Proven Long Life Lasers^{TM} in Optical Particle Counters

INTRODUCTION

Optical particle counters (OPC) utilize light illumination and extinction to determine the presence, size, number and/or concentration of particles. Particles are typically suspended in a fluid or air, which flow through the volume that is illuminated and viewed by the detection system. The basic components of such a system are a laser illumination source; a view volume in which the particles to be detected reside and into which the illumination is directed; and one or more sensors, which are typically photodetectors, that can detect optical disturbances of the illumination caused by the particles in the view volume. The illumination source in an optical particle detection system is typically a semiconductor diode laser. The laser source must be stable, quiet, and have long life.

While many OPC suppliers claim long life lasers, Hach Ultra has verified laser life testing, patented technology for improving both laser life and instrument performance, and has validated product field data to prove the performance. Long Life Lasers™ by Hach Ultra are now employed in all MET ONE 3400 Series portable air particle counters, MET ONE R4000, 6000 and 7000 Series remote air particle counters for continuous monitoring, and HIAC 9703 and HIAC 9705 liquid particle counters.

LASER LIFETIME (MTTF)

The road to long lasting lasers and reliable particle counters starts with choosing the right laser. Certain Gallium arsenide (GaAs) lasers offer the most mature laser technology and have the longest operating lifetime. GaAs lasers are now widely used in the fiber optic telecommunications industry where high performance and reliability are of paramount importance. This same technology is used in Hach Ultra MET ONE optical particle counters with lasers operating at the material peak wavelength near 830 nanometers. Typical GaAs lasers are rated to have a mean-time-to-failure (MTTF) greater than 100,000 hours. At 8,760 hours per year, this equates to over 11 years of continuous operation.[i]

While laser MTTF specifications provided by the supplier always look impressive, Hach Ultra does not rely solely on published supplier data. Instead, the company verifies laser life through internal testing before implementation in new products. Since it would be impractical to test a diode laser for 100,000 hours, other methods that are commonly accepted in the laser industry have been developed to accelerate aging. One such method is testing at an elevated temperature. Most laser manufacturers specify that GaAs diode laser life is reduced by a factor of two for about every 8 – 10 ^{o}C increase in temperature. Therefore, to verify laser life specifications, accelerated life testing was performed with 50 GaAs lasers in the engineering labs at Hach Ultra. Test duration was 5,320 hours at a temperature of 78 ^{o}C. This testing demonstrated that the lasers have a median life of 9.95 years at a normal operating temperature of 30 ^{o}C, consistent with the supplier's specifications.

LONG LIFE LASER DESIGN

While the relationship between laser life and temperature enables accelerated testing, it also provides an obvious solution to extending laser life by controlling the laser temperature. Some manufacturers use thermoelectric coolers (TEC) to control and lower the laser temperature. However, TECs require high input power, which can shorten battery life (or increase the weight of a portable particle counter by requiring a larger battery). Most manufacturers rely on passive cooling and reducing the power at which the laser operates (i.e. power "derating"). However, derating laser power can come at the expense of particle detection sensitivity if nothing else is done to improve the overall efficiency of the sensor.

In order to properly take advantage of passive cooling and laser power derating, Hach Ultra has enhanced the OPC sensor's ability to detect scattered light from particles using a given laser output. Improvements in detection, illumination optics, and collection optics along with patented methods for background noise suppression, have all led to improved overall sensor efficiency[ii]. Furthermore, one of the key techniques employed by Hach Ultra to reduce the overall background noise of the sensor is laser modulation[iii]. The technique of laser modulation is commonly used in the CD and DVD industry to reduce mode competition noise[iv,v,vi]. In an OPC, laser modulation also reduces mode competition noise to a level that it cannot be detected. This effectively lowers the overall background noise of the sensor and results in fewer false positives and better zero counts. Because a modulated laser is operating at a 50% duty cycle, laser lifetime is also improved. Thus, laser modulation not only improves the laser lifetime, but also improves the overall signal-to-noise ratio performance of the sensor. The application of laser modulation in a particle counter is patented by Hach Ultra and is unique to the MET ONE and HIAC particle counter product line.

