

### AN INTRODUCTION TO THE USE OF OZONE IN THE LAUNDRY INDUSTRY

#### Introduction

Commercial laundry operations have progressed over the years through enhanced washing machine technology by delivering higher load capacities, automated cycle management and better chemical administration achieving more consistent quality at a lower cost. Even with all this progress there remains room for significant improvement in laundry room performance. Areas offering the most opportunity include:

- Microbe Control
- Energy Use
- Water Use
- Chemical Use
- Effluent Wastewater
- Fabric Life
- Operational Efficiency

The introduction of ozone into the laundry cycle can bring improvement in all the areas above. This is because ozone not only enhances the performance of chemicals in the different washing steps but also can eliminate steps in the traditional wash cycle. At the same time since ozone works best in cold water it can drastically cut the energy costs tied to heating water. Other key benefits that ozone brings to laundries are noted below.

#### Ozone Benefits to Laundry Performance

**1. Ozone Eradicates Microbes** - Ozone is highly effective in eliminating bacteria, viruses and other microorganisms. In fact, ozone is more powerful and many times faster than chlorine as a biocide. Tests have shown that the use of ozone in commercial and institutional laundry facilities, using cold water (ambient temperature) washing, provides microbe kills not seen with conventional hot water laundering techniques – see test results on pg. 3.

**2. Ozone Reduces Energy Use** – Ozone works best in cold water so that sanitizing, historically done in hot water, can be done in cold water - saving considerable energy. Estimates of energy savings run as high as 90% in washing and 20% in drying. The Magnolia Manor, an assisted-living facility in Americus, GA (USA) has documented total energy savings of 51.3%.

**3. Ozone Reduces Water Use** – Ozone aids the effectiveness of traditional laundry chemicals and requires far less rinsing. Ozone wash systems also require fewer rinse steps typically reducing water usage and the resulting volume of effluent wastewater by 30-45%.

**4. Ozone Reduces Detergent and Chemical Use** Ozone makes existing chemicals work better, and reduces overall chemical demand in several ways:

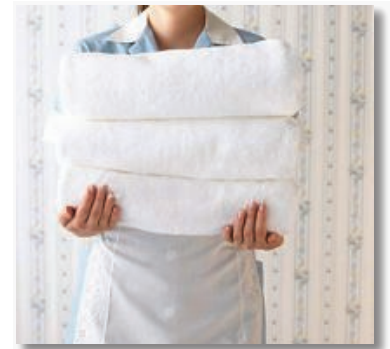
- **Ozone Increases Oxygen in the Wash Water** enhancing chemical effectiveness and reducing the amount of chemical required. Ozone and oxygen work by opening up fibers, oxidizing contaminants, and disinfecting, all while using cold to moderate-temperature water.

- **Ozone Oxidizes Linen Soils**, making them easier to remove from wash water.

- **Ozone Lessens Need for Harsh, High-pH Chemicals** traditionally used to remove Fats, Oils and Grease (FOG) by breaking molecular bonds and reducing molecular weights, thereby forming simpler compounds that are more easily removed. While virtually all ozone laundry systems use at least some chemicals, savings claims range from 25% to 40%. Actual savings will depend on the type of laundry, water temperature, water hardness, the number of washing steps and the system design.

- **Ozone Can Reduce Bleaching** in some applications and does not produce harmful chemical byproducts. Ozone can work safely in conjunction with hydrogen peroxide if a separate bleach cycle is desired. And because ozone accelerates soil removal from wash water, it helps to prevent re-deposition of soil onto the wash (one of the major causes of fabric graying), which eliminates the need for more bleaching.

- **Ozone can Reduce the Softening Step** - Because detergents have high pH levels, typically over 10, "souring" chemicals are added in a later step in the wash cycle to lower pH in the linen. Unfortunately, when souring chemicals coat linen fibers wash after wash, those fibers become stiff and feel rough to the touch. This roughness is the main reason that softener is used. With ozone, linen can be laundered at lower pH levels because less detergent is required, so little or no souring



chemical is needed. With no souring, no softener is needed, which means linens dry faster because they are unsullied by souring and softening chemicals that slow the drying process.

- Ozone deodorizes by breaking molecular bonds of most organic and inorganic compounds that cause odors.

**5. Ozone Improves Effluent Quality** – Effluent surcharges can be reduced because ozone oxidizes bacteria, other microorganisms and dissolved organic compounds that make up biochemical oxygen demand (BOD). Also, because fewer chemicals are used in ozone laundry systems, chemical oxygen demand (COD) can be reduced as well.

