

# **Air Emissions from the Automobile Manufacturing Industry**

## **A Bio-oxidation Pilot Study of Paint Emissions Control**

**Control #: 197**

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### **ABSTRACT**

Bio•Reaction Industries (BRI) was contacted by Toyota to assess the abatement potential of an engineered bio-oxidation system (biofilter). The proposed intent of the pilot was to evaluate the effectiveness of biofiltration as available alternative to traditional VOC removal technology on an existing 3 stage wheel paint booth. A pilot unit consisting of a biotrickling filter and a separate biomatrix chamber with a common, biologically active, sump was prepped and transported to the site where it was connected to the exhaust system serving the paint booths. Over a five day period, adjustments were made to airflow (adjusting residence time) and sump water recirculation spray (biotrickling filter flow rate and biomatrix chamber timing) while monitoring the VOC inlet and outlet concentrations using a gas chromatograph equipped with a flame ionization detector (FID - Method 25A). Rapid acclimation of the system was noted, with destruction efficiency (Dre) exceeding 70% at the end of the start-up period. After 6 weeks of operation DRE remained in the 65 to 75% range with fluctuations corresponding to changes in operating temperature. The removal efficiency fluctuations were directly related to the ambient air temperatures of the paint booths 60 - 68°F (15.6 - 20°C) and the effect of ambient temperatures on the airflow in the temporary ducting system to the pilot, having a direct influence on the operating temperatures of the bio-oxidation unit. Subsequent installation of a heating system produced consistent DRE's exceeding 75% that varied little during the duration of the pilot test. With an empty bed residence time (EBRT) varying from 15-35 seconds and operating at a consistent temperature the pilot unit achieved consistent VOC DRE greater than 85%. Limited speciation of inlet and outlet VOCs was performed in an attempt to assess overall system function for specific compounds as well as to evaluate individual performance of the biotrickling filter and the biomatrix chamber.

### **INTRODUCTION**

Bio Reaction Industries, LLC (BRI) and Toyota Motor Engineering & Manufacturing North America, Inc. (Toyota) began discussions in December, 2005 exploring the potential for controlling paint fume emissions associated with automobile aluminum wheel painting. Data from existing applications in the paint and coatings industry (actual bio-oxidation unit installations on paint manufacturing emissions) were shared with Toyota personnel, demonstrating the general effectiveness of the equipment on these emissions. The discussions culminated with an agreement to install a pilot bio-oxidation system to demonstrate control of a portion of the emissions stream (approximately 25,000 acfm, 42,500 m<sup>3</sup>/hr) from the completely

enclosed Toyota wheel painting operation at a facility near Vancouver, B.C. The paint booth operation runs on a 3 shift schedule during a normal 5 day production schedule. The trailer-mounted bio-oxidation unit was moved to the facility in mid-July, 2006 and began operating on the air emissions stream on July 24. The objective was to determine how effective the vapor-phase biofilter could be at achieving removal of VOCs (and odors) in order to satisfy Toyota's regulatory emission requirements. Various operational scenarios for the bio-oxidation unit were outlined and evaluations were carried out over approximately a ten week period, with the pilot decommissioned in late September, 2006.