LONG LIFE LASER™ PERFORMANCE

The correct laser with verified MTTF, combined with good thermal management and laser modulation, all combine to create the Long Life Laser by Hach Ultra. During the past three-year period after the introduction of the Long Life Laser, with thousands of units now shipped, less than 0.5% of the instruments have experienced a laser failure. The Weibull plot shown in Figure 1 illustrates the projected laser failures for all installed Long Life Lasers. Also shown is the failure data published by a competing OPC company touting a long lasting laser.[vii]

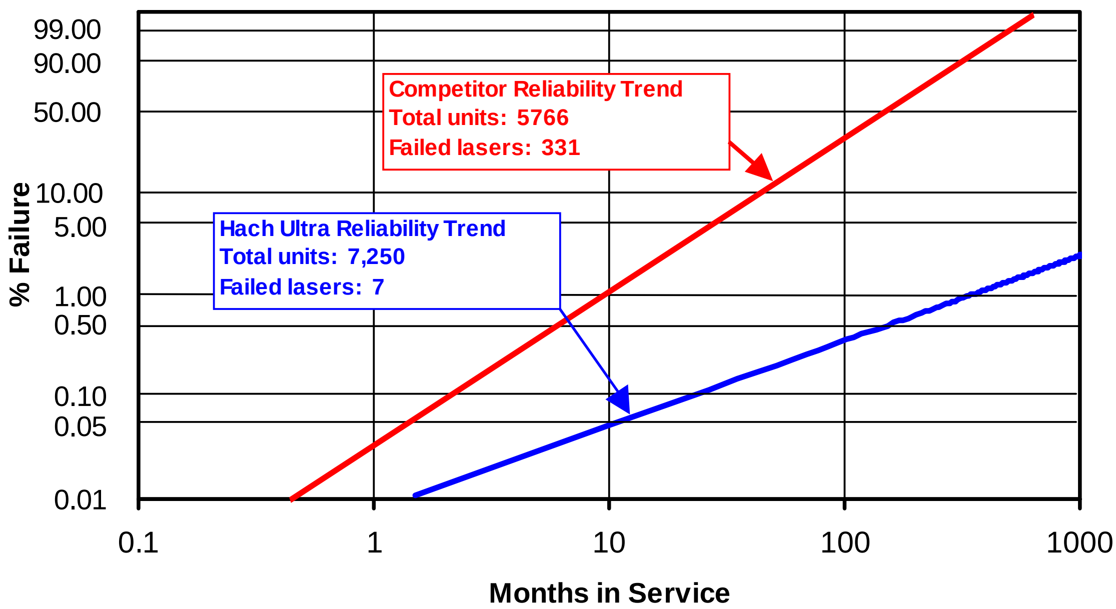

Figure 1: Weibull plot showing the % failures vs. months in service for the Hach Ultra Long Life Laser and published failures from a competing manufacturer touting a long lasting laser.

The Weibull plot illustrates that at the point where 10% of the competing instruments have experienced a field laser failure, less than 0.5% of Hach Ultra instruments are projected to have failed. To further illustrate this comparison, Table 1 shows a direct comparison of the number and percentage of estimated field failures for a sample size of 6000 air particle counting instruments over the same twelve-year period.

	Total units: 6000			
Service Year	Estimated Laser Failures			
	Hach Ultra		Competitor	
1	4	0.06%	93	1.55%
3	9	0.16%	480	8.01%
5	15	0.24%	999	16.64%
7	19	0.32%	1574	26.24%
9	24	0.40%	2162	36.03%
10	26	0.44%	2450	40.83%
12	30	0.51%	3000	50.00%

Table 1: A comparison of the number of field failures vs. service year

CONCLUSION

MTTF performance data demonstrates the superior performance of the Long Life Laser by Hach Ultra versus its closest competitor. While many OPC suppliers claim long life lasers, Hach Ultra has verified laser life testing, patented a technology for improving both laser life and instrument performance and has validated product field data to prove the performance. MET ONE and HIAC particle counters by Hach Ultra that employ the Long Life Laser technology are more reliable and have a lower cost of ownership than competing products without this capability.

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[i] Since the original testing and laser selection was completed, the Hach Ultra laser vendor now claims an MTTF of more than 1,000,000 hours.

[ii] Joel C. Johnson, "Method and Apparatus for Suppressing Stray Light in Particle Detectors", US Patent 6,414,754, July, 2002.

[iii] Kenneth L. Girvin and Adam J. Reed, "Method and Apparatus for Operating a Laser in an Extinction-Type Optical Particle Detector", US Patent 7,002,682, Feb., 2006.

[iv] Akira Arimoto, et al., "Optimum Conditions for the High Frequency Noise Reduction Method in Optical Videodisc Players," published in *Applied Optics*, vol. 25, No. 9, May 1, 1986.

[v] Masahiro Ojima, et al., "Diode Laser Noise at Video Frequencies in Optical Videodisc Players", published in *Applied Optics*, vol. 25, No. 9, May 1, 1986.

[vi] K. Petermann, book entitled *Laser Diode Modulation and Noise*, Copyright 1988 by Kluwer Academic Publishers, Chapter 4, pp. 100 to 105.

[vii] "Long Lasting Lasers: Factors that Influence Laser Life", Particle Measuring Systems, Inc., 2006.