**6. Ozone Improves Textile Life and Quality** – Shorter cycle times and cooler water temperatures with fewer rinse steps means less wear and tear on textiles. The water softening properties of ozone and reduced exposure to chemicals also improve fabric life. Ozone itself leaves no chemical residue in wash water or on linens.

**7. Ozone Improves Operational Efficiency** – Ozone impacts laundry efficiency by shortening or eliminating wash cycles and reducing drying time.

TABLE 2

OZONE WASH CYCLE

Traditional Program						EcoTex™ Program				
Step	Time (minutes)	Chemical	Fill Level	Gallons	Temp F°	Time (minutes)	Chemical	Fill Level	Gallons	Temp F°
Flush	3-6	Alkali	Low	20	90-100	SAVED STEP				
Break	8-12	Alkali Detergent	High	30	160+	8-10	pH: 8-11 Detergent +O <sub>3</sub> + O <sub>2</sub>	High	30	Ambient
Bleach	8-10	Chlorine Bleach	High	30	145-155	6-9	Bleach+O <sub>3</sub> + O <sub>2</sub>	High	30	95-115
Rinse	2-4		High	30	140-150	4-5	+O <sub>3</sub> + O <sub>2</sub>	Low	20	Ambient
Rinse	2-4		Low	20	120-130	SAVED STEP				
pH Reducer	4-6	Softner	High	30	110-120	2-4	Sour+ O <sub>3</sub> + O <sub>2</sub>	Low	20	Ambient
Soft	4-6	Softner	High	30	110-120	SAVED STEP				
TOTAL	31-48					20-28				

**OZONE’S ECONOMIC BENEFITS**

Ozone and oxygen work by opening up fibers, oxidizing contaminants, and disinfecting, in cold to moderate-temperature water. This means significantly less energy consumption. Wash cycles can be further reduced when a bleaching step is not required. Because ozone and oxygen are pH-neutral rinses and sours for pH adjustment can be eliminated by using a pH-neutral detergent.

**Water and Sewer**

Each wash program step eliminated saves water. In the example shown in table 2, the EcoTex™ process eliminated three of seven traditional steps. In a 55 lb washer, with an average of 25 gallons per fill, water savings could easily exceed 45% or 90 gallons per load. As water usage declines, so too will sewer costs. With 10 loads/day, a single machine can save 900 gallons per day. Depending on your municipal water provider, this can represent savings of as much as \$6.00 a day.

**Energy Savings**

As much as 103, 275 BTUs of heating per load could be saved, using the same 25 gallons per fill, if the six high-temperature steps were replaced. If the water heater has an energy factor (EF) of 0.65, this translates into an equivalent of 0.923

therms per load energy saving. At 10 loads a day, savings would add up to 9.23 therms or \$11.45 per machine per day.

A surprise energy saving is delivered in the drying cycle. Traditional laundry programs use multiple chemicals such as sours and softeners, which typically leave the fibers with a microscopic chemical coating. During drying, this chemical coating must be burned off before the water in the fabric can be evaporated. Because the EcoTex™ process involves minimal chemical use linen fibers are not coated by chemicals. Instead, the fibers are opened up by ozone during the wash. Thus, drying time can be reduced delivering directly proportional energy savings.

Assuming a 180,000 BTU/hr dryer and a traditional 45-minute dry cycle, a 20% reduction would yield savings of 27,000 BTU per load or 270,000 BTU per day or 2.7 therms per day at 10 loads/day.

At an average of \$1.24 per therm delivered and 11.93 therms per day energy savings per washer/dryer pair, each washer/dryer pair saves \$14.80 a day when equipped with an EcoTex™ ozone system.



### Chemical Savings

Typical multi-step laundry programs include alkaline detergents, destainers, "sour" pH reducers, and softeners. With the EcoTex™ process, typically the only chemicals required are a low pH detergent, bleach and a sour. Total chemical use per load can decrease from 12 oz. to 3-7 oz. Softeners are not usually necessary with the EcoTex™ process because a lower pH detergent is used and because oxygenated/ozonated laundry fibers are already opened, providing the characteristic fluffy feeling achieved with softeners. At \$0.05 per ounce, per load savings can range from \$0.25 to \$0.45, with per-machine-day savings of \$2.50 to \$4.50, based on 10 loads per day in a 55 lb washer.

