Using the GasTran® Deaeration System to achieve low dissolved oxygen levels for superior line speed and product quality: a case study in carbonated soft drink bottling

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Abstract:
In the battle to improve line speeds, production yields, and product quality for carbonated soft drink packaging, properly deaerated water is proving to be an essential ingredient for the blending and carbonation process steps in carbonated soft drink bottling[1].

By using process water deaerated to levels below 500 ppb (parts per billion) dissolved oxygen, several plants have been able to improve carbonation consistency without the need for constant operator adjustments and line stoppage. The ability to meet a consistent carbonation specification reduces product foaming during the fill process, enables faster line speeds, and higher yields on syrup consumption.

Best practice for water deaeration avoids the use of a stripping gas such as CO_2. When CO_2 is used to achieve lower dissolved oxygen levels the result is a lot of wasted CO_2 without the ability to control carbonation levels.

GasTran Technology uses process intensification principles to improve mass transfer processes involving gases and liquids. This technology works by imparting high shear forces on a liquid to create extremely small droplets, thus exposing a large liquid surface area through which efficient gas absorption and gas removal can occur.

Once the small droplets are created, vacuum is used to remove the dissolved gases to low levels not achievable in ordinary vacuum deaeration designs. No consumables or stripping gas is needed to achieve dissolved oxygen levels in the 200 to 500 ppb range, depending on temperature.

1) INTRODUCTION – ROTATING PACKED BEDS

Rotating packed beds (RPB) have been around for more than 3 decades as the lead process intensification technology attempting to use large gravitational fields to improve mass transfer efficiency. The fundamental differentiating idea behind RPBs was generating large centrifugal forces by rotating a packed rotor at high speeds, instead of relying on the singular force of gravity in packed or trayed columns.

The origin of RPBs goes back to the 1970's and Colin Ramshaw's work in the chemical process industry at ICI, most notably in trying to find an alternative to conventional distillation towers. Since then, a significant body of research has grown involving the use of rotating packed beds. The majority of this work consists of fundamental studies of RPBs, while very little has been written about industrial-scale installations. Partly, this is due to the fact that there have been relatively few industrial installations of RPBs. As

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[1] In this paper, "bottling" can be used interchangeably with the process for filling cans. While there are certainly aspects of the process that are unique whether the final consumer package is a bottle or can, for practical purposes in this paper they largely follow the same process.

well, some installations have been shrouded in corporate secrecy and others have failed to uncover true value for customers.

This paper will review multiple installations of GasTran® Vacuum Deaeration Systems. GasTran Technology developed out of the earlier work on rotating packed beds.

2) GASTRAN SYSTEMS COMPANY OVERVIEW

GasTran Systems was formed in 2004 to commercialize patented GasTran Technology, which was based on over two decades of work from Case Western Reserve University chemical engineering Professor Nelson Gardner. Dr. Gardner, one of the founders of the company, did a significant amount of research to contribute to the larger field of knowledge in RPBs (1), (2), (3).
Based in Cleveland, OH, GasTran Systems engineers, manufactures, and sells commercial process equipment based on the proprietary technology. GasTran Systems is one of the first companies to commercialize on a wide scale basis mass transfer equipment based on process intensification principles.
While the roots of GasTran Technology are in Dr. Gardner's work with rotating packed beds, the unique qualities of the technology and the company are clear. GasTran Systems has been granted a US patent for the technology and has additional patents pending in the US and abroad.

GasTran Systems employs a unique team of entrepreneurial engineers with the knowledge to design and implement new technology. Rather than attempt to radically transform or re-engineer existing manufacturing process, one of the guiding principles for the company is to find applications where customers will realize immediate tangible benefits. Combined with a focused approach to applied research and development, a significant installed base, and a strong knowledge of cost efficient manufacturing, the company expects to continue to bring the technology to new, untapped markets.

3) GASTRAN TECHNOLOGY – CONFIGURATION FOR VACUUM DEAERATION

While there are many different ways to implement a GasTran Unit, this paper will focus on a configuration for vacuum deaeration[2] of water. While this paper will not explore the research and development that went into this specific design, a variety of factors determine optimal performance given flow rates and vacuum pressures.

