

BLOWER & VACUUM BEST PRACTICES[®]

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April 2015

Blower and Vacuum System Optimization

**14 CAGI Low-Pressure Blower
Standards BL 5389 and BL 300**

**18 Atlas Copco Enters the Rough
Vacuum Market**

**22 Selecting the Most Effective
Blowers for Wastewater**

**26 Process Air Solutions Helps
Cannery Save Energy**

10 11 FAQs ON INDUSTRIAL VACUUM



Go with the Flow!

Using vacuum blowers for better hold down in CNC router table applications

PROBLEM:

For many years, the compressed air system for an industry leader in furniture manufacturing relied on vacuum instead of flow to provide hold down for their CNC router tables.

Despite having multiple rotary screw vacuum units providing up to 27" Hg vacuum, there was still significant scrap materials and downtime since the sheets would move after portions were cut away. The 40 hp vacuum screw units were upgraded to 100 hp units and special roller bars were added to keep the sheets in place, but the problems continued.

Additionally, the leather fibers and dust that go hand-in-hand with this type of installation were harsh on the vacuum screw units. Filters collapsed and airends had to be replaced due to contamination.



SOLUTION:

Kaeser provided a unique solution – it's not the vacuum that provides the hold down, it's the flow that keeps the sheets of wood in place. Kaeser recommended an Omega DB 236 with optional external STC controls and additional DB 236C units with integrated controls to replace the multiple vacuum screw units.



RESULT:

In addition to providing outstanding hold down, the blower packages have a significantly smaller footprint – almost a quarter of the size of the 100 hp screw compressors. These blower packages require less routine maintenance and are less sensitive to the ambient conditions. They also use less oil and require few consumables, making them a greener solution. Finally, the energy savings have been significant – only 120 hp is needed to provide exceptional hold down instead of the 320 hp previously used for the vacuum screw units. To save on space, energy, and maintenance costs, sometimes you just have to go with the flow!



Operating Energy Costs for Previous System:	\$119,000 per year
Operating Energy Costs for New System:	\$45,000 per year
Floor Space Required for Previous System:	175 sq. ft.
Floor Space Required for New System:	70 sq. ft.
Additional Savings in Maintenance Costs:	\$25,000 per year

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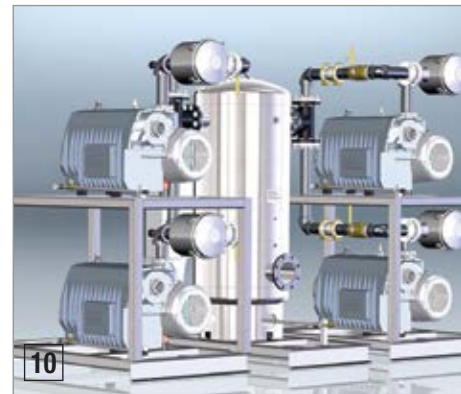
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FROM THE EDITOR

Blower & Vacuum System Optimization



I'd like to welcome many new readers from the blower and vacuum industry. Our editorial mission is to increase the awareness of high-ROI energy-efficiency projects. This mission is made possible thanks to Energy Managers and blower and vacuum system experts sharing their knowledge.

The term "Black Magic" comes up quite often when one talks of vacuum systems. Understanding Torr, Hgv, Hga, and mmHg calculations is not easy! Mike Ziegelski, from Busch Vacuum Pumps and Systems, shares an article, "11 FAQs on Industrial Vacuum" walking the reader through these and other vacuum system basics.

Please join me in welcoming our new Editorial Associate, Clinton Shaffer, who spoke to Atlas Copco's Jerry Geenen about their significant introduction of variable speed drive rotary screw vacuum pump systems to the rough vacuum market. Expert auditor Tim Dugan provides an insightful review of a vacuum system consolidation audit. The plant had three identical 200 hp 400 acfm liquid-ring vacuum pump systems running at 23" Hg and one 75 hp duplex system providing 2300 acfm at 20" Hg. Total system demand was 10,000 icfm at 21" Hg.

Turning to low pressure, the Compressed Air & Gas Institute (CAGI), is assisting the blower industry by introducing CAGI Standards BL 5389 and BL 300. "As customers' requirements evolved, manufacturers have extended their product offerings to include a complete blower package," according to Kenny Reekie, Product Manager, Low Pressure & Vacuum Products for Gardner Denver and Chairman of the CAGI Blower Section. "Test standards that take into consideration all of the additional components in the package now exist to provide a uniform means of measuring overall package performance."

As the wastewater industry invests in optimizing aeration systems, application engineers are designing blower systems able to use the least possible energy under all the varying working conditions they experience. Tom McCurdy, from Aerzen USA, shares a valuable article along these lines titled, "Selecting the Most Effective Blowers for Wastewater Applications."

Process Air Solutions shared an interesting can-drying application where they replaced an existing blower and air knife set-up with their custom-sized blower and multi-angle air knife and nozzle air delivery system. This eliminated product quality and worker safety issues, while significantly reducing energy consumption.

Thank you for investing your time and efforts into Blower & Vacuum Best Practices. Please look for our second *Supplement* coming in September 2015!

ROD SMITH

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BLOWER & VACUUM SYSTEM INDUSTRY NEWS

David Schardt Joins Tuthill Vacuum & Blower Systems

David Schardt has joined the Tuthill Vacuum & Blower Systems as Vice President of Engineering. Schardt will have responsibility for new product development and sustaining engineering and compliance. Schardt will lead the Lean Product Development process for the creation, testing, and introduction of new products and product enhancements. He will also lead the ongoing product engineering initiative to improve existing products to better serve customers.

Schardt comes to Tuthill from Manitowoc Company where he most recently held the position of Director of Engineering. He also held key engineering roles working with rotating equipment, including compressors, blowers and pumps, with Hayward Pool Products, Inter-City Products, and Carrier Corporation accumulating over 30 years of valuable experience.

Schardt has a Bachelor of Technology in Mechanical Engineering from State University of NY, College of Technology and a Master of Science in Industrial Engineering from University of Tennessee. He also holds six patents and is a member of ASHRAE and PDMA. Schardt and his family have relocated to Springfield from Brentwood, Tennessee.



David Schardt, Vice President of Engineering, Tuthill Vacuum & Blower Systems

Tuthill Vacuum & Blower Systems, manufacturer of KINNEY® vacuum pumps and M-D Pneumatics™ blowers and vacuum boosters, is a leader in the design and manufacture of high performance, reliable positive displacement blowers, mechanical vacuum pumps, vacuum boosters and engineered systems ready to install and run. Since 1969, Tuthill Vacuum & Blower Systems has been manufacturing at its main facility located in Springfield, Missouri.

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BLOWER & VACUUM SYSTEM INDUSTRY NEWS

Atlas Copco Adds VSD+ Technology to Vacuum Solutions Portfolio

Atlas Copco has extended its vacuum solutions product line for rough and medium vacuum applications to include a new range of highly-efficient vacuum pumps with variable speed drive (VSD) technology. The new range reduces energy usage by up to 50 percent with significantly better performance benchmarked against traditional oil-sealed and dry vane vacuum pumps. The GHS VSD+ features low noise levels and reduced environmental impact due to ultra-high oil retention at all operating pressures.



The new Atlas Copco GHS VSD+ rotary screw vacuum pump with variable speed drive technology.

“The new GHS VSD+ series’ performance is the latest in pioneering technology advancements in the vacuum industry,” said Jerry Geenen, regional business line manager, vacuum solutions North America, Atlas Copco Compressors. “Our vacuum engineers designed the new series based on well-known and durable plug-and-play design principals of our compressors to deliver peak performance

at operating vacuum levels commonly found in industrial vacuum applications.”

The GHS VSD+ range complements Atlas Copco’s full vacuum solutions line, which includes single stage oil-sealed rotary vane vacuum pumps and systems, fixed speed oil-injected rotary screw vacuum systems and new ranges of two-stage oil-sealed rotary vane vacuum pumps, vacuum booster pumps, piston pumps, liquid ring pumps and steam ejectors.