### Labor Savings

With reduced wash and dry cycle times, more laundry can be processed per operator hour, and fewer total operator hours are needed per day. Part-time operators will have more time available for other housekeeping duties.



### Fabric Life Savings

By avoiding exposure to harsh chemicals and extended dry times, the EcoTex™ process can extend usable fabric life by 20% or more, another direct cost saving.

**TABLE 2 TOTAL ESTIMATED COST SAVINGS FOR OZONE WASHING**

Item Saved	Savings		
	Per Load	Per Day	Percent
Water/Sewer	\$0.54	\$5.40	47%
Water Gas	\$1.14	\$11.44	90%
Hot Water	165 gal/load		86%
Dryer Gas	\$0.34	\$3.40	20%
Chemicals	\$0.25	\$2.50	42%
Labor	\$4.93	\$49.30	31%

Table 2 shows the total estimated cost savings for ozone washing projected on the basis of detailed calculations for each cost item. Per day savings are based on one 55 lb washer at ten loads per day.

**TABLE 3 LAUNDRY SAVINGS WITH ECOTEX™ OZONE SYSTEMS**

Systems	Potential Savings			
	Per Load	Per Month	Per Year	Sug. Retail Price
Model ECO35D - I	\$2.27	\$635.60	\$7,627.20	\$11,066
Model ECO35D - II	\$4.54	\$1,271.20	\$15,254.40	\$13,634
Model ECO35D - III	\$6.81	\$1,906.80	\$22,881.60	\$20,110
Model ECO35D - IV	\$9.08	\$2,542.40	\$30,508.80	\$23,110

**TABLE 4 ECOTEX™ TIME TO PAYBACK - CONSUMABLES ONLY**

Systems	Potential Savings	Estd Time to Payback (years)
Model ECO35D - I	17.41	1.45
Model ECO35D - II	10.72	0.89
Model ECO35D - III	10.54	0.87
Model ECO35D - IV	9.08	0.75

NOTE: Labor and linen savings NOT included

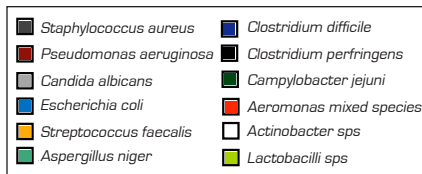
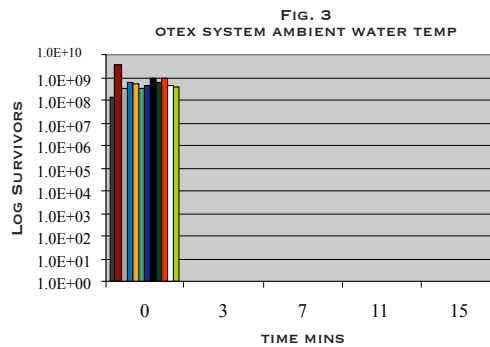
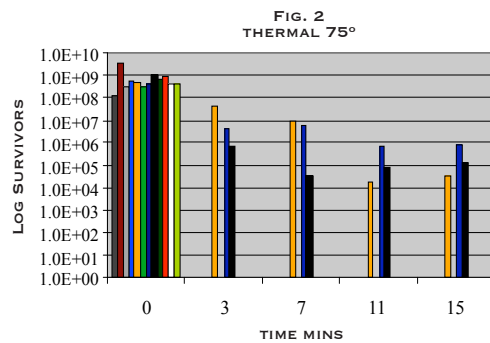
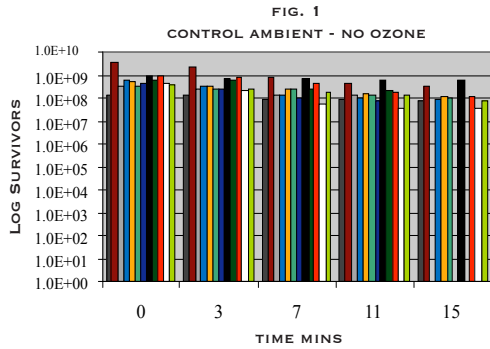
### It Adds Up

Combined deliver water, energy and chemical savings deliver a per-machine-day cost reduction of \$15.00 to \$25.00 depending on local water and energy costs. If machines run every day, monthly savings per machine can range from \$420 - \$700 or more. When labor and fabric savings are added, total savings can exceed \$800 per month for each washer.