As shown in figure 1, at the core of the GasTran Unit is a motor-driven, spinning rotor with porous packing material. Water is fed through a manifold into the center of the rotor, which creates a large centrifugal force, shearing the water into nano-sized droplets and sending it into the outer chamber. It is during this extremely short period of time that the water droplets are exposed to the vacuum, enabling the deaeration to occur. The dissolved gases in the water are evacuated out the top of the chamber to a vacuum pump. The deaerated water collects in the chamber and then drains out the bottom of the GasTran Unit.

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[2] The term deaeration, also referred to as degasification, refers to the process of separating and removing dissolved O_2, CO_2, and N gases from a liquid.

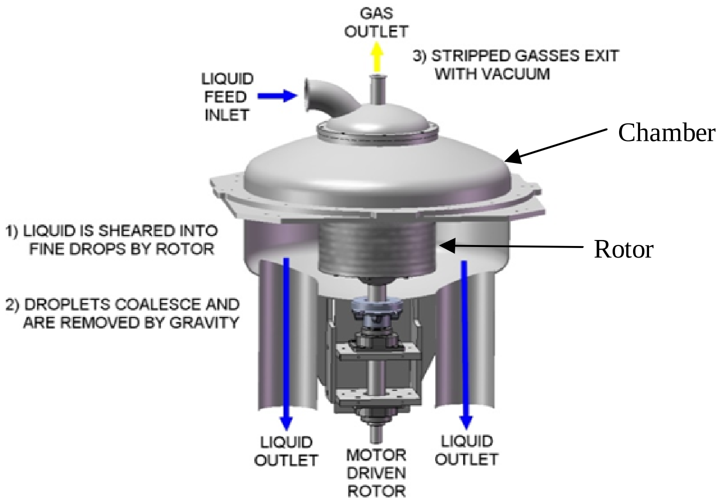

Figure 1 - The GasTran Unit as Set Up for Vacuum Deaeration

3.1 Core advantage

Vacuum levels applied are in the range of 1,000 to 2,000 Pa absolute, providing a deep vacuum for the deaeration. However, it is the expanded surface area of the water created in such a compact space that makes the low levels of dissolved oxygen achievable.

3.2 Materials of construction in beverage applications

When used in beverage, all materials of construction must be 300 series stainless steel with food grade seals. All of the internal and external surfaces of the unit are polished to a RA32 or better finish, and the top and bottom of the chamber are domed to promote good water drainage.

4) CARBONATED SOFT DRINK BOTTLING LINE OVERVIEW

At a fundamental level, carbonated soft drink (CSD) bottle and can packaging plants come in only a few different configurations. Every CSD packaging process starts with water treatment, including deaeration, and proceeds to blending of the water with a pre-made syrup, carbonation of the blend, and then to the filling of the containers. This process is shown in figure 2, together with the most common equipment options for each step.

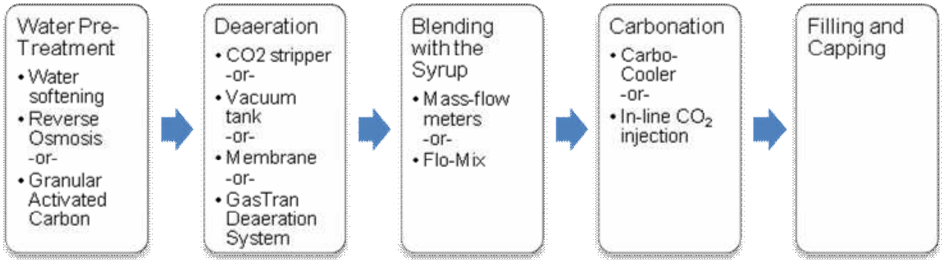

Figure 2 - CSD Bottling Line Overview

4.1 Water pre-treatment

While some variability exists, most bottling plants in the US use water from a Publicly Owned Treatment Works (POTW), eliminating the need for a large investment in water pre-treatment. To further adjust the water quality to meet quality standards for hardness and total organic carbon (TOC), many plants utilize water softeners and either reverse osmosis or granular activated carbon (GAC).