- The **GVS 20-300** series operates according to the proven oil-sealed rotary vane principal that has been successfully used for many years in all general vacuum applications of industry. The GVS 20-300 series ensures the highest possible performance at the lowest possible lifecycle cost. A built-in gas ballast valve is a standard fitting to assist in water handling capability.
- The **GHS 630-4800** series combines a technologically advanced fixed speed screw design with robust oil-sealed rotary technology. All GHS 630-4800 vacuum packages are fitted with a vacuum control valve at the pump inlet; the control valve matches delivered capacity to actual demand, provides minimal fluctuations in vacuum level and reduces wear and maintenance as a result of fewer stop/starts.
- The **GVD 0.7-28** series of small, two-stage oil-sealed rotary vane pumps deliver ultimate vacuum pressure, high pumping efficiency and superior vapor-handling capabilities with quiet operation. These pumps offer reliable performance that set the industry standard for research and development and scientific pumping applications. All pumps and motors in this series are also approved to UL and CSA standards; the patented mode selector switch makes the GVD 0.7-28 suitable for both high vacuum or high throughput applications.
- The **GVD 40-275** series of two-stage oil sealed rotary vane vacuum pumps offer high ultimate vacuum, rapid pumping speeds, quiet operation and the ability to handle water vapor. These direct drive rotary vane pumps are compact and vibration-free; finger-proof fans and coupling housings offer excellent operator protection. A comprehensive range of accessories enables use of the GVD 40-275 in a wide variety of vacuum applications.
- The **ZRS 250-4200** mechanical booster pump is based on a simple rotary lobe principle and is ideal for applications requiring high pumping speeds for pressures from 0.01 to 50 mbar. The booster pump must always be backed by another pump to deliver against a high-pressure differential to atmospheric pressure; because it operates



“The new GHS VSD+ series’ performance is the latest in pioneering technology advancements in the vacuum industry.”

— Jerry Geenen, Atlas Copco

at relatively low pressure and is not exposed to a high amount of corrosive process media, the booster pump is also highly reliable.

- With over 10,000 units sold, the Atlas Copco **GLS 250-500** series of rotary piston pumps sets the standard for performance and reliability as the vacuum industry's most efficient and space-saving design. The GLS series has been upgraded to deliver even better reliability and productivity with minimal maintenance and process downtime — crucial for demanding applications that serve the automotive or aerospace industry.

- Atlas Copco **liquid ring vacuum pumps** are offered as standard packages in a number of configurations, suitable for operation in once through, partial or total recirculation. The AW liquid ring vacuum pumps are available for both single (AWS) and two-stage pumps (AWD) with capacities from 200-37500 m³/h and vacuum levels down to 30 mbar (a).

Atlas Copco's comprehensive vacuum solutions support a range of industries and applications from mining, cement, paper, refineries and food manufacturing, to aerospace, automotive, refrigeration, glass, bottling, canning and woodworking.

Visit www.atlascopco.com

United Blower Focuses on Industrial Applications

Based in Ball Ground, Georgia, United Blower is a leading supplier of positive displacement (PD) and turbo blower systems to the wastewater industry in North America. Their signature system is the heavy-duty "Quiet Pulse" three-lobe PD blower with pulsation control channels. Helical timing gears, oil-splash bearings, automatic v-belt tension, three-side enclosure access, and direct motor and blower air ducting permit a standard 24-month warranty. The company also offers a standard-duty two-lobe PD blower.

Developed and manufactured in the U.S., United Blower also supplies 50 to 400 horsepower turbo blowers offering up to 20% savings on blower power consumption.



United Blower, Inc.

The Gold Standard in Blower Solutions

I've been in the blower business over 45 years and I can confidently say that UBI provides one of the best experiences in the industry. We believe in the quality of our products, we take the time to care for our clients, and we will always be American made.

—Vic Miolee
VP and Co-Founder

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systems in
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25 years of wastewater industry
excellence



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Developing Industrial Distribution, Contact Vic Miolee, tel: 770-479-3000, email: sales@unitedblower.com, www.unitedblowerinc.com

BLOWER & VACUUM SYSTEM INDUSTRY NEWS



Ashley Delrosso, Nikki Purser, Vic Miolee, Samantha Cameron, Wieker Milee and Al Nevins in front of a 75 hp enclosed turbo blower package from United Blower (left to right).

“Big is better when it comes to energy efficiency in many applications,” says Founder and Vice President Vic Miolee. “This Made in the U.S.A. turbo blower is high-speed direct-driven, uses airfoil bearings, a permanent magnet motor perfectly matched to a VFD, and can supply air flows up to 10,000 scfm and discharge pressures to 18 psig.”

The Company was founded 25 years ago by Mr. Miolee and has established itself in the municipal and industrial wastewater market. The Company is now looking to diversify and is developing a network of industrial distributors who can apply their technology



The United Blower “Quiet-Pulse” three-lobe, heavy-duty PD blower on display at WEFTEC.

and custom engineering capabilities to industrial bulk handling, pneumatic conveying, and processing applications. “Over my career, I have been directly involved in innovative application engineering for many industrial applications, including many thousands of horsepower of installed blowers in Southeastern U.S. carpet mills and textile plants,” said Miolee. “Our application engineering team and I personally are looking forward to working with industrial distributors again on their applications.”

Visit www.unitedblowerinc.com

FIPA Releases New Low-Leak Suction Plates for Sheet Metal Handling

FIPA announced the release of its new SPLT series suction plates. With these new, extremely reliable and highly flexible state-of-the-art plates, FIPA makes automated sheet metal handling a lot easier. “The launch of the SPLT series further expands our technology, product solutions and commitment for sheet metal handling”, says Rainer Mehrer, President of FIPA.

Previous sheet metal handling tools use an increasing number of laser-cutting systems and punching machines with grippers that have automated loading and unloading systems. After processing, however, any suction cup that attempts to grip at a point with a cut-out, will constantly be drawing in air. This air leakage causes the vacuum circuit to break, which causes the other suction cups in the circuit to drop the product. For this reason, vacuum suction cups on standard suction plates are often positioned to ensure that no suction cup is lowered onto a cut-out. However, this solution restricts the flexibility of the sheet metal handling, as each side of the product requires a suitable suction plate.

Visit www.fipa.com



The FIPA Low-Leak SPLT Series Suction Plates

Vacuum and Low Pressure Technology at IPPE 2015

The International Production & Processing Expo (IPPE) broke several records with 30,350 poultry, meat and feed industry leader attendees from all over the world. In addition, there were 1,284 exhibitors covering almost 500,000 net square feet. Held at the Georgia World Congress Center January 27-29, 2015 in Atlanta, the Expo is the world's largest annual poultry, meat and feed industry event of its kind and is one of the 50 largest trade shows in the United States. IPPE is sponsored by the U.S. Poultry & Egg Association, American Feed Industry Association and North American Meat Institute.



John Troyer in front of the Gardner Denver Elmo Rietschle S Series VSI Twister rotary screw vacuum pump.



Paul Mosher, John Troyer, Tim McDonald, Shawn Boynton, Jason Hobbs, Scott Goodwin and Dave Conley at the Gardner Denver Elmo Rietschle booth (left to right).

The vacuum and low pressure industry was represented at the show. Vacuum technology plays a prominent role in this industry in food processing, vacuum packaging, and general packaging applications.

Gardner Denver had a very large booth displaying an extensive array of Elmo Rietschle vacuum and air compressor technologies. Gardner Denver Elmo Rietschle is a market leader in all food processing segments including vacuum packaging supporting tray sealing, forming, and chamber machines as well as trim removal processes. “We offer the meat, poultry and feed packaging and processing market a broad range of vacuum and low pressure systems including radial, side channel, liquid ring, rotary vane, claw and screw technology,” said Paul Mosher from GD Elmo Rietschle. “Each application is unique and our broad product range allows us to find the best fit for each client.”

A highlight in the Gardner Denver Elmo Rietschle booth was the S Series VSI Twister rotary screw vacuum pump. These are oil-free, water-cooled pumps using a closed-loop, self-circulation cooling system. “Clients favor the VSI rotary screw due to lower maintenance costs versus rotary vanes,” said Gardner Denver’s John Troyer. “A huge production-output benefit for clients is the shorter evacuation times due



Michael Delahunt, Lantheaume Pierre and Jim Hupp, from Oerlikon Leybold Vacuum, in front of their RUVAC WAU 2001 FP dry vacuum booster (left to right).

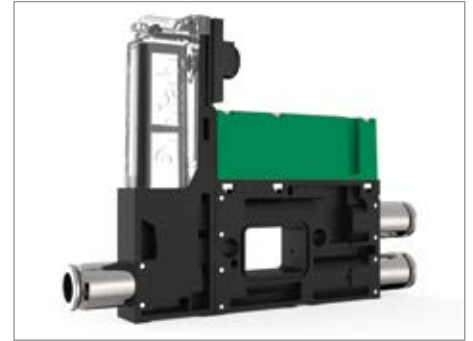
to the high suction capabilities of the unit.” (www.gd-elmorietschle.com)

Oerlikon Leybold Vacuum has their U.S. headquarters not far from ours in the outskirts of Pittsburgh, PA. They have long been a market leader in the global food packaging and processing industry. “Our typical applications include bulk, chamber, modified atmosphere (MAP), rollstock and rotary chamber packaging applications,” said Leybold’s Jim Hupp. “We are also strong with food processing machines such as massagers, marinaters, tumblers, blenders, vacuumizers and stuffers.”