### Average Laundry Facility Costs

Water/Sewer: \$0.006/gallon  
 Av. Nat'l Avg Natural Gas: \$1.24/therm  
 Chemical Costs: \$0.25/oz  
 Av. Facility Labor Cost: \$10.00/hr

National averages (USA) as of December 2005 for consumables and labor costs were used to project cost savings (in U.S. dollars) obtainable with four production models of the ClearWater Tech EcoTex™ ozone laundering system. Actual savings may vary based on geographical locations, water conditions and actual washing programs used at specific facilities.



### Microbiological Benefits of Ozone

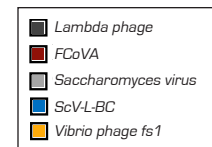
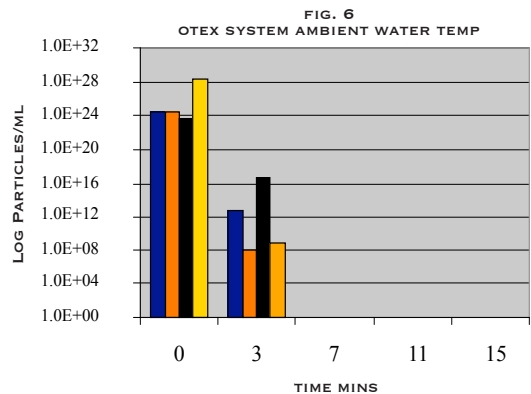
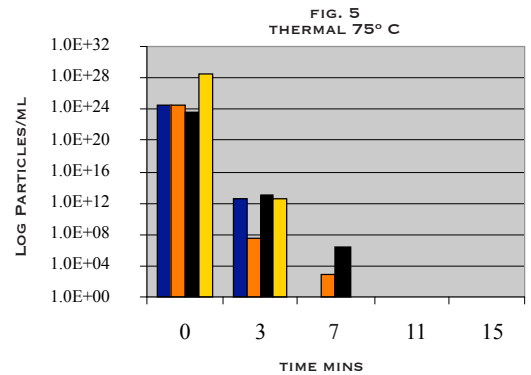
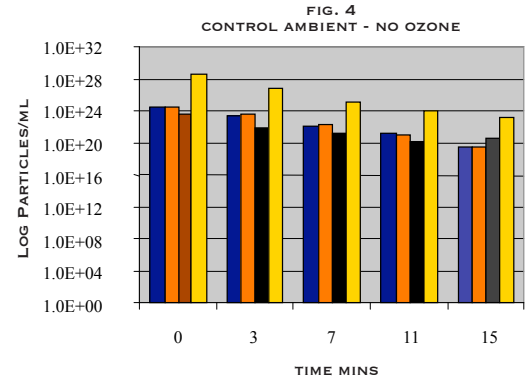
In tests conducted by Dr. Desmond O'Conner, Microsearch Laboratories, Halifax, United Kingdom, a single unit with EcoTex™ ozone technology was employed.

Test samples were taken from the wash drum throughout the wash cycle to determine the concentration of dissolved ozone in the water. This was measured by using the Chemets method, which employs DPD [N, N-diethyl-p-phenylenediamine] chemistry. Dissolved ozone levels increased from 0.2 ppm at the start to 0.6 ppm after 15 minutes, with samples being taken at 3, 7, 11, and 15 minutes of washing. Data obtained are presented in Figures 1-3. Figures 1, 2 and 3 show results of bacterial sampling at ambient temperature - no ozone (control), 75°C (167°F = thermal washing), and ambient temperature with EcoTex™ ozone technology, respectively.

Note that without ozone and at ambient temperature cold water laundering (Figure 1), only small amounts of bacterial kills were obtained. With thermal washing (Figure 2), three strains of bacteria remained at significant levels even after 15 minutes. But with ozone at ambient temperature (Figure 3), no bacteria were present after 3 minutes of washing.

Figures 4, 5 and 6 show similar results of virus and phage sampling at ambient temperature - no ozone (control), 75°C (167°F = thermal washing), and ambient temperature with EcoTex™ ozone technology, respectively. Note that without ozone and at ambient temperature (Figure 4), only small amounts of viral inactivation were obtained. With thermal washing (Figure 5), viral inactivation was obtained after 5 minutes and the same results were obtained with ozone at ambient temperature (Figure 6) after 5 minutes (but at lower cost).

