptane treatment, Titan 4000 hydroxyl generator.

**The date on the front of this report is July 2nd., 2013
which would be 1 1/2 years before this report was written
Kinda Fishy.**

Hydrocarbon Removal (2-methyl-Furan Treatment)

The experiment was repeated with 2-methyl-furan, a hydrocarbon which reacts twice as fast with hydroxyls compared with n-heptane to increase the opportunity to detect hydroxyl formation. The Titan unit was powered on at 2034 (8:34 PM) and was operated for 2 hours. During this time the 2-methyl-furan was monitored and showed no decrease in concentration with the decay rate shown as a regression, slope in ppm per hour (Figure 2). It can be concluded that there was no observable 2-methyl-furan decay when the unit was operational.

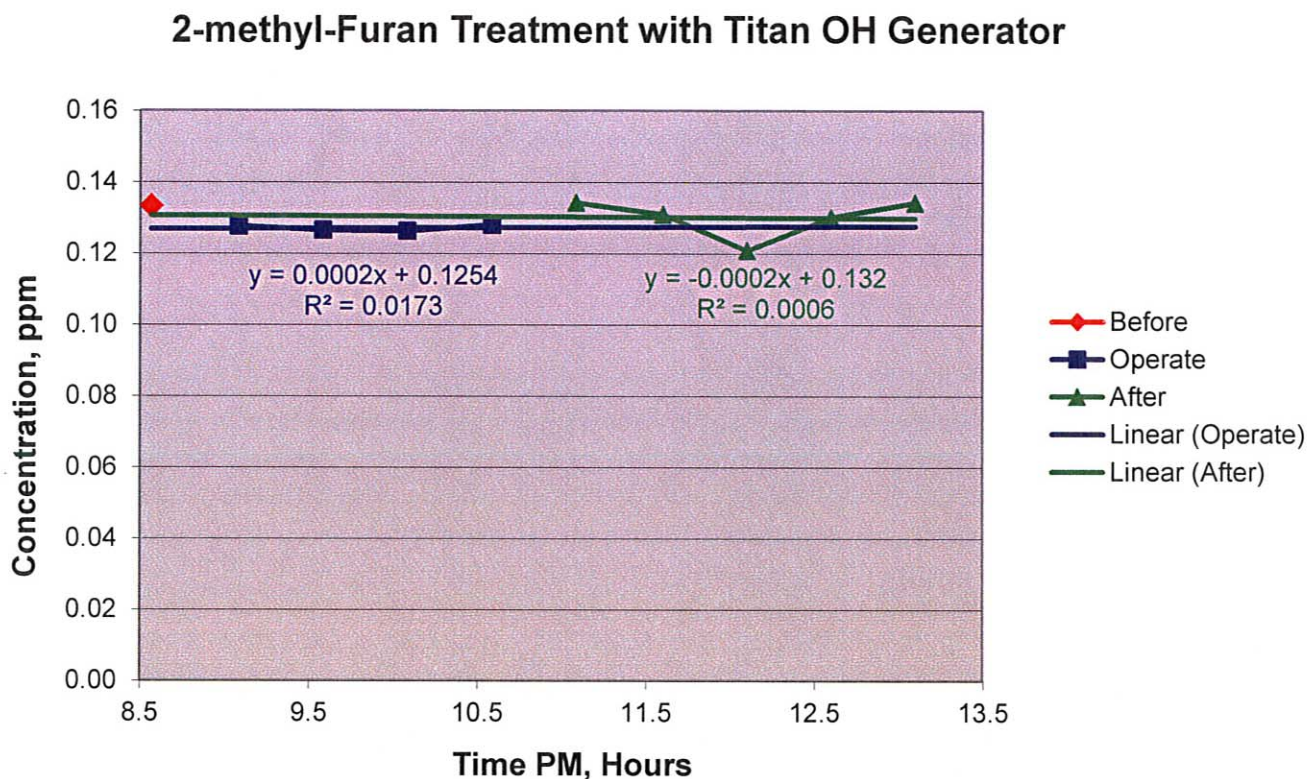


Figure 2 2-methyl-Furan treatment, Titan 4000 hydroxyl generator.