Prominently displayed at the Oerlikon Leybold Vacuum booth was a RUVAC WAU FP roots booster pump. This dry pump range provides flows to 1449 cfm at $< 6 \times 10^{-3}$ when combined with their SOGEVAC® FP forevacuum pump. (www.oerlikon.com/leyboldvacuum)

PIAB Announces New piPUMP™ MICRO Ejector for Creating Vacuum

Piab, a leading supplier of industrial vacuum technology, offers its patented COAX® technology in a new small sized ejector called piPUMP™ MICRO. COAX® is the most energy efficient ejector technology based on a multi-stage concept for creating vacuum with compressed air.



The Piab piPUMP™ MICRO Ejector for Creating Vacuum

The piPUMP™ can be used for small centralized systems but perhaps even more suitable for semi-decentralized systems, i.e., a few units creating vacuum supporting a few small cups each. Thanks to very low weight and small dimension it can also be used as a fully decentralized ejector on a Delta robot for example. The small footprint of the unit provides flexibility in mounting and use. Installation is a breeze with push-in connections and a common feed for compressed air, regardless of the number of units chosen. The central exhaust allows the exhaust to be drawn away in clean room environments.

Because COAX® Cartridges are up to twice as fast as other cartridges and provide three times more flow than a conventional ejector with the same air consumption; the piPUMP™ MICRO is able to provide a high performance even at low or fluctuating feed pressures (14-87 psi). Additionally, piPUMP™ MICRO vacuum units begin producing vacuum immediately when the pressure valve is turned on, making maximum use of the compressed air and consuming significantly less energy than traditional vacuum pumps.

Visit www.piab.com

To read more [Industry News](#) articles, visit www.blowervacuumbestpractices.com

11 FAQs for Industrial Vacuum

By Mike Ziegelski, Director of After Sales, Busch Vacuum Pumps and Systems

► The application of vacuum generating equipment has many uses in industry today. Unfortunately, vacuum remains a bit of a mystery. The objective of this article is to provide answers to the most commonly asked questions for when vacuum is used to make, move or transform a product or item.

1. What is vacuum?

Vacuum is the term used to describe the region of pressure below atmospheric pressure or the surrounding area:

1 Atmosphere @ sea level = 14.7 PSIA =
0 PSIG = 29.92" Hg

When speaking of vacuum, remember that it is the opposite of pressure; high vacuum means low pressure.

2. How is vacuum measured?

There are a number of units of measure that can be used to describe the level of vacuum. Vacuum can be expressed in either gauge or atmospheric values. A simple rule of thumb is that gauge values start at zero while absolute values end at zero. In the U.S., the most common way that vacuum is referenced is in inches of mercury, gauge ("Hgv):

29.92: Hgv (gauge) = 0" Hga (absolute)
0" Hgv = 14.7 PSIA
0" Hga = 0 PSIA

For process applications that run at higher (or deeper) vacuum levels, vacuum is often expressed in an absolute scale as the pressure level needs to be read in finer increments. Torr or millimeters of mercury (mmHg) are the

most commonly used, both of which provide the same reading or indication:

1 Torr = 1 mmHg
760 Torr = 760 mmHg = 0" Hgv = 29.92"
Hga = 14.7 PSIA

3. What is the function of a vacuum pump?

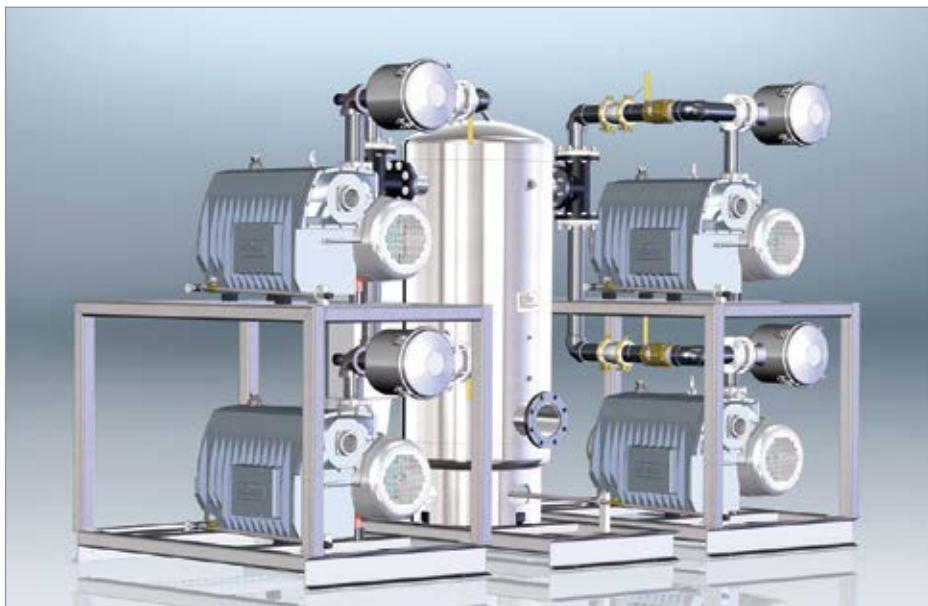
The main function of a vacuum pump is to:

1. Handle air leakage and/or non-condensables into the vacuum system in order to maintain a specific vacuum level.
2. To evacuate a volume or space from an initial pressure to a lower pressure.
3. A combination of the above.

4. How are vacuum pumps rated?

Depending on the pump manufacturer, vacuum pumps are usually rated in ACFM or SCFM. ACFM or Actual Cubic Feet per Minute measures the volume of air at a given pressure under actual vacuum conditions (i.e. expanded air). SCFM or Standard Cubic Feet per Minute measures the volume of air at a given pressure at atmospheric conditions (i.e. non-expanded air).

As a result of the measurement, ACFM values will always be greater than SCFM levels except at atmospheric pressure where they are the same (also called nominal capacity). In order then to accurately compare vacuum pump performance, advertised capacities should



A Custom-Built Busch Vacuum R5 Quadruplex Package

be converted into either ACFM or SCFM which is easily done by establishing the ratio of a volume at a specific vacuum level by using the following equation:

Ratio of a volume = P1/P2 where: P1 = 29.92" Hga

P2 = Vacuum level, "Hga

For example, suppose a pump has a rating of 5 SCFM @ 20" Hgv. How do we determine ACFM? First, convert the gauge reading to absolute:

$P2 = 29.92" \text{ Hgv} - 20" \text{ Hgv} = 9.92" \text{ Hga}$

Then divide P1 by P2: Ratio of a volume = $29.92/9.92 = 3$

To convert to ACFM multiply the SCFM rating @ P2 by the ratio of a volume: $\text{ACFM} = 5 \times 3 = 15$

To convert from ACFM to SCFM, divide the level of ACFM by the ratio of a volume. See the below for a chart of common ratio's.

"HGV	"HGA	RATIO
0	30	1.0
5	25	1.2
10	20	1.5
15	15	2.0
20	10	3.0
25	5	6.1
27	3	10.3
28	2	15.6
29	1	32.6
29.5	0	71.4

5. What level of vacuum do I need for my application?

Most industrial vacuum applications require vacuum levels in the 10 – 25" Hgv range. For some process and production applications the operating range is higher, usually between 26 – 28" Hgv (50 – 100 Torr).

Too often, specifying higher than necessary vacuum levels results in higher vacuum pump

capital and operating costs, not in higher performance/production/throughput. As a rule of thumb, the required vacuum level for a given process should be that level that is required to efficiently perform the "work" required (plus a safety factor).

For example, with an application that requires a vacuum level of 20" Hgv and has a constant leak rate of 5 SCFM at atmospheric pressure, the calculated inlet capacity at the vacuum pump to maintain the vacuum level would be 15 ACFM (5 SCFM x Ratio of 3). If using a rotary vane style vacuum pump this would translate into a motor size of approximately 1.5 HP.

However, if a higher vacuum level is specified (let's assume 25" Hgv) with the same 5 SCFM leak rate, the size of the pump increases as the calculated inlet capacity at the vacuum pump doubles in volume to 30.5 ACFM (5 SCFM x Ratio of 6.1) to maintain the higher vacuum level. This now means that the same rotary vane style pump would require a 5.0 HP motor in order to meet the increased capacity requirement at the higher vacuum level. Higher costs will always be realized when higher than necessary vacuum levels are specified.

6. How do I know which style of pump to use?

In today's marketplace there are many different styles and types of vacuum pumps available. Mechanical or motive fluid powered, rotary or reciprocating, oil-less or lubricated; there are many choices to choose from.