Another especially resistant organism to conventional laundering is *Clostridium difficile*, which at the least causes diarrhea. This bug is usually acquired in a hospital or nursing home settings. It is sometimes referred to as *Clostridium difficile* Acquired diarrhea or (C.D.A.D). Although in most cases it causes a relatively mild illness, occasionally and particularly in elderly patients, especially those who are on a course of strong antibiotics, it may result in serious illness and even death. The bacterium produces toxins, which are responsible for the diarrhea and which damage the cells lining the bowel. Because it is a spore-former, *C. difficile* can survive outside the human body. It is totally eradicated from soiled linens and cleaning items (mops, wiping cloths) during ozone cold water laundering.



## DESIGN APPROACHES TO OZONE LAUNDRY SYSTEMS

A properly designed ozone laundry system will improve laundry performance by activating laundry detergents, reducing water usage, cutting the number of wash steps in the cycle and virtually eliminating the need for hot water. Each of the design approaches discussed below has merit even though some have advantages over others. Irrespective of the design selected though, an ozone laundry will dramatically outperform a traditional laundry in terms of both higher laundry quality and lower operational costs.

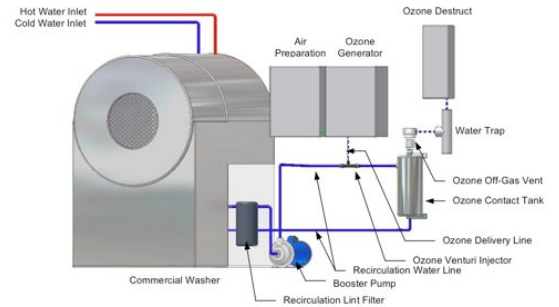
- Recirculation Injection (RI)** – This system circulates water between the washer and the ozone system re-oxidizing and returning newly charged ozone-enriched water to the washer continuously. To facilitate this continuous recirculation, piping along with pumps, contact vessel and filters must be installed. An oxidation-reduction-potential (ORP) controller, or an ozone parts per million (PPM) controller is highly recommended for monitoring and controlling ozone concentration in the water. Even though the RI approach can handle heavy microbe loads and save water it is seldom used because it is also the most complex and expensive of the four design alternatives. Another reason this design is not widely adopted involves the continuous maintenance necessary to keep lint filters clean for proper system performance.

- Direct Water Injection (DWI)** – With DWI equipment, ozone is directly injected via a venturi into the cold water supply line leading to the washer. This is a single charge system, although some DWI systems also incorporate a single pass contact vessel, which slightly increases ozone levels in solution. The ozone-enriched water is not recharged once it enters the washer.

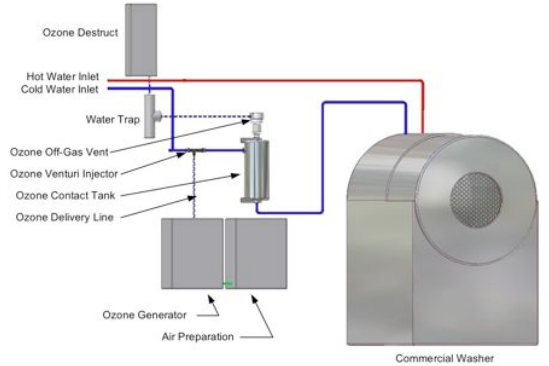
- Charge System (CS)** - A variation of the DWI approach includes a recirculation loop from the contact vessel to the ozone system. A charge system mixes ozone with cold water and then continually recycles it between contact vessel and the ozone system to maintain a predetermined ozone level in the water, as measured by ORP level or ozone PPM. The CS approach makes it possible to achieve higher effective concentrations of ozone in the water prior to releasing it into the washer. The ozone-enriched water is not recharged once it enters the washer.

- Diffusion** – With Diffusion systems, ozone is continuously injected directly into the sump of the washer throughout each step of the wash cycle. Because it directly injects ozone into the washer sump, as opposed to the water supply, no additional pumps, contact vessels, filters, or piping are needed. The Diffusion approach delivers verified disinfection with improved laundry quality at the least cost when compared to other design approaches. Disinfection is achieved not only in the ozone-enriched water but also in the direct contact between ozone gas and linen as they tumble together in the wash drum. Diffusion systems control the amount of ozone gas that is diffused into the washer and also use ozone monitors as a shut-off control should any ozone ever be detected in occupied areas.