## **DISCUSSION**

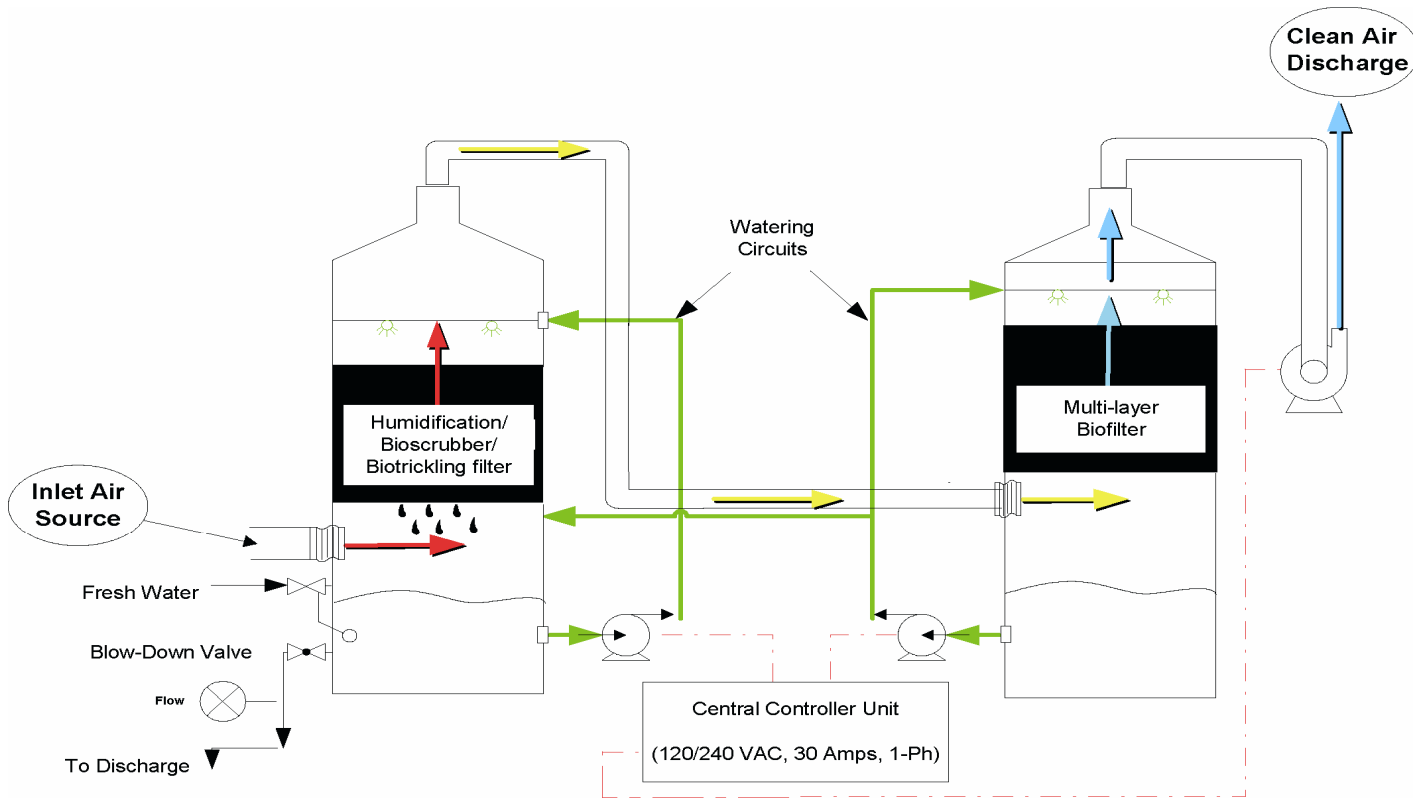
The start-up went quickly with the assistance of Toyota employees and the trailer-mounted unit was operational by the third week in July (Monday the 24<sup>th</sup>). An eight-inch ( $\approx 20.5$  cm), flexible line was connected to the existing exhaust duct (downstream from the 'in-house' particulate control wet mats on the painting lines), through which the slipstream to the bio-oxidation system was drawn. The emissions stream contained relatively low concentrations of a number of typical paint and coating volatile compounds. The bio-oxidation unit had an induced-draft fan with relatively low pressure drop (less than 4 W.C. in.,  $\approx 10.2$  cm), that operated continuously for approximately 10 weeks.

The system consisted of a single biotrickling filter (BTF) tank and one biofilter (BF) tank, connected by a short duct (Figure 1). The emissions slipstream entered the biotrickling filter column, with x-flow plastic packing, from the bottom, passing out the top then into the bottom of the biofilter, biomatrix chamber, flowing upward (countercurrent to the water flow from the sprinkler system) through the BRI patented, balled (BioMatrix™) media then through the fan and out a short exhaust duct (Figure 2). Sampling ports were located in the inlet duct and the exhaust duct (prior to the fan) to evaluate the removal efficiency of the combination system. In addition a sampling port was located between the tanks (the bio-trickling filter and the biofilter), to evaluate the differential removal efficiency. BRI and Toyota personnel provided the manpower for monitoring and sample collection. All sampling and analyses were conducted using the methods established and approved by the US Environmental Protection Agency (EPA). All VOC samples were collected and analyzed in situ using calibrated equipment (GC-FID) as per Method 25A.