The first step in selecting a vacuum pump suitable to the process is to ensure that the pump is designed to operate at the required vacuum level or vacuum range. For instance, pumps designed specifically for high vacuum service should never be applied or operated on applications in the rough vacuum range



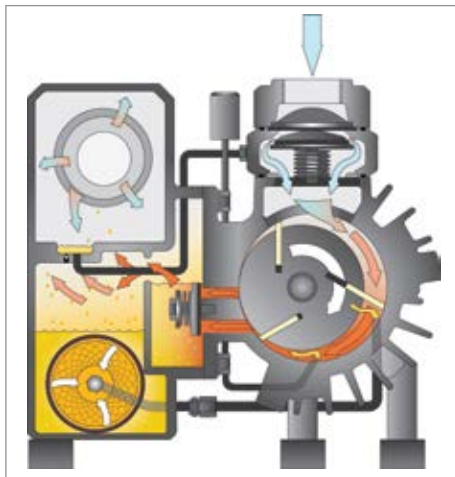
(as they are not designed to handle the larger volumes of airflow at lower vacuum levels).

The shape of the pump performance curve in relation to the required vacuum level is also a consideration. Never select a pump where the required vacuum level falls into or past the "knee" of the curve, as pump efficiency at that point is reduced. (Note that the shape of the curve and the position of the knee of the curve are dependent on the selected pump technology.)

Next consider the condition of the incoming airstream. In vacuum cooking for example, large amounts of water vapor are removed under vacuum so as to reduce the level of moisture in the product. This highly saturated air would quickly foul an oil lubricated style of pump as the vapor can condense prior to or within the pump itself. A water sealed liquid ring pump however, which also acts as a condenser, would not suffer any ill effects — its performance would actually be enhanced by the condensing vapor.

Finally, consider the total cost of ownership of a vacuum pump, not just its initial purchase price. Vacuum pumps have different levels of efficiency (ACFM/kW) depending on the pump design and technology. Too often, the cheapest pump to purchase turns out to be the most expensive pump to own, long term.

11 FAQs FOR INDUSTRIAL VACUUM



7. Do I use individual pumps or a central system?

For companies that have multiple machines that use vacuum pumps, the question is often raised, “should I stay with individual pumps or should I move to a central vacuum system?”

Either method has its advantages and disadvantages. Individual pumps, usually located on or near the machine, are less expensive to purchase when compared to a central system. Their location at the machine also eliminates the need for a plant wide vacuum piping system to connect all of the vacuum use points to the central system.

Individual pumps can require more maintenance than central systems (as there are more pumps to service). In addition, noise, heat, oil or smoke emitted by the pump(s) can make for an undesirable situation for workers on those machines.

Central systems, when properly applied, can provide for all current and future vacuum requirements. When supplied as a duplex system, the individual pumps can be sized to continuously provide 100% of the required plant capacity (with 100% backup) or to provide 100% of peak load capacity (where each pump covers say 60% of total load), and where the pumps run “on demand,” they provide for energy and operating cost savings. Central systems can also be supplied in an expandable configuration where additional pumps/controls can be easily integrated as future demand increases.

8. What about using receivers or tanks?

A common misconception with vacuum is that the addition of a receiver or tank will help to increase the performance of the machine/pump/system. This of course is not always 100% correct as it depends on a number of factors and sizing considerations.

For certain applications, like vacuum thermoforming, the receiver actually does the work by quickly evacuating the mold volume once the control valve is energized. The vacuum pump in these applications simply is used to evacuate the tank between forming cycles, not specifically to do the mold evacuation.

For many applications, simply adding a receiver will only add to the overall volume

of the vacuum system and can actually hinder performance. As there is no storage effect realized (which is the opposite of compressed air), the use of a receiver volume should generally be limited to those applications that require evacuation of a volume, or where the receiver is used as a part of a central vacuum system, acting as a ballast to help stabilize the vacuum level (as vacuum demand changes).

9. Why does pressure drop have such a significant impact on vacuum systems?

When it comes to designing vacuum systems, pressure drop can have significant impacts on vacuum system size, efficiency and costs — but why? Unlike water or compressed air systems, vacuum has a natural limitation on how much “work” a given vacuum pump can do (work as in the difference between the pressure level at the pump inlet vs. the pump exhaust) so system pressure drops as small as 1 mm (1 Torr) can have an impact on system design depending on the required operating pressure.

Consider that as it operates, a typical vacuum pump takes in air at the inlet below atmospheric pressure (vacuum), compresses it, and then discharges the air at the pump exhaust at, or slightly above, atmospheric pressure (14.7 PSIA at sea level). With the lowest possible vacuum attainable being 0 PSIA, the maximum pressure differential (or work) that the vacuum pump can provide is then 14.7 PSIA at sea level (or the atmospheric pressure wherever the pump is installed). Therefore, the vacuum pump compression limitation is 1 atmosphere.

In a typical compressed air system, the compressor has no such limitation. This means that pressure drop in a piping system can usually be overcome by simply



increasing the pressure at the supply point so as to increase the pressure level at the use point. Depending on the required vacuum level and the amount of pressure drop in the system, that same approach may not be possible with vacuum.

10. What is Pressure Drop?

Pressure drop (ΔP) is a loss of pressure due to frictional forces exerted on a fluid flowing in a pipe. These frictional forces include the pipe walls themselves and characteristics of the piping architecture (elbows, valves, expansions/contractions, etc.).

For a given flow, the smaller the diameter of the pipe and the greater the number of hindrances, the greater the pressure drop. So again, why is this so important to vacuum system sizing/design?

As an example, let's imagine a process that uses a vacuum dryer and which requires a capacity of 100 ACFM at 10 Torr (at the dryer) and that a vacuum system is selected that will exactly match this requirement. Now let's say that the only reasonable amount of floor space available for installing the vacuum system is located on the other side of the facility which will require the installation of a dedicated piping system. However, after installation of the vacuum and piping systems, it is determined that a 2 Torr pressure drop would exist and the best that the vacuum system could then provide at the dryer would be 12 Torr. By selecting a vacuum system based on the capacity requirement at the dryer and not accounting for the pressure drop in the connected system, this would have resulted in an undersized system that could mean longer drying times, reduced output and/or excessive residual moisture in the product.

In this case, a vacuum system with a capacity rating of 125 ACFM @ 8 torr (at the system) would have been required to ensure delivery of 10 Torr at the dryer. Here, the 2 Torr pressure drop results in a system that needs to be 25% larger than first thought, increasing both the initial capital cost for the equipment as well as its long term total cost of ownership.

11. How is Pressure Drop Reduced?

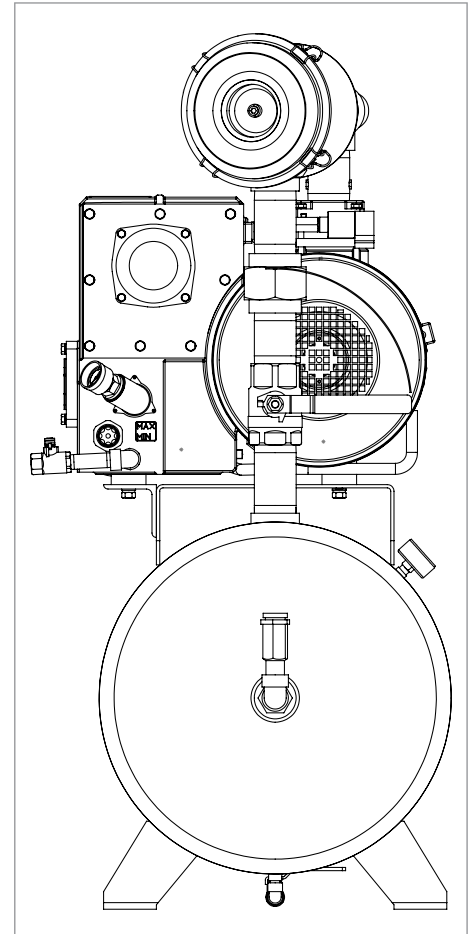
So now that we know the impact of even a small amount of pressure drop on vacuum system sizing, what can be done from a design perspective to eliminate it? The answer is relatively intuitive.

Let's start with an understanding that totally eliminating pressure drop or designing for zero pressure drop is not going to be practical or feasible for the vast majority of industrial vacuum system installations. For most of these installations, where the required vacuum level is 25 Torr or higher, designing with the following specification, is usually very feasible and economically viable.

$$\Delta P < 10\% P_b \text{ (absolute scale)}$$

Next, whenever feasible, locate the system as close to the process or point of use as possible to minimize both the length of pipe and number of fittings, elbows, valves, etc. In many installations, this is much easier said than done as floor space is often at a premium (especially in existing facilities), so a practical approach should apply.