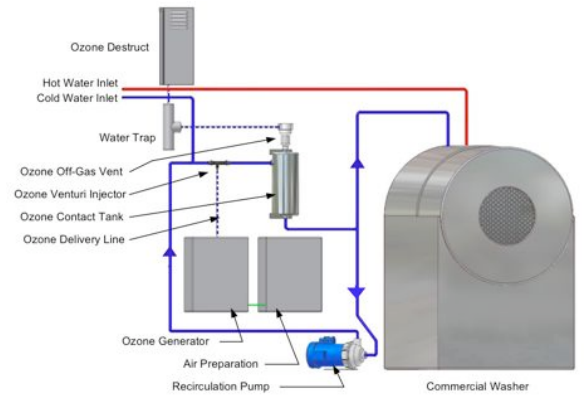
### RECIRCULATION INJECTION



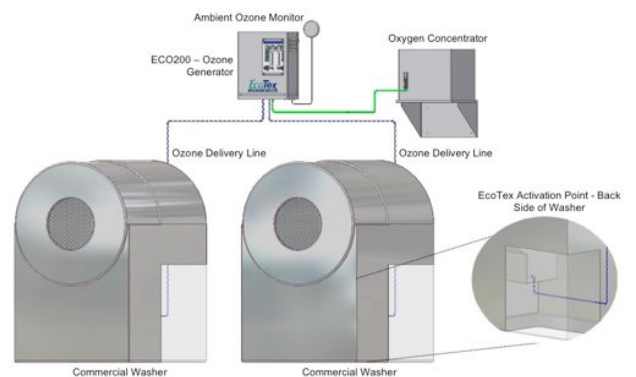
### DIRECT WATER INJECTION



### CHARGE SYSTEM



### DIFFUSION



**TABLE 5**

**OZONE SYSTEM COMPARISON**

<b>Design</b>	<b>Advantages</b>	<b>Disadvantages</b>
Recirculation Injection (RI) Method	<ul style="list-style-type: none"> <li>• Continuous ozone supply recharging throughout each programmed step of wash cycle</li> <li>• Provides direct ozone contact with linen</li> <li>• Little to no bleaching effect</li> </ul>	<ul style="list-style-type: none"> <li>• Complex plumbing &amp; installation</li> <li>• High price - long payback period</li> <li>• Large footprint with additional piping, pumps, contact tank, filters, etc.</li> <li>• More maintenance including filter cleaning required, as much as three times per day</li> </ul>
Direct Water Injection (DWI) Method	<ul style="list-style-type: none"> <li>• Slightly smaller footprint than the RI method</li> <li>• Wall-mountable, except for some contact vessel variations that may be floor mounted</li> <li>• Less up front cost than the RI method</li> <li>• ORP &amp; PPM controllers can confirm ozone is being transferred to water and an ozone residual is detected</li> <li>• No bleaching effect</li> </ul>	<ul style="list-style-type: none"> <li>• Complex plumbing &amp; installation</li> <li>• Single pass ozone contact vessel</li> <li>• Single charge ozone, NO ozone recharging during wash steps</li> <li>• High price - long payback period</li> <li>• Large footprint with additional piping, pumps, contact tank, filters, ORP, PPM controller, etc.</li> <li>• More components to maintain</li> <li>• No verified microbe kill in linen</li> </ul>
Charge System (CS) Method	<ul style="list-style-type: none"> <li>• Slightly smaller foot print than the RI method</li> <li>• Wall-mountable, except for contact vessel, which is generally floor mounted</li> <li>• Less up front cost than the RI method</li> <li>• Multiple pass ozone injection prior to use in washer</li> <li>• ORP &amp; PPM controllers can confirm ozone is being transferred to water and an ozone residual is detected</li> <li>• No bleaching effect</li> </ul>	<ul style="list-style-type: none"> <li>• Complex plumbing &amp; installation</li> <li>• Single charge ozone, NO ozone recharging during wash steps</li> <li>• High price - long payback period</li> <li>• Large footprint with additional piping, pumps, contact tank, filters, etc.</li> <li>• More components to maintain</li> <li>• No microbe kill in linen</li> </ul>
Diffusion Method	<ul style="list-style-type: none"> <li>• Continuous ozone recharging throughout each step of the wash cycle</li> <li>• Direct ozone contact with linen for verified microbe kill</li> <li>• Low capital investment, low lease payment</li> <li>• Short payback, as little as 2 months with lease financing</li> <li>• Easy to install and maintain - no added plumbing contact tanks, pumps, filters, etc.</li> <li>• Minimal components to maintain</li> <li>• Small footprint, wall-mountable so no floor space required</li> <li>• Low operating costs</li> <li>• Low bleaching effect</li> </ul>	<ul style="list-style-type: none"> <li>• Ozone systems that are improperly calibrated and installed can produce ambient ozone issues</li> </ul>