While the basic quality of the water is usually quite acceptable, the incoming temperature, dissolved oxygen (DO) levels, and total dissolved solids (TDS) in the water can vary widely from plant to plant as well as seasonally.

4.2 Deaeration

In the bottling world, deaeration has historically been thought of as the pre-treatment step for removing the dissolved oxygen that exists naturally in water sources. The DO was believed to interfere to some extent with the carbonation step, and so basic designs were used to strip the DO from the water using a stripping gas.

A common approach was to use either a spray mechanism or some packing material in order to generate surface area in the water, and inject CO_2 gas counter-current to the water stream. This would remove DO to levels down to the 1.5 to 2.5 parts per million (ppm) range, while simultaneously absorbing CO_2 gas into the water. This method results in highly variable DO levels and wastes large amounts of CO_2 gas. In some cases as little as 10% of the CO_2 gas used actually gets absorbed into the water, with the remainder venting to the atmosphere.

An alternative approach to deaeration starting about five years ago was to use hollow-fiber, hydrophobic membranes. The process water passes through the membranes, while a vacuum pressure applied to the core of the membrane removes the dissolved gases. The gas molecules are small enough to fit through the holes in the membrane material, while the water molecules are not. Sometimes this vacuum pressure is applied together with a sweep gas of either carbon dioxide or nitrogen in order to reduce the equilibrium concentration of the stripped gas. Several practical problems have prevented membranes from delivering sustained deaeration performance below 1 part per million DO. Primary among them is rapid degradation and fouling of the membrane material from inconsistent incoming water quality and the increasing frequency of sanitary cleaning cycles on the bottling lines. In summary, despite large investments by CSD bottling plants and costly replacements of cartridges, membranes have failed to deliver a significant and sustained lower DO to the rest of the bottling line.

The most recent approach to deaeration in the CSD industry involves the GasTran Deaeration System. This solution uses a vacuum pump and mechanical shearing to improve deaeration efficiency. It requires no consumable gases or cartridges and achieves sustained deaeration performance in the ranges from 200 to 500 ppb DO, depending on the incoming water parameters. Plant to plant differences in sanitary cleaning procedures and pre-treatment equipment do not affect or degrade performance.

4.3 Blending

Blending involves mixing the flavored syrup concentrate with the deaerated process water. Every product, from Dr Pepper® to Diet Coke® has its own unique blend. Most CSD products range from a 3:1 to 6:1 ratio of water to syrup.

In the 1960s, the Flo-mix design by Mojonnier Brothers became widely used for mixing the syrup with the process water. This design uses a simple system for metering the syrup into the water for blending prior to carbonation.

More recent methods take advantage of modern flow control valves such as Micro Motion and process feedback loops to continuously control the flow of both the syrup and the water. The BRIX of the mixture is measured in real time and provides feedback to the flow control valves.

BRIX is a measure of the mass ratio of dissolved sugar to water. Most bottling lines measure the BRIX of the blended soft drink as a primary measure of blending quality control. Both the newer and the older style of blending control benefit from deaerated water due to improved metering accuracy and resulting quality control. In particular, use of CO_2 stripping methods to achieve lower DO make tight control of the modern flow control valves extremely difficult.

4.4 Carbonation

As with the Flo-mix designs, Mojonnier Brothers also standardized most CSD plants in the 1960s around the Carbo-Cooler design for final carbonation of the product. A typical Carbo-Cooler design cools the soft drink using heat exchanger plates while injecting CO_2 into the liquid to arrive at a final carbonation specification for the beverage. Pressure is also controlled in the CO_2 injection tank to enable better absorption.

Typical carbonation levels for CSD products in the bottle range from 2.2 volumes to 4.1 volume of CO_2 to liquid.

Other manufacturers use similar methods for carbonating and most of them involve some degree of cooling of the soft drink.

Once again, effective deaeration plays a key role in the carbonation process. DO in the water not only masks true carbonation but requires more CO_2 and greater pressures to achieve desired CO_2 absorption.