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Appendix

Test Condition Summary for the Hydroxyl Generator Experiments

Operating Conditions

Titan Heptane Treatment Feb 23, 2012

1745 stop venting; insert Titan
1804 start Chars\tscan
1818 4 ul CCL4 injected
1819 95 ul Heptane injected; cham temp 293.2K; DP is 11.8C
1828 first GC of heptane
1846 ccl4 first gc
1929 Start power
Titan
2129 stop power Titan

Heptane Decay

Time Hours	ppm Before	ppm Operate	ppm After
6:28 PM	0.129439		
6:43 PM	0.132694		
6:58 PM	0.135423		
7:14 PM	0.130143		
7:29 PM	0.129477		
7:29 PM		0.12947703	
7:44 PM		0.13633888	
7:59 PM		0.12943818	
8:14 PM		0.13530948	
8:29 PM		0.1331505	
8:45 PM		0.12713729	
9:00 PM		0.13338526	
9:15 PM		0.12913448	
9:30 PM		0.13364741	
9:30 PM			0.133647
9:45 PM			0.138777
10:01 PM			0.131536
10:16 PM			0.136257
10:31 PM			0.133982

This test was supposedly done after the n-heptane test but is dated 4 months before the n-heptane test.

Operating Conditions

Titan 2-methyl-furan Treatment Oct 05, 2011

2034 Start power Titan

2235 stop power Titan

Time	2-methyl-furan Decay			Ozone Production		Formaldehyde Production	
	ppm	ppm	ppm	Time	O3 ppm	Time	HCHO ppm
	Before	Operate	After	Hours		Hours	
8:34 PM	0.133356						
8:34 PM	0.133356				no data		Not detected
9:05 PM		0.127629					
9:35 PM		0.126507					
10:05 PM		0.126258					
10:35 PM		0.127999					
11:05 PM			0.13418				
11:36 PM			0.130883				
12:06 AM			0.120732				
12:36 AM			0.130068				
1:06 AM			0.134236				

The following 4 pages are of a report dated July 15 - 20, 2007 by S. Pekarek of the Czech Technical University showing the oxidation effects of OZONE on N-Heptane.

Ozone eats the heck out of N-Heptane which is why the RGF unit and the Boss both reduced the N-Heptane without any humidity.

I guess LRRR missed this report.

Page 23 is a chart of a test showing that when a Titan Hydroxyl Generator has humidity it will oxidize the heck out of N-Heptane.

Non-thermal plasma *n*-heptane decomposition enhanced by supplementary addition of active species

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Non-thermal electrical discharges are intensively studied for the purposes of volatile organic compounds decomposition. We investigated the increase of *n*-heptane decomposition by the hollow needle to mesh electrical discharge with a layer of TiO₂ photocatalyst on the mesh when additional ozone and other active species were supplied to the discharge. As a source of ozone and these species we used the secondary discharge operating in series with the main discharge. We found optimum operational parameters of the secondary discharge from the standpoint of ozone generation. The parameters of the secondary discharge were then adjusted to these optimum parameters and ozone and other active species produced were supplied into the main discharge. In this way we were able to increase the *n*-heptane decomposition efficiency from 47 % to 53 % with the total specific input energy 287 kJ/m³.

1. Introduction

There exists a great interest in the non-thermal plasma produced by atmospheric pressure electrical discharges due to its application for decomposition of air pollutants [1-4]. The ionization, excitation and dissociation of the gas molecules promote the oxidative decomposition of volatile organic compounds (VOCs) diluted in it. The reaction mechanism underlying the VOC decay is rather complicated and in many cases it is not well understood.

The non-thermal plasma electrical discharges in air-like mixtures produce ozone and depending on humidity also OH radicals. Both these species are involved in VOC decomposition [5]. The idea that is behind our research therefore is that to increase the decomposition efficiency of VOC it is necessary to supply to the main discharge for VOC decomposition additional ozone and other active species from the secondary discharge. The main and the secondary discharge operate in series.

Operation of electrical discharges in parallel is frequently used e.g. in industrial ozonizers [6]. However the operation of electrical discharges in series is not so frequent [7].

Our aim therefore is to find operational regimes of the secondary discharge in the mixture of air with VOC for which the ozone production will reach its maximum. Ozone and other active species produced will then be supplied to the main discharge and we will investigate the effect of the main discharge enhancement on the VOC decomposition efficiency. As a representative of VOCs we chose *n*-heptane CH₃(CH₂)₅CH₃ because it is not only a part of organic solvents but also a part of automotive and aviation fuels. It also represents a wide group of

saturated hydrocarbons with single bonds; see Figure 1.