For installations that are less than 50 linear feet away from the vacuum pump or system, using a pipe diameter that is the same size as the pump inlet is usually acceptable. Again, minimizing the use of fittings, elbows, etc., is recommended so as to not add to the overall linear length of the piping system.



As with most decisions, the pipe size selection will ultimately come down to two things; effectiveness and cost. The pipe must be sufficiently sized to meet the requirements at the point of use, otherwise product quality and batch times could be compromised. Undersized pipe could require purchasing a larger than necessary vacuum pump, as indicated in the earlier example. On the other hand, oversized pipe can mean added capital and installation costs. **BP**

For more information contact Busch Vacuum Pumps and Systems, tel: 1-800-USA-PUMP, email: info@buschusa.com, www.buschusa.com

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The New CAGI Low-Pressure Blower Standards BL 5389 AND BL 300

By Scott A. Williams, Contributing Editor

Industrial standards provide a common means of understanding and communicating performance. This article examines the rationale and applications of the Compressed Air & Gas Institute’s standards for determining the energy efficiency of low-pressure blower packages.

► The Compressed Air & Gas Institute (CAGI) has championed the development of two new annexes to the performance standards of compressors: ISO 1217 for positive displacement packages (rotary vane, rotary lobe, rotary screw, etc.), and BL 5389 for dynamic machines (centrifugal, turbo, etc.). Positive displacement and dynamic blowers employ different technologies to deliver air. As such, each machine type requires test methods specific to the technology.

CAGI standard BL 5389 provides a new simplified approach for centrifugal machines. This includes multi-stage machines and single-stage, high-speed turbo blowers. The new test code for testing turbo blower efficiency takes into account all energy inputs used to provide useful air output. It provides a “wire-to-air” energy measurement of a turbo package and reports the kW needed to deliver a given volume flow rate of air at a given pressure. CAGI started by utilizing existing test standards for centrifugal compressors and adapted them for use with blowers. In many cases, blowers are actually simpler to measure than compressors.

Importantly, the results obtained from test methods described in BL 5389 and ISO 1217 can be compared against each other directly using BL 300 (Simplified Acceptance Test of Electric Driven Low Pressure Air Blower Packages), a new CAGI standard designed to enable the collection and presentation of comprehensive and consistent performance data independent of blower technology. Applying this standard, prospective blower buyers and their technical advisors can make reliable comparisons.

- BL300 allows comparisons between dynamic blower technology and dynamic blower technology.
- It facilitates comparisons between positive displacement blower technology and positive displacement blower technology.
- Significantly, it also provides guidance for comparing dynamic blower technology with positive displacement blower technology.

The Push for Better Standards

Rob Haseley, Manager of Test Engineering and Qualification for Ingersoll Rand and Chairman of the Standards Committee for CAGI, emphasized that the development of the BL 300 standard was driven by the use of low-pressure compressed air in wastewater applications.

“There was a need for a standard because wastewater treatment facilities can get rebates from utility companies, but there was no test methodology to prove out the efficiency,” Haseley explained. “Now the BL 300 standard gives customers and manufacturers a way to demonstrate the efficiency of the product that we didn’t have before. That’s important because the customer is buying a black box. What they care about is the power it takes and the amount of airflow it puts out. That’s the main feature of the standard, the test methodology to measure power in and flow out, and the new standard was developed to test the whole package, wire-to-air. Long term, I expect it will become part of an ISO standard for low-pressure blowers.”

Blowing Bubbles

The need for blower test standards arose with the increased cost of power and the attention to operating costs in a key process of wastewater treatment. Aerobic microorganisms, known as “bugs” in the wastewater field, feed on the waste in a biological reactor or a treatment

basin. A constant oxygen supply is required to keep the bugs thriving and productive. Increasingly, wastewater plants are introducing the required oxygen through fine bubble aeration via diffusers submerged in the wastewater.

Fine bubble aeration systems use high volumes of low-pressure air, typically supplied by blowers. Since the bubbles are small, they have a high surface area to volume ratio, providing an opportunity for most of the oxygen in the air stream to be transferred to the water before the bubbles pop at the surface.

As electricity to power the blowers is often the largest cost in operating a wastewater process, manufacturers of blower packages began to provide their own assessments of energy efficiency. Head-to-head comparisons of energy efficiency between different technologies were difficult to make with confidence, however, because inconsistencies in test methods that can create disparities in performance data.

An Impetus for Change from the Consortium for Energy Efficiency (CEE)

In 2010, CAGI members were approached by the Consortium for Energy Efficiency (CEE) to address the need for test standards for dynamic blower packages among the CEE membership. “CEE is a consortium of energy efficiency program administrators from across the USA and Canada that work together to achieve lasting and verifiable energy efficiency,” said Jess Burgess, Senior Program Manager at CEE. “Energy efficiency programs in many regions have goals to help their wastewater facility customers to reduce their energy costs and improve performance, and blowers typically offer the largest savings opportunity in a wastewater facility.”

According to Burgess, CEE members were interested in the energy savings claims that surrounded turbo blowers when they were new to the market six or seven years ago. “Based on CEE member experience,” Burgess explained, “turbo blowers offer the potential to reduce blower energy consumption by 20 percent or more, resulting in potentially thousands of dollars of energy savings each year. CEE did a technical review and quickly understood that the technology had outstripped the test procedures used for blowers at that time. It was necessary for each manufacturer to do some interpretation of the existing test procedure, which introduced opportunities to test in ways that could favor one’s own products. This fostered distrust in the marketplace, as many customers and their representatives felt they could not trust equipment performance claims. CEE members thought that was a negative thing because the technology was promising and the energy savings from these technologies were real. The credibility of energy performance claims and product information is significant to energy efficiency program administrators, so CEE reached out to blower manufacturers and to CAGI to show our industry’s support for a new set of energy test procedures to place turbo blower products and all blowers on a level playing field.”

Burgess emphasized that blower projects for wastewater treatment may have a 6- to 18-month timeframe with a significant investment of time and personnel, and energy efficiency program incentives from utilities may run into tens of thousands of dollars. Having more credible and higher quality test data for turbo blowers will enable efficiency programs to support blower projects with greater confidence and investment, and will allow energy performance to be a more significant factor in customer purchase decision-making.



Gardner Denver IQ Blower Package



Atlas Copco ZS 160+ VSD Blower Package (cabinet side removed)

THE NEW CAGI LOW-PRESSURE BLOWER STANDARDS BL 5389 AND BL 300



Hoffman by Gardner Denver Revolution Turbo Blower Package

“Based on discussions with many organizations in the wastewater industry, we expect this standard is going to impact the way that many blowers are specified and purchased for wastewater treatment facilities,” Burgess said. “With credible energy information on front end, there is confidence that the installed system will realize true energy savings.”

Creating the new CAGI BL 5389 Blower Standard

A working group was formed within CAGI’s Blower Section, and members embarked on a standard development project that initially resulted in the release of the BL 5389 standard in 2013 as an interim step. BL 5389 was intended to eventually become an annex to ISO 5389, which provides an extremely detailed, complex procedure to test and rate turbo blowers. The CAGI standard provides a simplified, easily integrated, cost-effective, yet highly accurate wire-to-air approach to testing that is applicable to all dynamic blower packages in all industrial and municipal air applications.

BL 5389 specifies standardized test procedures and conditions using complete, as-supplied packages representing actual field running conditions. Test boundaries are defined for the air intake system, inlet pressure, relative humidity, inlet temperature, static discharge pressure, discharge temperature, pipe diameters and flow. Measurements of electrical input are made for the drive system (main drive motor, gearbox, variable frequency drive (VFD), electromagnetic compatibility (EMC) filter, harmonics filter, etc., as appropriate) and package auxiliary devices (enclosure ventilation fan, lubrication

system, bearing controller, main drive motor cooling system, etc., as appropriate). Since actual test conditions are rarely consistent, BL 5389 specifies required corrections to ensure that test results and guaranteed performance values are comparable, manufacturer to manufacturer and package to package.

The CAGI BL 300 Standard Creates a Level Playing Field for Testing

When blower performance is tested according to ISO 1217 or BL 5389, as appropriate, BL 300 enables the fair comparison of package performance on a level playing field. “BL 300 is a standard means of evaluating of blowers which provides users with complete package performance data that was just not available before,” according to Chris Johnson, Vice President of Thomas Associates, Inc. and Executive Director of CAGI. “It includes a reference to ISO 1217, the standard for testing positive displacement blowers, and to BL 5389, the standard for testing turbo blowers.”

Johnson notes that both turbo blowers and positive displacement blowers may be appropriate to a given wastewater treatment application. “BL 300 includes a section geared toward helping prospective buyers and their technical advisors compare the performance of positive displacement and turbo blowers and interpret test results.”