4.5 Filling and capping

A variety of different suppliers and vendors over the years provided equipment to the step of filling the bottle or can containers and finally sealing the container before sending it on to packaging. From the 1960's through the present, increased demand and the need to reduce cost per unit drove improvements in filling valve design and controls and faster line speeds. In general, the speed of a filler is governed by the number of valves incorporated into the rotary filling wheel. Modern bottling lines are rated to run at speeds up to 2,200 cans per minute or 1,000 bottles per minute.

Foaming of the product during filling is the most common limitation on filling speed versus rated capacity. Foaming can be caused by a variety of factors but one of the biggest is due to the release of CO_2 that can occur during the filling process. When exposed to the drop in pressure (going from line pressure to atmospheric pressure), the liquid releases CO_2, causing a volcanic effect in the container and liquid to spill out prior to sealing of the container.

Foaming often results in a variety of other quality control and yield problems, including inaccurate fill heights in the bottle and product spillage. Spillage can end up being a problematic wastewater issue. Net contents, the primary measure of filling accuracy, is a critical metric for delivering customer quality.

5) THE ROLE OF BETTER VACUUM DEAERATION IN CSD PLANTS

Starting with its first CSD installation in 2006, GasTran Systems brought a new option to the deaeration step in the bottling line. Using a vacuum pump capable of drawing deep vacuum pressures of 1,000 to 2,000 Pa absolute and the ability to continuously shear large volumes of water through the rotor, the GasTran Vacuum Deaeration System showed it could consistently deliver water with DO levels below 500 ppb.

At the time, the benefits of achieving this level of DO were not well understood. Now, with the benefit of more than 8 installations, a definitive connection can be made between the theories on low DO and solving real bottling line performance challenges.

5.1 Side-effects of high dissolved oxygen

The presence of dissolved oxygen in the process water produces several consequences detrimental to the control of the final CO_2 level in the final package, as well as the accurate control of bottle fill levels while minimizing product waste.

Due to the interaction between dissolved O_2 and CO_2 in solution, dissolved oxygen acts to increase the partial pressure of CO_2 required to carbonate to the defined specification. This interaction decreases the real carbon dioxide solubility in water and also acts as a promoter for increased carbon dioxide degasification during mixing and rapid pressure changes.

To increase the overall solubility of CO_2, many bottling lines compensate with higher pressures in the Carbo-Cooler and/or lower water temperatures. This causes several unintended consequences in the process.

5.2 Compensating with higher pressures

The main problem with increasing pressures to obtain carbonation requirements are the higher pressure drops as the liquid transitions from process pressure to atmospheric pressure. Taken by itself, a larger pressure drop is not a significant issue. But when DO is still present in solution, most fillers will suffer from increased foaming as the CO_2 rapidly expands out of solution. This escape of the CO_2 often is seen as a “volcanic” eruption out of the bottle as a foamy liquid. When the foam escapes, the result can be a “low fill” condition in the bottle, meaning the liquid volume does not meet the minimum specification. These bottles get rejected as an expensive yield loss after capping. The foam itself is problematic in part because it ends up in the plant’s wastewater stream.

5.3 Compensating with lower temperatures

The other compensation method for carbonation control is to decrease the liquid temperature. This increases the solubility of carbon dioxide by lowering the necessary partial pressure required to dissolve the carbon dioxide making it more soluble and more stable when DO is present. The obvious problem with this is the high cost of cooling.

5.4 The trade-off between carbonation and foaming

In an effort to reduce foaming and minimize cooling costs (especially in warmer locations), the tempting choice can be to maintain lower pressures and not cool the water.

The likely result might be low carbonation levels, which could lead to off-spec product or reduced shelf life, since the primary limiter to shelf life in CSD products is currently carbonation leakage (i.e. “flat” product).

5.5 CO_2 stripping to lower DO levels

Using CO_2 stripping towers to achieve low DO levels had been considered one way to achieve better carbonation control in the final product. Given enough CO_2, DO in these towers can be lowered to 1,000 ppb or less. High CO_2 costs and poor stripping efficiency, however, make this option an expensive one. With increasing awareness around controlling carbon emissions, the CO_2 offgas from these strippers becomes an even less cost-effective and environmentally-friendly alternative.