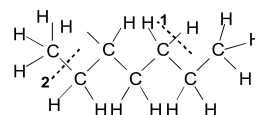


Figure 1. Structure of *n*-heptane.

However production of ozone by the secondary discharge in the mixture of air with *n*-heptane could not be separated from *n*-heptane decomposition. The discharge is a dynamic system in which for different electrical parameters the *n*-heptane concentration is different provided constant initial *n*-heptane concentration. We therefore present also the production of ozone simultaneously with the changing concentration of *n*-heptane.

2. Experimental arrangement

The experimental set up, shown in Figure 2, consisted from two electrical discharges connected in series. The main discharge – MD – used a hollow needle to mesh electrode with a layer of a photocatalyst TiO₂ globules on the mesh. The secondary discharge – SD – used a hollow needle to mesh electrode configuration. Both discharges were enhanced by the flow of air with *n*-heptane through the needle electrode.

The needle N electrode and the mesh M of the main discharge were situated in a circular glass discharge tube. The stainless steel needle (Terumo-Belgium) had an inner and outer diameter of 0.7 mm and 1.2 mm respectively. The tip of the needle was sharpened at the angle 15°.

The stainless steel mesh had rhombus cells dimensions 0.6×0.5 mm and thickness 0.15 mm.

With the aim to obtain maximum decomposition efficiency with a minimum energy density we used a discharge with a layer of photocatalyst TiO_2 on the mesh. The cylindrical globules had the diameter 3 mm and the height 4 mm. Mass of the globules was 2.07 g. The distance d between the needle and the mesh was adjusted to 12 mm.

The electrode arrangement of the secondary discharge consisted from a needle and a mesh situated perpendicularly to the needle. The needle and the mesh were the same as in the case of the main discharge. These electrodes were situated in a stainless steel discharge chamber. The distance d between the tip of the needle and the mesh was adjusted to 8 mm.

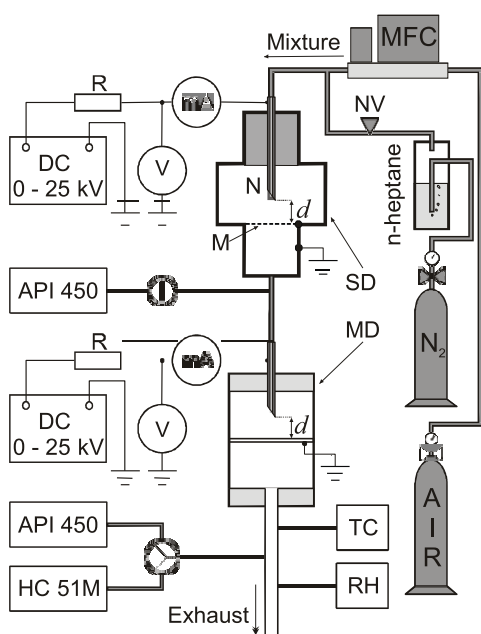


Figure 2. Experimental arrangement

For each of the discharges was used its own regulated DC HV power supply 0-25 kV (Ultravolt) and its own ballast resistor $R = 6.89 \text{ M}\Omega$. In case of the main discharge the needle was biased negatively and in case of the secondary discharge the needle was biased positively. Both discharge chambers were cooled by a fan and were kept at room temperature.

A gas flow, either an air or a mixture of air with n -heptane, was supplied into the needle of the secondary discharge and after passing through this discharge it was supplied into the needle of the main discharge. Air was supplied from a cylinder.

A mass flow controller MFC Bronkhorst adjusted the gas flow through the needles. A needle valve NV controlled precise dosage of n -heptane into the air stream from a bubbler, which contained liquid n -heptane.

To determine the concentration of n -heptane without the treatment and with the treatment by the secondary, main and by both discharges together a FID total hydrocarbon analyser HC 51 (measuring range 0-1300 ppm) placed at the exhaust from the main discharge was used. Calibration of this analyser on n -heptane was performed using samples of different concentrations of this VOC in air in Tedlar sampling bags.

Ozone concentration was measured by the absorption of the 254 nm U.V. spectral line with API 450 ozone monitor either after the secondary discharge or either the main discharge.