When blower packages are compared using BL 300, wastewater plant managers, engineers and technical advisors can use CAGI datasheets to access the following performance information:

- **Compressor Data:** This lists manufacturer-provided information such as rated operating pressure, rated capacity at rated operating pressure, drive motor nameplate rating, and compressor rated speed.
- **Performance Table:** A performance table shows delivered airflow for a range of discharge pressures.
- **Package Performance Chart:** This type of chart plots performance curves for specific power across a range of capacities.
- **Test Summary Report:** The test summary report provides a range of as-tested values, specified/guaranteed conditions, data corrected to specified conditions, and a comparison to guarantee.

A consulting engineer can use this information to evaluate whether positive displacement or dynamic blower technology makes better

economic sense given the plant's process design and the variability of demand for air. This can lead to more confident recommendations.

A wastewater engineer or plant manager can use this information to compare offers from multiple suppliers of blower packages to determine which technology and which proposal meets the project parameters while providing the lowest total cost in the long term.

To aid in the clear interpretation of results, each value listed in the CAGI datasheet includes a reference to the relevant section of the standard.

CAGI Datasheets on Blower Performance

John Conover, Business Development Manager, Blowers and Low Pressure Compressors with Atlas Copco, was a member of the CAGI sub-committee that developed the standards. "Blowers can use a lot of power so they should be efficient," Conover said. "Maybe one machine costs less to buy, but by using the CAGI datasheets buyers can determine which machine has the lower total cost because it is more efficient. Buyers can use that information to work with their utility in determining financial incentives or rebates related to equipment upgrades, which can reduce the cost of investing in greater efficiency."

Conover believes that there's more to CAGI datasheets than consistently measured performance data. "A datasheet adds credibility by showing that the manufacturer tested their equipment according to a CAGI standard. It's a way for a manufacturer to demonstrate that they are a company going to market in a reputable way. I think this fits the mission of all companies that are part of CAGI."

Positive displacement blowers and turbo blowers use different technologies that can make it difficult to compare the efficiency of machines head-to-head. The new CAGI BL 300 standard enables consulting engineers and prospective customers to evaluate machines that are tested consistently according to their underlying technology and then fairly compare the data that emerges. CAGI data sheets provide consistent, corrected information that enables comparison of blower packages on a level playing field.

There's no law that requires manufacturers to state blower package performance according to a standard, but CAGI expects market demands for efficiency will lead manufacturers to state low-pressure blower performance according to BL 300. Manufacturers have done this for many years using ISO 1217 with higher-pressure positive displacement equipment, such as rotary screw compressors, and using ISO 5389 for higher-pressure turbo compressor packages. What's more, CAGI standards can be used by all manufacturers, whether or not they are CAGI members.

"Purchasers and specifiers can help us, responsible manufacturers, and themselves by making informed decisions and using only equipment that is tested to this standard," said Johnson. "Better yet, ask for CAGI datasheets."

"As customers' requirements evolved, manufacturers have extended their product offerings to include a complete blower package," according to Kenny Reekie, Product Manager, Low Pressure & Vacuum Products for Gardner Denver and Chairman of the CAGI Blower Section. "Test standards that take into consideration all of the additional components in the package now exist to provide a uniform means of measuring overall package performance. These standards are not intended to serve as an application primer that says what you should buy. Instead, they're about fair, consistent, unbiased information that can be used to make well informed business decisions." ^{BP}

For more information on the Compressed Air & Gas Institute, please visit www.cagi.org

CAGI standard BL 300 is intended as a guide to aid the manufacturer, the consumer and the general public. The existence of a standard does not in any respect preclude anyone, whether they have approved the standard or not, from manufacturing, marketing, purchasing or using products, processes or procedures not conforming to the standard. CAGI standards are subject to periodic review and users are cautioned to obtain the latest editions.

To read similar articles about **ISO and CAGI Standards**, please visit www.blowervacuumbestpractices.com/standards/iso-cagi.



Atlas Copco ZS 37+ VSD Blower Package (ghost view)

ATLAS COPCO ENTERS THE ROUGH VACUUM MARKET

By Clinton Shaffer, Editorial Associate, Blower & Vacuum Best Practices

► Bringing a New Technology to an Established Market Segment

Atlas Copco recently released a new series of oil-sealed rotary screw vacuum pumps specifically designed for the rough vacuum utility market. Their new vacuum pumps, called the GHS VSD+ Series, boasts a unique technology that is relatively uncommon in the rough vacuum utility market, namely variable speed drive (VSD) controls. According to Jerry Geenen, Atlas Copco's VP and Business Line Manager of the company's Utility Vacuum Division in North America, there are not many, if any, companies that utilize VSD technology in their vacuum pump products.

"Hardly any OEMs install VSDs on vacuum pumps right now," Geenen said in a recent conversation with the team at *Blower & Vacuum Best Practices*. "Our vacuum pumps consume around 50 percent less energy than alternative technologies. They are the most energy-efficient oil-lubricated vacuum pumps on the market."



Figure 1: Atlas Copco is bringing variable speed drive technology to the rough vacuum utility market with its GHS VSD+ Series of oil-sealed rotary screw vacuum pumps.



Jerry Geenen, VP and Business Line Manager North America, Utility Vacuum

vacuum pumps are traditionally fixed-speed machines, the air compressor giant wants to bring the energy savings that VSD technology can yield to benefit companies that use vacuum pumps.

What is the Rough Vacuum Utility Market?

The term "rough" is one of a series of descriptors used when defining the various levels of vacuum that are required by certain applications. The other classifications include medium, high and ultra-high, and each describes a particular market segment across the vacuum industry. According to "Industrial Vacuum 101," a series of books that delves into the basic principles of vacuum science, the rough vacuum segment consists of systems that "operate within the pressure range of 760 torr to 1 torr," or from 0.00" HgV (Inches of Mercury Volume) to 29.88" HgV (Bott 16).

For a quick reference, here are the basic parameters of each vacuum market segment, as outlined in "Industrial Vacuum 101":

- **Rough Vacuum:**
760 torr to 1 torr
- **Medium Vacuum:**
1.00 torr to 0.001 torr
- **High Vacuum:**
0.001 torr to 1×10^{-6} torr
- **Ultra-High Vacuum:**
Below 10^{-6} torr

To put these measurements into perspective, keep in mind that 1 torr is equivalent to 29.88" HgV.

The benefits of using VSD-controlled vacuum pumps for rough vacuum utility applications will be discussed later in the article. For now, it is beneficial to know that industries like woodworking, food processing, material handling, plastic thermoforming, and industrial applications all operate within the rough vacuum range.

Attacking the Status Quo

Atlas Copco sees an opportunity to improve upon the processes within the rough vacuum market segment. As mentioned previously, there are not many OEMs that utilize VSD technology for controlling vacuum pumps, and Atlas Copco believes that the GHS VSD+ Series of oil-sealed rotary screw vacuum pumps can help manufacturers reap significant energy savings.

In our conversation with Geenen, we discussed several examples of specific applications that can potentially benefit from the new technology, examining the status quo of these applications and reviewing how VSD controls can help each application achieve energy savings.



Figure 2: The GHS 730 VSD+ is part of Atlas Copco's new series of oil-sealed rotary screw vacuum pumps.

Woodworking

One application area that could benefit dramatically from VSD-controlled vacuum pumps resides in the woodworking industry, specifically in facilities that use computer numerical control (CNC) routing machines. According to Geenen, that industry has undergone some significant changes.

“CNC routing has changed a lot over the last 10 years,” Geenen told us. “Even five-person facilities now have a CNC router using vacuum hold-down.”

These manufacturing plants can range from small five-person shops to operations with over 500 personnel. Larger operations could have as many as 30 router tables running at a given time. Generally, this application requires approximately 20 to 25" HgV at the point of use.

Geenen walked us through a theoretical example. A typical vacuum pump system for a medium-sized woodworking facility might include three 10-hp dry vane pumps, which are generally stacked on a frame with inlet filters and controls for each pump. These machines are simple on/off machines that operate at a fixed-speed, and they run constantly throughout the shift. Depending on the size of the facility and its production rate, these machines could run 8 hours a day, or they could run on a 24/7 basis.

Since fixed-speed machines are sized to handle the peak demand, these vacuum pumps run at 100 percent load, even when demand may only require 60 to 75 percent. Operating all-out, regardless of the demand, can waste significant amounts of energy (Refer to Figure 3). That's where Atlas Copco believes a VSD-controlled machine can make the most impact.

In this scenario, Geenen recommends implementing one of Atlas Copco's new GHS 900 VSD+ vacuum pumps, which would eliminate the three-machine setup and all of the maintenance that goes along with it. With its soft start option, the VSD+ consumes less energy at startup. The VSD-driven machine maintains an optimum vacuum

level and adjusts to the facility's demand. If no machinery is being used, which might be the case during a lunch break, the machine scales down to 10 percent. The vacuum pump can then ramp up to 100 percent during peak demand times. It even boasts a sleep mode, which enables the machine to stop automatically if demand drops to zero for a set amount of time.