**Figure 1 Pilot Bio-oxidation Unit**

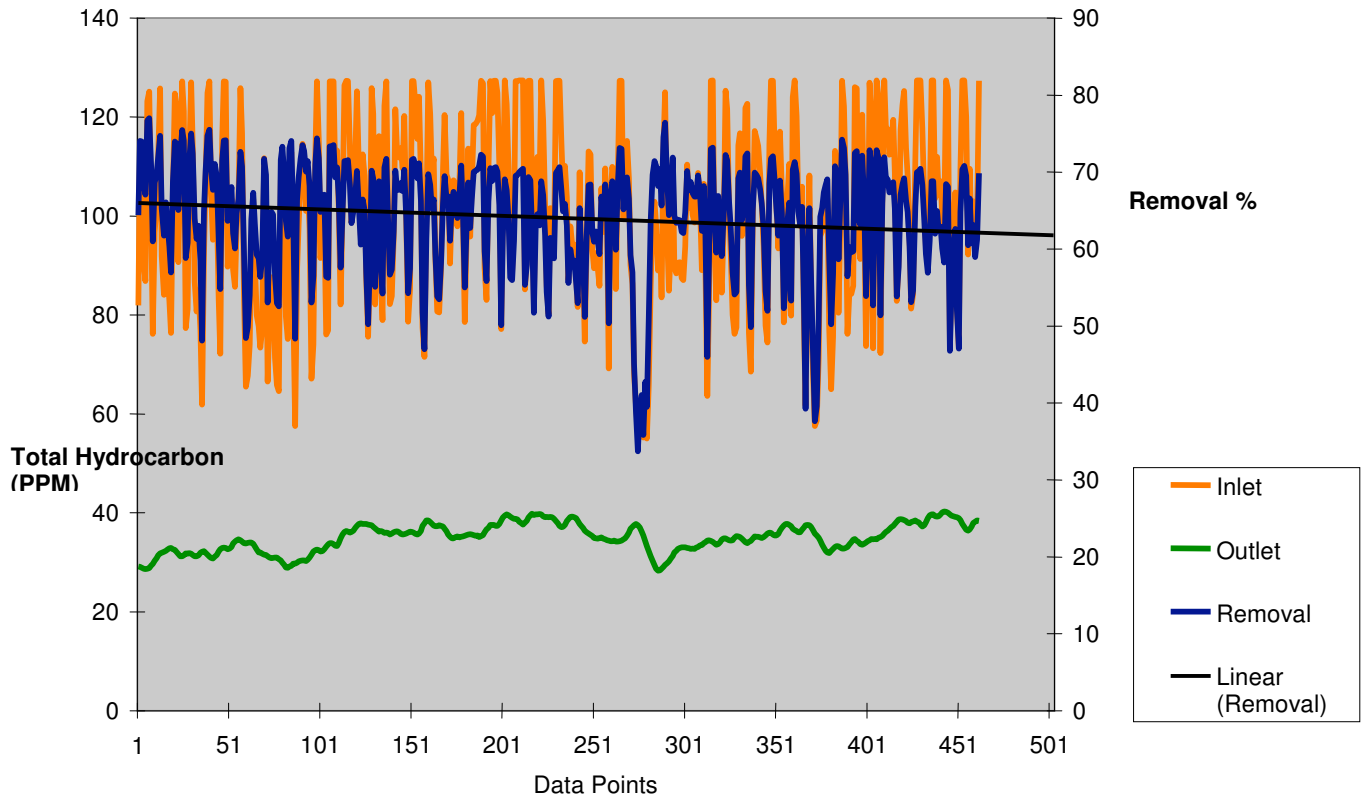


**Figure 2 Block Flow Diagram – Pilot Unit**



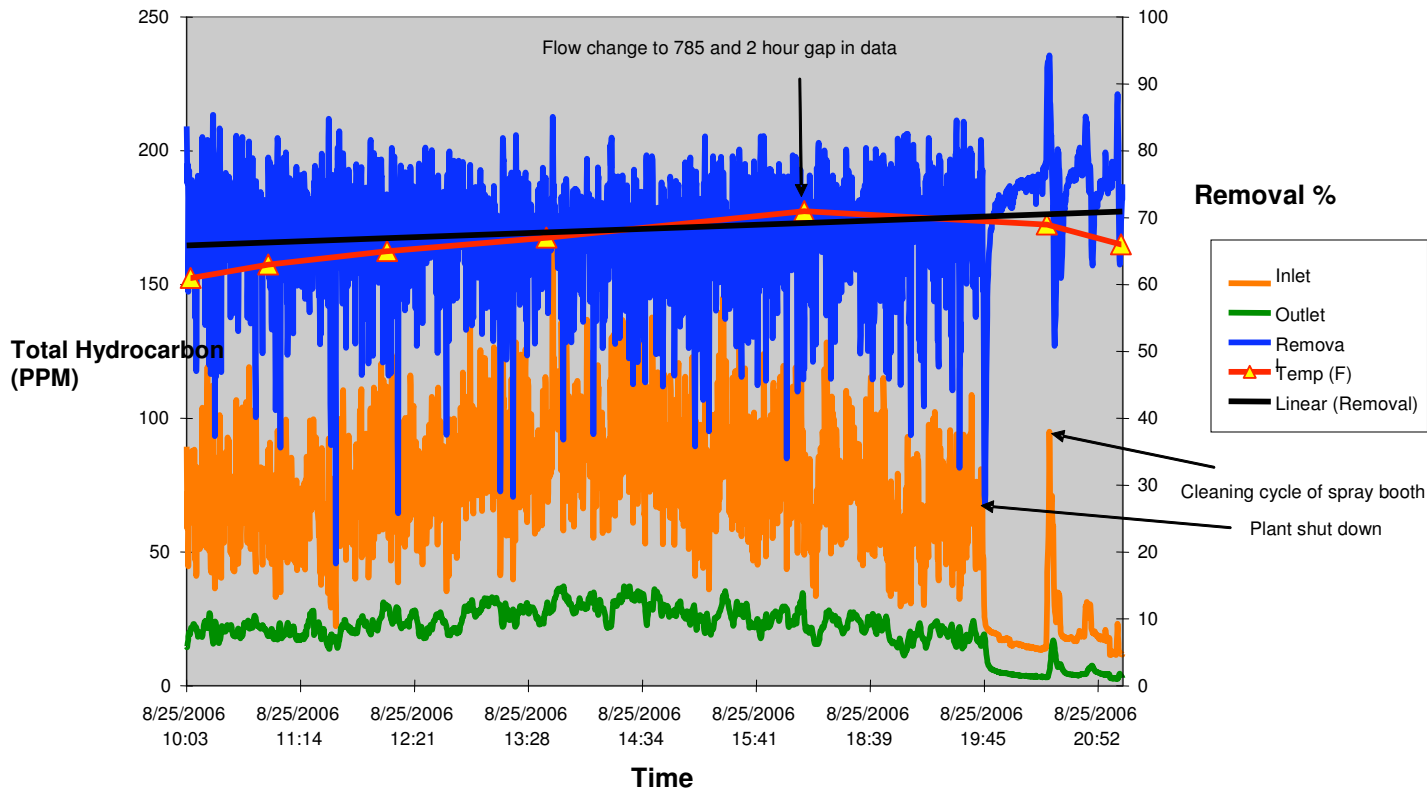
After fine tuning by BRI personnel during the first day of start-up, July 24<sup>th</sup>, GC-FID sampling was initiated on the afternoon of July 25, 2006. The average destruction efficiency (DRE) at that time was 65%. The inlet VOC concentration average was 100.7 ppmv and the outlet average was 35.0 ppmv. The highest removal efficiency during this approximately 1.5 hour GC-FID evaluation was 75% (Figure 3). The removal efficiency was better than expected as the unit had been gutted, cleaned and the media completely replaced prior to shipment to the facility, and there had only been approximately 36 hours of operation prior to testing. In addition, the operating temperature of the bio-oxidation unit was much lower than the desired operating temperature that had been demonstrated as optimum for VOC removals at paint manufacturing applications. After the initial start-up and testing it was decided to allow the bio-oxidation unit to run at the existing conditions for several weeks in order to achieve more extensive microbial growth in hopes of achieving even higher removal efficiency.