This option was also problematic for proportional flow control blending systems, such as those incorporating mass flow metering. Coupled with a CO_2 stripper, these blenders fail to achieve their prescribed benefits, since CO_2 bubbles lower the liquid density and disturb the flow metering.

5.6 Foundation to better blending and carbonation

Given the challenges CSD bottlers face with carbonation and BRIX control, sustaining low DO below 500 ppb in the deaeration step provides a solid foundation for carbonation stability, overall product quality, and increased line efficiency. Furthermore, achieving low DO without the addition of CO_2 prior to carbonation is the most logical and best economic option, leaving vacuum deaeration as a clear choice.

Installing a vacuum deaeration system capable of sustained low DO does not by itself guarantee success, however. Making the transition to better quality and faster bottling speeds requires a holistic approach to the production line. Each step affects the subsequent parts of the process. Equipment and operating parameters will require re-tuning and adjustment both prior to and after installation, until the entire line begins to work in harmony.

Choosing a vendor that understands the entire line and can anticipate the adjustments required becomes a critical component to installing a vacuum deaeration system. Furthermore, fundamental training and the close involvement of the quality department when making adjustments helps insure the best practices established will remain long after the system is installed.

Finally, quality vendors provide both a preventative maintenance service program and remote diagnostic tools standard with each system.

6) TODAY’S CSD BOTTLING ENVIRONMENT

6.1 Flat markets bring pressure to reduce cost

After experiencing explosive growth in the US market from the 1960s through the 1990s, the last decade for the CSD market has been characterized by very slow growth and even some years of market contraction (Figure 3 – US Carbonated Soft Drink Market). Changing consumer taste, increasing health consciousness, and the emergence of bottled water are three of the primary drivers of what has become a nearly flat market for CSD products.

Period	Compound Annual Growth
1960 - 1970	7.8%
1970 - 1975	4.8%
1975 - 1980	6.2%
1980 - 1985	5.1%
1985 - 1990	3.7%
1990 - 1995	2.8%
1995 - 2000	2.2%
1996 - 2001	1.6%
1997 - 2002	1.2%
1998 - 2003	0.6%
1999 - 2004	0.6%
2000 - 2005	0.4%
2001 - 2006	0.0%

Figure 3 – US Carbonated Soft Drink Market[3]

Without growth and facing a huge amount of competition in the beverage category, cost reduction strategies become of prime importance for CSD bottling plants[4] to meet aggressive pricing strategies. Recent cost increases in ingredient and packaging materials only put more pressure on plants to cut costs by increasing throughput and yields.

6.2 SKU proliferation and frequent change-overs

During the last decade, to meet demand for new products, package sizes, and package types, the huge growth in the number of beverage stock-keeping-units (SKU's) brings a new challenge to today's bottling plant.

Gone are the days when a single line bottled 3 or 4 different flavors in 3 or 4 package sizes. Today, it is not uncommon for a single CSD plant to handle over 150 different SKU's and a single line to handle more than 75.

In combination with inventory minimization strategies, SKU proliferation puts a premium on maximizing line up-time, fast start-ups, and rapid change-overs, while not having to constantly retune settings for BRIX, carbonation, pressure, etc. For this reason, CSD plants need a reliable feed of low DO water on demand.

6.3 Increased clean-in-place requirements

Another trend driven in large part by changing consumer tastes is the popularity of non-CSD products. These products include fruit juice cocktails (both with and without real fruit juice), teas, and flavored waters, to name a few. Many non-CSD products have a pH higher than CSD products and must be preceded by a clean-in-place (CIP) cycle[5].

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[3] Source: Beverage Marketing Corporation

[4] It should be noted that the three largest CSD marketers (Coca-Cola, Pepsi-Cola, and Dr. Pepper Snapple Group) diversified their beverage portfolio in the last decade through acquisition and new products to include successful bottled water brands as well as other non-CSD products.

[5] CIP cycles are the most common method of clean and sanitizing bottling equipment *in place*, that is, without disconnecting piping or moving pieces of equipment. While CIP

Most modern bottling lines run many of these products back-to-back with CSD products. Together with the importance of bottling line flexibility and increasing product change-overs previously mentioned, the frequency of CIP is also rising.