**Advantages of “Diffusion” Systems**

- Diffusion Systems put more ozone into linen than can be done with injection systems because:
  - Ozone is being diffused into the water during the ENTIRE step, in ALL wash steps, in the wash cycle (up to 35+ minutes of dosing in each wash load). Injection systems only dose the water PRIOR to it being injected into the washer.
  - Ozone does NOT stay in solution in the agitated water inside the washer (only a minute or two) without being replenished constantly during the wash cycle. Without replenishment, ozone is steadily diminished and ceases to be as effective in aiding the wash process, OR more importantly, provide adequate disinfection.
  - Independent laboratory tests have shown that high concentrations of ozone gas flowing around the linen inside the wash chamber are more effective at disinfection than ozone-enriched water alone.
- Diffusion is safe and presents NO danger to people in a laundry room because:
  - Ozone in the gaseous form remains in the washer during operation and exits the washer with the water effluent. (Validated by ozone monitors in over 2,000 diffusion laundry systems operating worldwide)
  - Even if ozone does not fully exit the washer with the water effluent, there is TOO LITTLE gas remaining to be of any consequence to worker safety. Monitors, which are used in all diffusion installations, provide the proof that ozone does not reach unhealthful levels in occupied areas of the laundry.
- Diffusion is operationally superior to DWI, CS and RI systems because:
  - Diffusion utilizes a SINGLE ozone delivery line into the washer sump - NO complex plumbing as needed with the DWI, CS and RI systems, which require some variation of specialized piping, contact vessels, additional pumps, ORP monitors, off-gas destructs, etc.
  - Diffusion enables precise control of ozone levels inside the washer drum that is maintained throughout each wash step in the wash cycle, which enables verifiable microbe kill.

## Summary and Conclusions

The use of ozone in commercial laundries can be a cost-effective windfall to laundry operators, especially in Nursing Care, Hotels and Hospitals where quality laundering is vital for the health and safety of patients and guests. Depending on current practices, a typical laundry can generate cost savings to achieve full payback on the investment within 8 to 18 months. This is possible because ozone enables washing to be done in cold water, saving considerable energy. Ozone also saves water as a result of reductions in detergent use and the number of rinses required. Washing and drying cycles can be shortened with ozone use making it possible to do more wash in less time and ozone cold-water cycles are gentler to fabrics, extending linen life. Ozone cold-water laundering even reduces COD (chemical oxygen demand) and BOD (biological oxygen demand) in laundry effluent, protecting the environment.

Of particular significance to hospitals and nursing facilities is the ability of ozone to destroy or inactivate a wide variety of microorganisms within a few seconds to a few minutes. The "usual suspects" [*S. aureus*, *Ps. aeruginosa*, *Candida albicans*, *E. coli*, *Streptococcus faecalis*, *A. niger*, *C. perfringens*, *Campylobacter jejuni*, and *Aeromonas, Actinobacter and Lactobacilli* species] are quickly destroyed, and four virus strains, representative of

single- and double-strand RNA and DNA, are quickly inactivated.

The "superbug" *Methicillinresistant Staphylococcus Aureus* or (MRSA) described by Time Magazine as the "new killer bug", is prevalent in hospitals and nursing homes. This microbe is especially dangerous to the sick and elderly and can spread quickly if not vigilantly controlled. Fortunately MRSA is quickly eradicated during ozone cold-water washing whereas it can remain unaffected in standard thermal washing with bleach.

Another particularly resistant organism to conventional laundering is *Clostridium difficile*, which causes to diarrhea. This bug is usually acquired from a hospital or nursing home setting. It causes *Clostridium Difficile Acquired Diarrhea* or (C.D.A.D). Although in most cases it causes a relatively mild illness, occasionally and particularly in elderly patients, it can result in serious illness and even death - especially those who have recently taken or are on a course of antibiotics. The bacterium produces toxins, which are responsible for the diarrhea and which damage the cells lining the bowel. Because it is a spore-former, *C. difficile* can survive outside the human body for extended periods but it is totally eradicated from soiled linens during ozone cold-water laundering.

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