**Figure 3 Toyota Paint Emissions VOC FID Trace 07/25/2006**



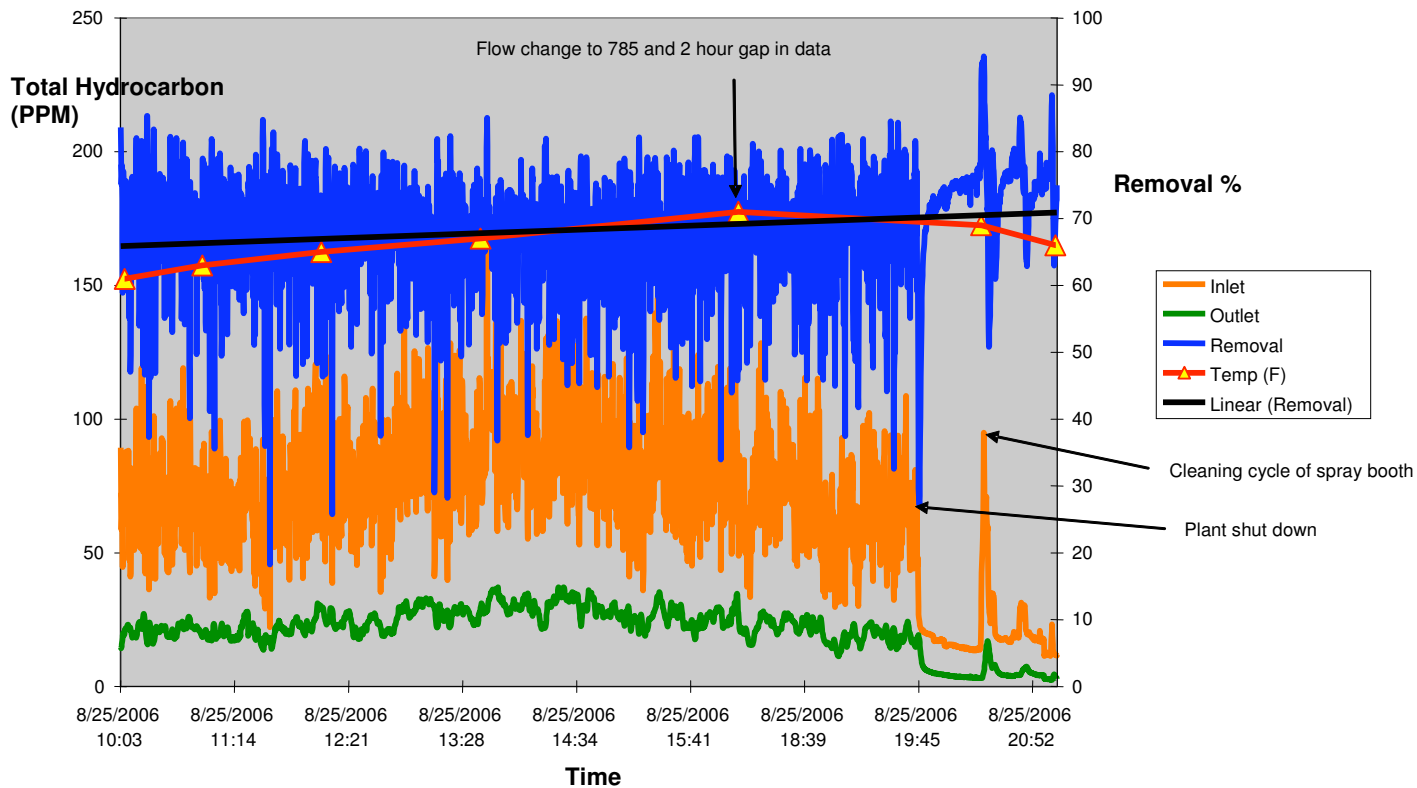
The bio-oxidation unit was allowed to continuously operate at conditions of temperature and pH as determined by the inlet gas stream and external or atmospheric conditions. However, periodic blowdown with the addition of fresh water took place (conductivity reduction) to insure the best possible conditions for microbial growth. Another series of GC-FID tests were started the week of August 21. The initial test results indicated that even with the 4 to 5 week acclimation period removal efficiency was not as high as had been anticipated (only 60 to 65% DRE). The most probable reason was thought to be the relative low operating temperature, approximately 65°F ( $\cong 18^{\circ}\text{C}$ ). An additional FID evaluation was conducted on August 25 with a reduced airflow to determine if the greater retention time would increase removal efficiency (Figure 4). A slight, but gradual increase in removal efficiency was observed (average of 65% DRE increasing to an average of 71%) as the temperature increased from approximately 61°F to 71°F ( $\cong 16^{\circ}\text{C}$  to  $\cong 22^{\circ}\text{C}$ ).