At the output of the main discharge tube was measured the temperature TC and the relative humidity RH of the mixture.

3. Experimental results and discussion

As far as we varied operational parameters of discharges (current) the experimental results concerning n -heptane decomposition and ozone production by separate discharges and by both discharges together are presented as functions of the discharge current. These dependencies are frequently presented as functions of specific input energy (energy density or Becker parameter). For the purpose of comparison we therefore for important situations mention the values of specific input energy in the text.

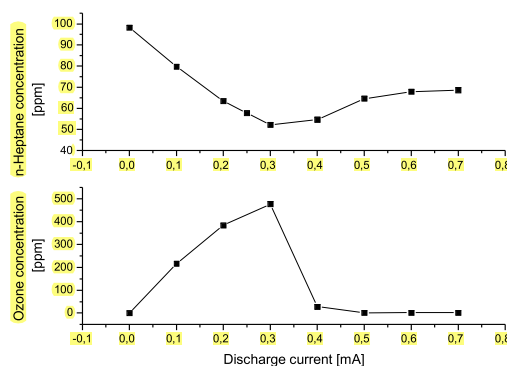


Figure 3. Main discharge with TiO_2 globules. n -Heptane (upper curve) and ozone concentrations (lower curve) versus discharge current. Distance between the needle and the mesh $d=12$ mm. Relative humidity 19%. Needle biased negatively.

As far as the experiments dealing with ozone production as well as with *n*-heptane decomposition were performed with both polarities of the needle (main discharge - needle biased negatively; secondary discharge - needle biased positively) it is worth to mention electromagnetic emission of the discharge. The usage of devices containing EPROMs (e.g. humidity sensors, HC51-M, etc.) was complicated if they were placed close to the discharge, because the electromagnetic radiation from the discharge namely in case of positive polarity of the needle could erase them. That is why these devices during the experiments were shielded.

As it is seen from Figure 3 most of the *n*-heptane is decomposed when the discharge ozone production reaches its maximum that is for the discharge current 0.3 mA. At this point the decomposition efficiency is 45.7 % and specific input energy is 151.2 kJ/m³. It can be therefore concluded, that more important role in *n*-heptane decomposition is played by ozone rather than by other active species such as OH radicals. The basic idea to increase the decomposition efficiency therefore is to supply to the discharge additional ozone from the secondary discharge. As far as both discharges operate in series the discharge medium for the secondary discharge will also be the mixture of air with *n*-heptane.

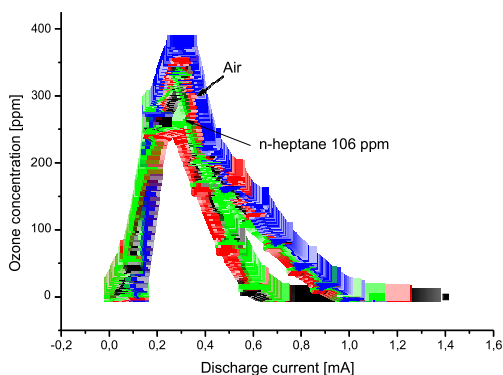


Figure 4. Secondary discharge ozone production. Effect of *n*-heptane addition. Needle biased positively. Discharge in air and the mixture of air with *n*-heptane. Concentration of *n*-heptane without the discharge 106 ppm.

As this secondary discharge we used hollow needle to mesh discharge. We tried to find its operational regimes giving maximum ozone production. The experimental results concerning ozone production for the secondary discharge in air and in the mixture of air with *n*-heptane for the needle biased positively

are shown in Figure 4. From this figure we can take following conclusions:

- Addition of *n*-heptane decreases ozone production in comparison with ozone production from air.
- The value of current for which ozone production reaches maximum does not substantially depend on *n*-heptane concentration.

Thus to enhance the main discharge by supplementary addition of ozone the secondary discharge should operate with the discharge current around 0.3 mA. An important fact also is that discharge current required to reach maximum ozone production for positive polarity of the needle does not substantially depend on *n*-heptane addition. This is an important conclusion because the *n*-heptane supplied to the secondary discharge is by this discharge also decomposed, therefore its concentration changes depending on the discharge current. This effect is demonstrated in the following Figure 5. As far as we will use as a source of ozone the discharge with the needle biased positively we give the results for this polarity of the needle and for *n*-heptane concentration without discharge 106 ppm.