Membranes, a low-cost option for deaeration, have repeatedly been proven to rapidly deteriorate with frequent exposure to CIP temperatures and pH fluctuations. On occasion, even membrane housings have permanently deformed to the point of catastrophic failure when exposed to high CIP temperatures.

Some installers of membrane manufacturers have attempted to isolate the membranes during CIP cycles in order to slow deterioration, but this solution prevents the membrane system from being adequately cleaned and leaves it vulnerable to biological growth.

6.4 Company sustainability initiatives

A still emerging trend is the sustainability and 'green' initiatives. Every one of the major CSD beverage marketers and bottling companies have significant programs in place to become more environmentally friendly, with a significant focus on both reducing water usage and carbon emissions. These initiatives benefit by reducing water waste due to foaming and production of off-spec product. Likewise, eliminating inefficient CO_2 stripping practices provides average savings of approximately 1,000 tons per line per year when switching to vacuum deaeration.

Of course, the proactive approaches to reducing CO_2 emissions by the bottlers do not by any means prevent future legislative risks from further increasing the CO_2 cost to bottlers. Future legislation and international agreements could drive both purchase and emission costs higher.

7) BENEFITS OF THE GASTRAN TECHNOLOGY FOR CSD CUSTOMERS

7.1 Line speed increases from reduced foaming decrease costs

As previously referenced in section 4.5, the biggest limiter today of line speed is product foaming. A GasTran Vacuum Deaeration System has been shown in multiple installations to significantly reduce foaming, enabling faster line speeds and reduced production costs. Depending on the SKU, bottling line speed increases typically range from 10% up to 40%.

7.2 Lower product costs through higher yields and less waste

While quantifying the exact increases in yields and reduced waste has been extremely difficult, the observations from plant personnel are clear. The vacuum deaeration system results in less foam overflowing the bottles and produces more product that meets specification. This means higher yields on costly high fructose syrups, less wastewater to treat, and fewer off-spec packages to destroy.

7.3 Improved net contents and tighter carbonation control increase quality

By enabling customers to achieve six sigma quality on net contents and carbonation at multiple installations, GasTran Systems is helping to deliver quality products to customers.

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practices in the CSD industry vary widely, they typically incorporate some bit of high temperature (82 deg C) cycle, an acid cycle, and a caustic cycle.

7.4 Reduced CO_2 emissions make for a cost-effective and sustainable alternative

By replacing inefficient and ineffective CO_2 strippers, a vacuum deaeration system gives the dual-pronged benefit of reducing operating costs while dramatically reducing a plant's carbon footprint.

Table 1- Select GasTran System installations and resulting CO_2 savings

	Before DO (mg/L)	After DO (mg/L)	CO_2 savings (mtons/year)
PepsiAmericas - Austin, IN #1	2.8	0.35	837
PepsiAmericas - Austin, IN #2	3.1	0.35	996
PepsiAmericas - Indianapolis, IN	1.9	0.18	830
Pepsi Bottler - Southeast US	1.2	0.20	250
Pepsi Bottler - Northeast US	2.8	0.40	1,278
Pepsi Bottler - Great Plains US	1.1	0.25	976

Carbon dioxide costs at CSD plants in the US commonly range from between $107/mton to $241/mton, depending on facility location.

7.5 Superior Cleanability

As part of good plant-wide sanitary practices, it is recommended that the water treatment system, including the deaerator, be a part of the overall CIP cycle. In addition to the polished stainless and passivated surfaces that come in contact with the process water, each GasTran Vacuum Deaeration System includes a CIP cycle that recirculates water and cleaning solutions throughout the system and rotor. Our engineering team will also custom-program our software to fit into each plant's particular protocol. Spray balls on the tanks are an additional option depending on specific requirements.