The GHS VSD+ package has been designed to operate efficiently and continually over the entire range (10 to 100 percent), allowing it to optimally meet peak demand and other operating points throughout a facility's varying demands and operating shifts. Its ability to vary its performance compared with fixed-speed

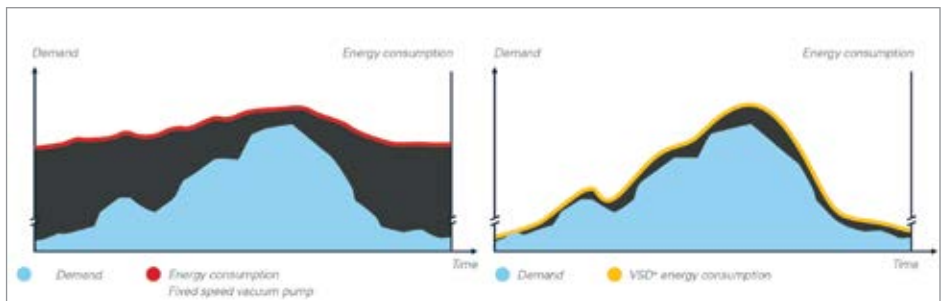


Figure 3: Vacuum pumps with variable speed drive adjust to match energy consumption with demand.

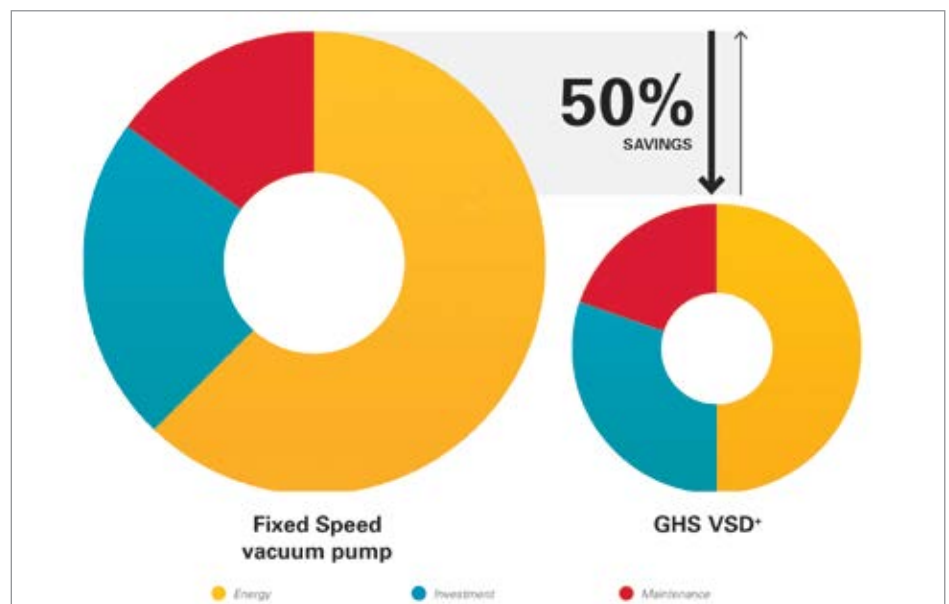


Figure 4: Variable speed drive vacuum pumps increase energy savings by up to 50 percent compared with fixed-speed vacuum pumps.

ATLAS COPCO ENTERS THE ROUGH VACUUM MARKET

vacuum pumps allows Atlas Copco to create a tangible return on investment (Refer to Figure 4), yielding significant energy savings after the VSD installation.

Food Packaging

Another market within the rough vacuum utility range is the food packing industry. In an application like meat or poultry packaging, the air within the package needs to be evacuated by a vacuum during the sealing process. This generally calls for an operating vacuum level of 27 to 29.8" HgV, depending on the application.

According to Geenen, the typical setup for an application like this would include a 25-hp lubricated vane vacuum pump, which could be supplemented by a vacuum booster (for the higher vacuum level applications operating closer to 29.8" HgV). In some cases, you will find these vacuum pumps in clean room production areas. In others, you will find them in a centralized location, such as a compressor room.

The opportunity for improvement again lies in the variations of demand that occur during production, since there are generally multiple packaging lines that intermittently shut off and go online. In this situation, Geenen recommends replacing the existing system with a GHS 730 VSD+, which is a 15-hp vacuum pump that generates more cfm than comparable lubricated vane technology at its desired vacuum level. While it might seem contradictory to see a machine with less hp produce more cfm, Geenen explained that it is possible due to the efficient design of the Atlas Copco rotary screw and the integrated VSD drive. These enable the use of a smaller motor in the vacuum pump.

In addition to installing a smaller hp vacuum pump with an improved cfm-to-hp ratio, Atlas Copco offers a ZRS vacuum booster to improve

productivity at higher vacuum levels, such as 29.8" HgV. The ZRS vacuum booster features a unique hydrokentic drive system that allows the booster to engage earlier than any other vacuum booster on the market. This helps reduce pump downtimes significantly when compared to traditional cut in/cut out vacuum boosters.

Key Advantages of Using a VSD-Controlled Vacuum System

The recurring theme of these rough vacuum utility applications is the variation in demand, and traditional vacuum systems use fixed-speed rotary screw vacuum pumps to supply the required pressure. With that in mind, Atlas Copco believes that there are number of benefits to implementing a VSD-controlled vacuum pump for these applications.

1. **Response to Varying Demand:** As a market leader in VSD technology, Atlas Copco can leverage its existing VSD expertise in the rough vacuum utility market. The variations in demand that are common in rough
2. **Maintaining Optimum Pressure:** The VSD-controlled vacuum pumps from Atlas Copco help facility managers achieve an accurate control of their pressure supply. While pressure from fixed-speed machines may continuously fluctuate during operation, the VSD controls provide a more stable pressure band (Refer to Figure 6).
3. **More cfm, Less hp:** As mentioned previously, the implementation of an Atlas Copco VSD-driven vacuum pump can deliver more cfm at a lower hp, again reinforcing the fact that the machine can deliver a tangible ROI through energy savings.
4. **Consolidation:** Maintenance professionals may have nightmares about the countless machines that operate within their facility. Replacing three machines with one

vacuum applications make VSD controls a logical choice, especially for those looking to enhance the energy efficiency of their facility (Refer to Figure 5).

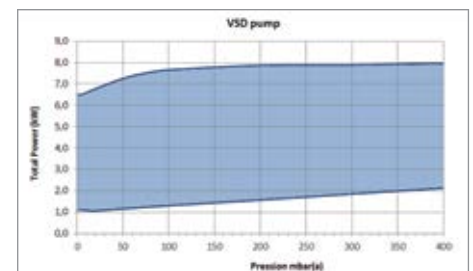
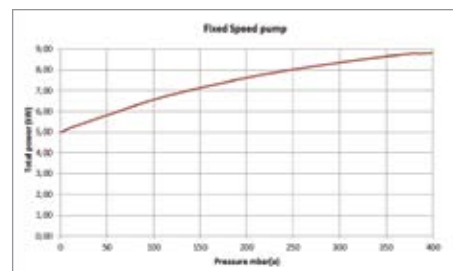


Figure 5: When the demand decreases, the VSD slows down the vacuum pump, consuming less energy.

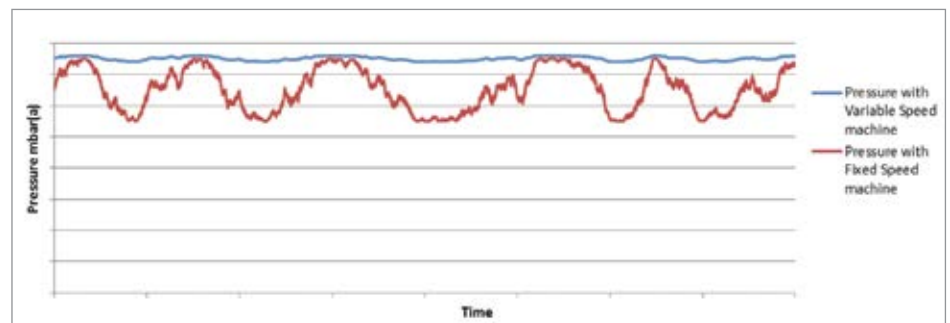


Figure 6: Holding the pressure constant with VSD technology reduces energy utilized by fixed-speed vacuum pumps operating within a pressure band.

easy-to-maintain vacuum pump can help reduce maintenance costs and help facility managers sleep a little easier.