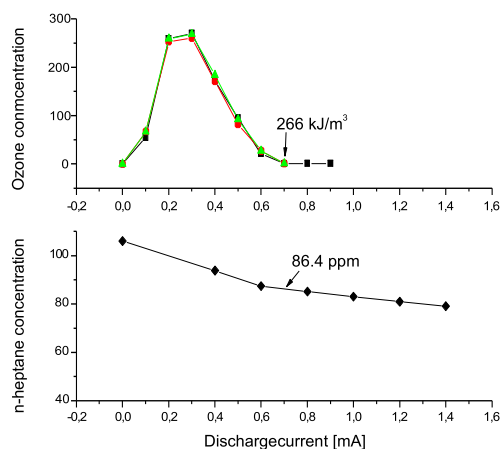


Figure 5. Ozone (upper curve) and *n*-heptane concentration (lower curve) versus discharge current for the secondary discharge. Distance between the needle and the mesh $d=8$ mm. Relative humidity 19%. Needle biased positively.

From Figure 5 is seen, that when the discharge ozone production falls to zero, the slope of the dependence of *n*-heptane concentration versus current changes. Therefore the upper curve for ozone produced by the discharge is not for constant *n*-heptane concentration.

In the range when the discharge ozone production has a nonzero value (for current changing from 0 to 0.7 mA) the *n*-heptane concentration decreases from initial value 106 ppm to 86.4 ppm, which corresponds to the decomposition efficiency 18.5 % and specific input energy 266 kJ/m³.

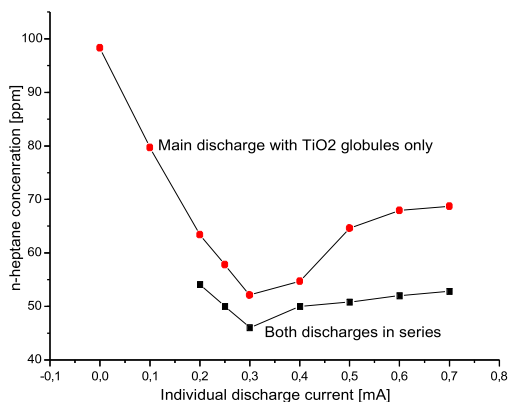


Figure 6. *n*-Heptane decomposition by the main discharge and by both discharges in series. Flow of the mixture through each discharge 1.5 slm. Relative humidity 17.5 %.

Finally in Figure 6 is shown the dependence of *n*-heptane concentration versus current at the output of the main discharge and at the exhaust from both discharges in series. We can see that the maximum *n*-heptane decomposition by the main discharge, that is the decrease of *n*-heptane concentration from 98 ppm to 52 ppm (decomposition efficiency 47 %) is obtained for the discharge current 0.3 mA (specific input energy 151 kJ/m³). Then we switch on the secondary discharge and supply ozone and active species from this discharge into the main discharge. If the discharge current of the secondary discharge is adjusted to the value corresponding to maximum ozone production, that is to 0.3 mA then the *n*-heptane concentration decreases from 52 to 46 ppm, which corresponds to the decomposition efficiency 53 %. To calculate the total specific input energy of both discharges to obtain decomposition efficiency 53 % the specific input energy of the main discharge 151 kJ/m³ should therefore be added to the specific input energy of the secondary discharge 136 kJ/m³ so that we obtain 287 kJ/m³. Thus for the increase of decomposition efficiency of 6 % is required 136 kJ/m³, which is roughly about the same specific input energy as is required for the decomposition efficiency of the main discharge 47 %.

Conclusions

In this work we studied the increase of *n*-heptane decomposition by the additional supply of ozone and other active species to the hollow needle to mesh electrical discharge with a layer of TiO₂ photocatalyst on the mesh. As a source of ozone and other active species we used the secondary discharge in the hollow needle to mesh electrode configuration, which worked in series with the main discharge. For the secondary discharge we investigated the effect of *n*-heptane addition and the effect of discharge operational parameters on ozone production.

We found that the value of current for which the ozone production for the needle positive reaches maximum does not substantially depend on *n*-heptane concentration.