8) CASE STUDY – PEPSIAMERICAS, INC. – AUSTIN, IN

PepsiAmericas Inc. is the second largest bottler of Pepsi-Cola products in the world, with more than $3 billion in annual revenues. PepsiAmericas also bottles and packages non-Pepsi products, such as Dr Pepper® and Hawaiian Punch®, on a contract basis. PepsiAmericas' plant in Austin, IN is an anchor bottler for the company, with two CSD bottling lines (#1 and #3) and one CSD canning line (#2).

In July 2006, PepsiAmericas contracted GasTran Systems to build a vacuum deaeration system capable of supplying 568 lpm deaerated water to either their can line #2 or their bottle line #3 so its impact could be evaluated on both can and bottle production. The new system replaced a Mojonnier De-Ox CO_2 stripping column and was installed in September of 2006. GasTran Systems' personnel oversaw the manufacture, installation, and start-up of the system. The system is pictured in Figure 4 with the GasTran Unit at the very top of the frame.

Figure 4 - GasTran Deaeration System Installed in Austin, IN

For removing the DO, the GasTran System used a vacuum pump operating in the ranges from 1,000 to 2,000 Pa absolute as measured by a vacuum gauge on the system. The De-Ox system had used carbon dioxide to reduce DO levels. As a result of the change in equipment, the plant was able to save over 837 metric tons of CO_2 annually.

Immediately after start-up the lower levels of dissolved oxygen were noticed in the process water, with DO levels of between 300 and 500 ppb (at temperatures of 9 deg C and 6 deg C respectively) measured by a Mettler-Toledo Thornton dissolved oxygen meter included with the system. This compared with prior DO levels averaging 2,800 ppb with the De-Ox system.

The lower levels of DO achieved in the process water produced three measurable benefits.

8.1 Faster fill speeds
Lower DO levels produced significantly less foam, enabling faster line speeds on a variety of products and package sizes.

Table 2 – Sampling of Line Speed Increases Achieved

Product/size	*Speed before GTS (units per minute)*	*Speed after GTS (units per minute)*	*Increase*
Dr Pepper 0.5 liter PET	600	750	25%
Pepsi 24 oz PET	400	600	50%
Pepsi 12 oz PET	550	700	27%
Dr Pepper 12 oz PET	500	700	40%

8.2 Less variation in carbonation levels
Running a 12 oz (355 ml) Pepsi PET (plastic) bottle on line #3, a significant improvement in the distribution of carbonation levels was achieved even while running at 150 bpm (bottles per minute) faster line speeds (see Figure 5 and Figure 6).

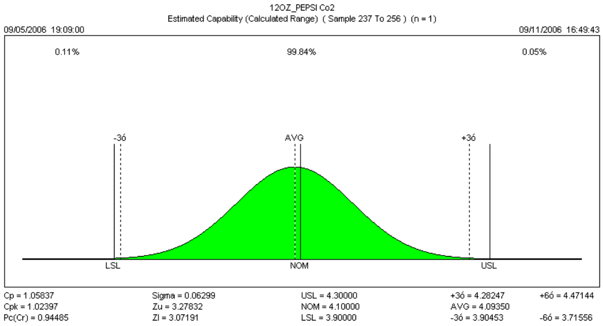

Figure 5 – Carbonation Levels Prior to Installation

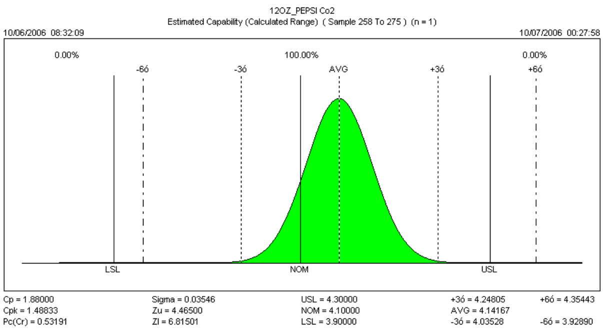

Figure 6 – Carbonation Levels after Installation

8.3 Less variation in net contents

Running a 12 oz can of Dr Pepper® on line #2 reduced foaming, enabling them to increase line speed while simultaneously improving fill accuracy, as is shown by graphs of net contents (Figure 7 and Figure 8).