**Figure 4 Toyota FID 08/25/06 (400 acfm)**



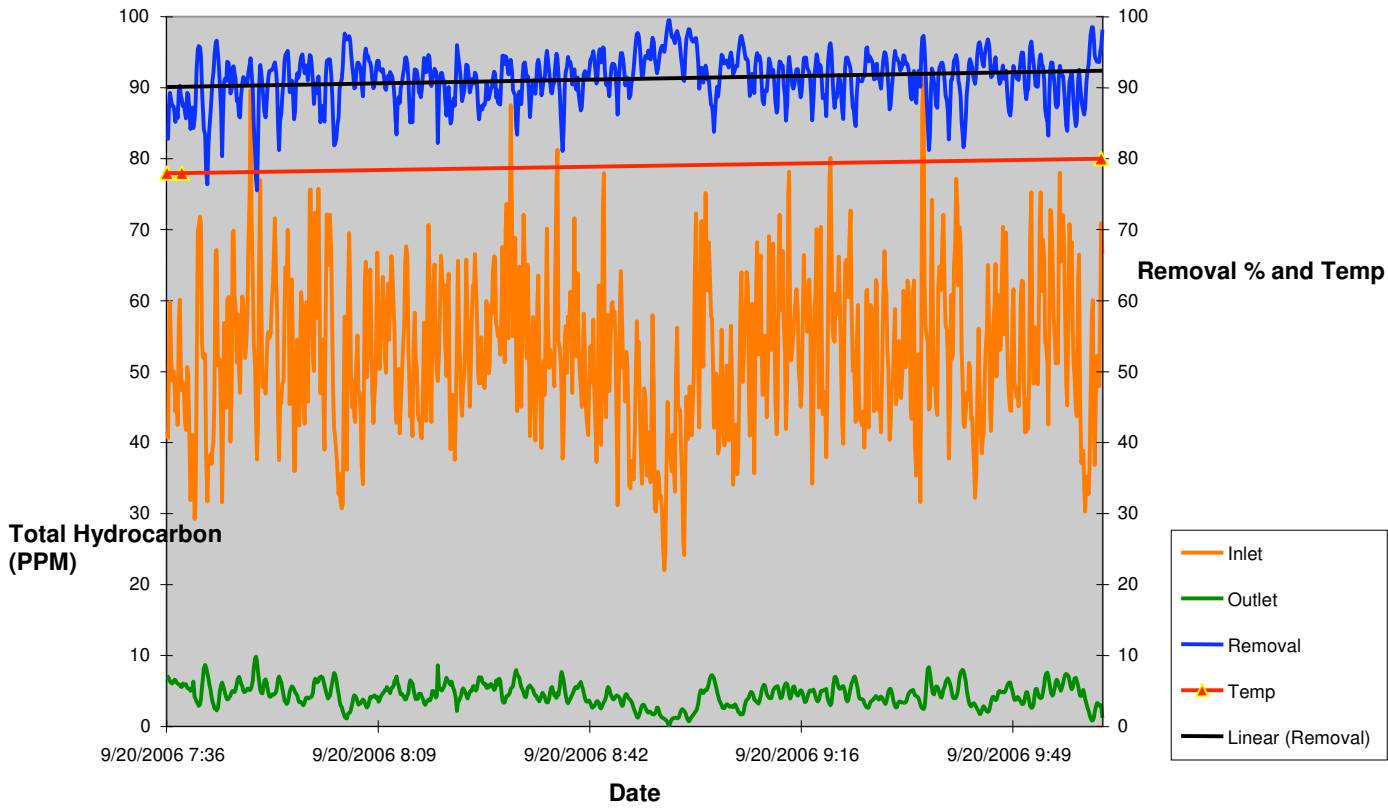
Following this evaluation the airflow was increased providing a decrease in EBRT while maintaining the temperature above 70°F ( $\cong 21^{\circ}\text{C}$ ). The FID data shows lower removal efficiency, as would be expected with the decrease in EBRT, but the same sort of trend of increasing DRE at an operating temperature in excess of 70°F ( $\cong 21^{\circ}\text{C}$ ) (Figure 5). There may be an additional effect of time of operation at this increased flow (acclimation) which also may contribute to an increase in DRE. However, the impact of increasing temperature noted in Figure 5 tends to corroborate the initial hypothesis regarding the operating temperature of the system.