We adjusted operationally parameters of the secondary discharge to maximum ozone production and we supplied ozone produced into the main discharge. In this way we were able to increase the *n*-heptane decomposition efficiency from 47 % (for specific input energy of the main discharge 151 kJ/m³) to the decomposition efficiency 53 % (for specific input energy of the secondary discharge 136 kJ/m³).

Acknowledgement

The financial support of the Ministry of Education, Youth and Sports (Research Plan MSM 6840770017 of the Czech Technical University) is highly appreciated.

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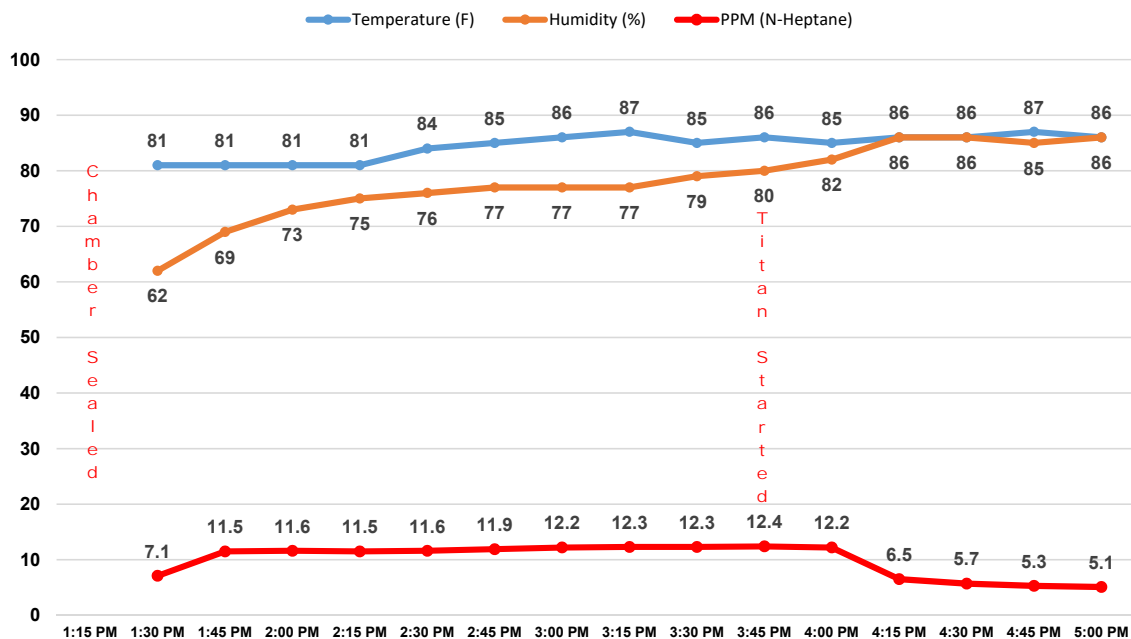
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Titan Hydroxyl Generator Oxidation of N-Heptane

Comments	Time	Temperature (F)	Humidity (%)	PPM (N-Heptane)
Chamber is sealed with 100 cfm circulating fan running and 1 tbl spoon of heptane in beaker.	1:15 PM			
	1:30 PM	81	62	7.1
	1:45 PM	81	69	11.5
	2:00 PM	81	73	11.6
	2:15 PM	81	75	11.5
	2:30 PM	84	76	11.6
	2:45 PM	85	77	11.9
	3:00 PM	86	77	12.2
	3:15 PM	87	77	12.3
	3:30 PM	85	79	12.3
Titan is powered on.	3:45 PM	86	80	12.4
	4:00 PM	85	82	12.2
	4:15 PM	86	86	6.5
	4:30 PM	86	86	5.7
	4:45 PM	87	85	5.3
	5:00 PM	86	86	5.1

Titan PCO Oxidation of N-Heptane

May 17th. & 18th., 2016



A small plastic container of water was placed in chamber to facilitate raising humidity. Chamber was sealed at 1:15 PM with a 100 cfm circulating fan running and 1 tbl spoon of N-Heptane in a beaker. Chamber was let set dormant for 2 1/2 hours to allow N-Heptane to fully evaporate and come to steady state. A Titan 1000 Hydroxyl Generator was turned on at 3:45 PM. Within 1 hour and 15 minutes the N-Heptane level was reduced from 12.4 PPM to 5.1 PPM a 59% reduction.