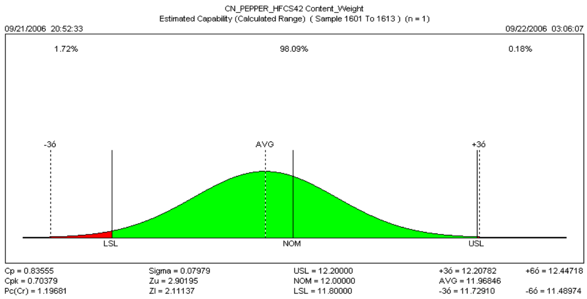

Figure 7 - Net Contents Prior to Installation

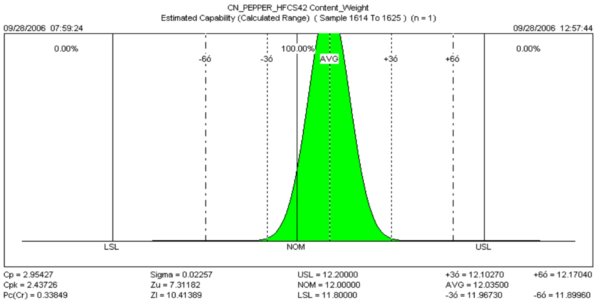

Figure 8 – Net Contents after Installation

Another measure of fill accuracy is reject rates. At the Austin plant every unit is scanned optically for low fills. If the package is underfilled, it is removed from the production line and destroyed. On the can line, Dr Pepper reject rates have been reduced from 1.7% to a negligible rate and Pepsi reject rates from 2.26% to a negligible rate.

8.4 Summary

The vacuum deaeration system at the PepsiAmericas' Austin, IN plant made a significant impact on their operation. Reduced foaming allowed the production line to run dramatically faster than before, increasing plant capacity and reducing cost per case. Meanwhile, quality of the product improved as measured by carbonation and net contents, reducing off-spec product and therefore yield loss.

At the same time, eliminating the carbon dioxide stripping column saved tens of thousands of dollars per year, reducing plant CO_2 usage by over 837 metric tons per year. This provided a straightforward return on investment through cost savings.

The success of the system in providing process water to both can and bottle lines was further verified when they purchased their second GasTran Vacuum Deaeration System in early 2008. GasTran Systems installed this 1041 lpm system to provide deaerated water to the remaining two CSD lines in April 2008.

9) CONCLUSION

Based on the success of more than 8 installations of GasTran Vacuum Deaeration Systems in CSD bottling plants, we have observed a strong case for reducing dissolved oxygen levels in the process water to levels below 500 ppb without the use of a CO_2 stripping gas.

As a foundation for establishing exceptional bottling line performance, the GasTran Systems approach is superior to other alternatives in these terms:

1) Reliability in consistently achieving dissolved oxygen levels below 500 ppb
2) Lower operating costs with no consumable membranes or stripping gas
3) Ability to meet stricter quality standards for carbonation and net contents
4) Better cleanability

PepsiAmericas' Austin, IN plant experienced these and other benefits within days of starting up its first system, and purchased a second system 18 months later to validate the strong return on investment of the first one.

GasTran Technology provides an example of applying process intensification principles to bring value and tangible benefits to end users without having to radically alter established processes. This success is a product of our focus on applied research and development and our ability to learn in the field, with the customer at our side.

Looking forward, GasTran Systems is in the process of completing a significant body of work on performance enhancements and product features, allowing us to continue to bring innovative solutions in vacuum deaeration based on process intensification principles to both beverage and non-beverage markets.

REFERENCES

(1) M. Keyvani & N.C. Gardner, "Operating Characteristics of Rotating Beds," *Chemical Engineer Progress 85:48 (*1989).

(2) Guo K.; Guo F.; Feng Y.; Chen J.; Zheng C.1; Gardner N.C., "Synchronous visual and RTD study on liquid flow in rotating packed-bed contactor," *Chemical Engineering Science* May (2000)

(3) Chong Zheng, Kai Guo, Yuanding Feng, Cun Yang and N.C. Gardner, "Pressure drop of centripetal gas flow through rotating bed," *I & EC Research* 39(3) pp829-843 (2000).