**Figure 5 Toyota FID 08/25/06 (400 acfm)**



During the final week of August an electric hot water heater and heat exchanger system was added to the pilot unit. After another period of operation (approximately 3.5 weeks), with the heat exchanger operating and maintaining the airstream temperature in excess of 75°F ( $\cong 24^{\circ}\text{C}$ ) additional FID testing was conducted. A dramatic increase in removal efficiency was observed (Figure 6). During this 2-hour span of FID data collection the temperature increased slightly and the removal efficiency ranged from 76% to >99% DRE, with an overall average of 91%. These data indicated that the metabolic rate increase produced by the elevated temperature further demonstrated the ability of the bio-oxidation system to achieve quite good removal efficiency of VOC's from this paint emissions airstream. Positive odor removal results were also confirmed by Odor Panel Testing performed by Toyota personnel.

**Figure 6 Toyota FID DATA 09/20/06 (600 ACFM)**



## CONCLUSION

Based on the data collected and the observations made during the course of this pilot study it is apparent that a bio-oxidation system can be used to treat a paint line consisting of solvent based emissions streams. This removal efficiency is more than adequate to meet Toyota VOC reduction requirements for normal production operation. The general design of this bio-oxidation pilot system was appropriate for achieving near optimum removal efficiency, as demonstrated during the operation. Start-up and media acclimation time was minimal at only about 36 hours. Increasing the operating temperature of the bio-oxidation system greatly increased the VOC removal efficiency. Varying the airflow through the system provided data to appropriately size a commercial system for the application. The full-sized system is being designed, built and installed for control of the paint line emission at the facility. This bio-oxidation system will provide cost effective alternative control for these and other emission streams, while achieving substantial savings in annual operating costs when compared to thermal oxidation systems. In addition, there are no products or byproducts of combustion:  $\text{NO}_x$ ,  $\text{SO}_2$ ,  $\text{CO}$ , and no additional  $\text{CO}_2$  from the fuel. In fact, the bio-oxidation system is expected to produce 50 - 80% less  $\text{CO}_2$  than a comparable thermal oxidizer. In addition, Toyota expects to see an operating cost reduction due to the elimination of natural gas consumption (that otherwise would be required for a thermal oxidizer) of approximately \$210,000/year.

## **ACKNOWLEDGEMENTS**

We would like to thank all who assisted in this pilot study, especially Glen Sasaki, Ashley Meek and others at the facility who kept the unit up and running between sampling visits.

**KEY WORDS:** biofilter, paint emissions, air emission controls