5. **Centralization:** While some installations have already adopted the centralization strategy for vacuum pumps, there are still plenty of opportunities to replace multiple machines and centralize vacuum pumps in one location, which could help optimize system performance.

Dispelling the “Black Magic” of the Rough Vacuum Utility Market

As Atlas Copco enters the rough vacuum utility market, they are bringing more than just their established market leadership in VSD technology. During our conversation

with Geenen, he explained that the industry jargon of the vacuum market can be overwhelmingly complex. He added that the vacuum industry maintains that mystifying complexity as a sort of “black magic” that only they can understand. One of Atlas Copco’s major initiatives as they enter the market is to relate vacuum industry jargon with compressed air terminology, effectively dispelling the black magic and making the technical details more accessible.

In addition to that new philosophy, Geenen mentioned that Atlas Copco has some existing synergies that will help the company enter the rough vacuum utility market. The combination of its sales force, distributor network, and its recent acquisition of Edwards, an established developer and manufacturer of vacuum

products, will work together in Atlas Copco’s new venture.

Overall, the message from Geenen was very clear: “Atlas Copco has gone into the vacuum market. We are here to stay. We bought Edwards and want to get into the utility and rough vacuum space.” **BP**

For more information contact Jerry Geenen, VP and Business Line Manager for Utility Vacuum in North America, email: jerry.geenen@us.atlascopco.com, or visit www.atlascopco.com/vacuum.

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To read more about **Vacuum Technology**, please visit www.blowervacuumbestpractices.com/technology/vacuum



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How To Select The Most Effective Blower Technology FOR WASTEWATER APPLICATIONS

By Tom McCurdy, Aerzen USA

Given numerous variables when selecting an aeration blower system for wastewater applications, and equally numerous claims by technology providers, it is not surprising that confusion exists. Worse than confusion is the disappointment that results when a blower technology fails to perform as anticipated — and operating cost and efficiency benefits go unrealized.

This guide explains three blower technologies and, using examples from actual wastewater plants, describes the most effective technology for particular applications and why. Of course there is no substitute for a consultation specific to your application; however, the guide can help raise the right questions and ensure a productive vendor and technology evaluation process.

► Introduction

Energy consumption and cost have been the key drivers behind the development of more efficient aeration blower systems. These systems can account for as much as 60 percent of the total energy consumption of a wastewater treatment plant (WWTP). Therefore, the payback on greater energy efficiency is significant.

Technological advancements in aeration blowers are providing new options for reducing energy consumption. However, these options also require greater understanding of the overall system and fluctuations in operating conditions in order to optimize the total cost of ownership and maximize return on investment.

If the choice of an aeration blower was simply based on the energy efficiency or initial cost of

the technology — irrespective of the operating conditions — it would be easy to select the most effective aeration blower. However, once installed, the cost-benefit intended is not likely to be achieved if the technology is misapplied.

An accurate cost-benefit analysis must include the capital expenditure of the aeration blowers themselves, and the operating variables. Consider daily and seasonal swings in oxygen demand, fouling and aging of diffusers, air flow control and turndown capabilities, total blower efficiency and energy consumption over time, mode of operation, blower accessories, and plant set up when making your decision.

Operating variables can significantly affect cost and benefit. With energy efficiency the primary driver of aeration blower technology, the goal of this paper is to illustrate the most efficient and cost-effective way to achieve energy efficiency based on real-world applications and right-sizing blower technologies.

An Overview Of Current Blower Technologies

There are four main blower solutions for wastewater aeration applications: positive displacement blowers, turbo blowers, hybrid blowers, and combination blower technologies. The following sections provide brief introductions to these approaches and outline the benefits and limitations of each.

Positive Displacement (PD) Blow

These blowers are defined as rotary lobe blowers with straight or twisted lobe rotors without internal compression. Often, they are referred to as "the workhorse" for its

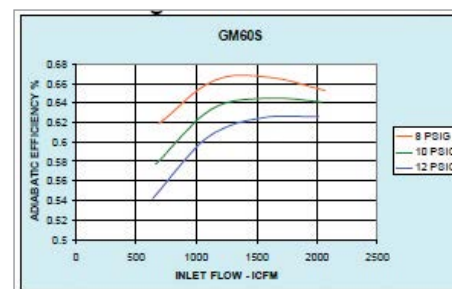
flexibility to perform well despite changing conditions, the PD blower has a lower initial cost than its turbo and hybrid counterparts. However, the PD blower's lower cost can be offset by higher energy consumption, depending upon the operating conditions. When it comes to turndown, PD far exceeds turbo blower technology by achieving ratios as high as 4:1.

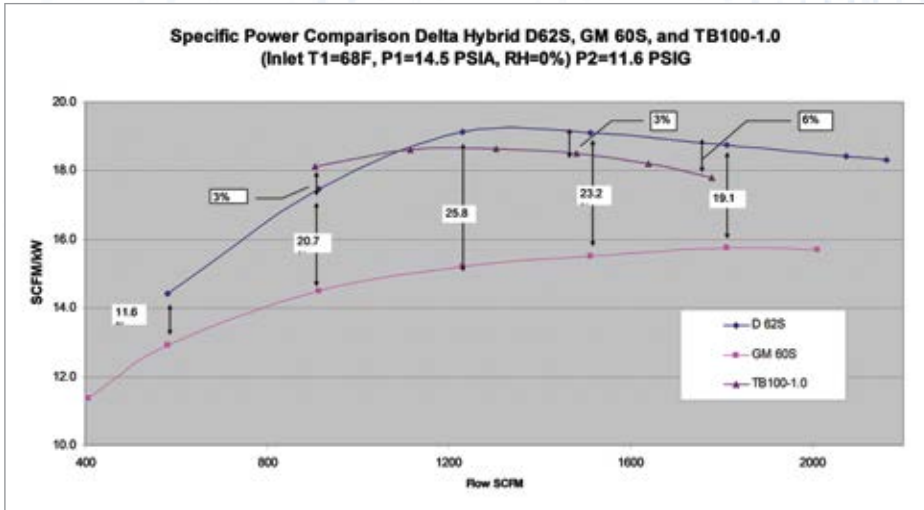
PD Basic Design Principles

- Constant volume against varying pressure
- Flow changes by varying speed with variable frequency drive (VFD)
- Large turndown (typically 4:1)
- Adapts naturally to changes in pressure and temperature
- Widely used
- Low initial cost

PD Limitations

- Slip between rotors increases with differential pressure
- Efficiency drops at lower speed
- Efficiency drops at higher pressure





Turbo Blowers

When operating near its design point, the turbo technology may be the most efficient and therefore performs cost-effectively in applications with narrow swings in turndown. Turbo has a higher initial cost than its rotary lobe and hybrid counterparts. However, in applications with less variation in operating conditions, the additional cost can be compensated for in lower energy consumption.

Turbo Blower Advantages

- Higher efficiency than conventional rotary lobe technology
- Small footprint reduces cost to design new and retrofit blower rooms
- Integrated package including blower, motor, and controllers makes installation easier

Turbo Blower Limitations

- Limited operational range relative to pressure and airflow (typically 2:1 turndown)
- Limited on/off cycling due to airfoil bearing limits, and limited wear on electronic components

Hybrid (Rotary Lobe Compressors) Blowers

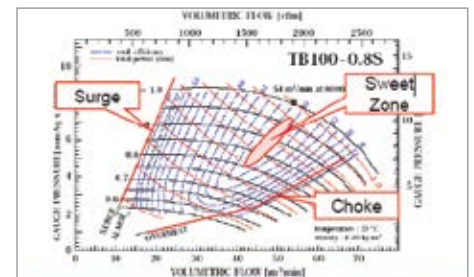
This technology provides energy efficiency comparable to turbo and the flexibility of PD technology. The hybrid uses a low-pressure screw rotor instead of a straight or twisted rotary lobe rotor. In applications with large swings in flow and pressure, hybrid blowers can achieve rates as low as 25 percent of the original design point.

Hybrid Design Principles

- Constant volume against varying pressure
- Large turndown (typically 4:1)
- Flow changes by varying speed (VFD)
- Rotors mesh, compressing air inside housing

Hybrid Advantages

- Comparable efficiency to turbo
- High efficiency throughout range
- Tolerant of variations in pressure



Hybrid Limitations

- Less efficient at very low pressure than rotary lobe blowers
- Higher capital cost (10% higher than PD)
- Larger footprint than turbo

Combination Blower Technologies

For large WWTPs, applying a combination of blower technologies at various points in the treatment process can improve overall energy efficiency and reduce initial and long-term operating costs. This solution can be especially effective in a retrofit application and in processes where the duty cycle on the blower can be as low as running only one hour per day.

Centrifugal Design Principles

- Dynamic compression
 - “Sweet zone” of highest efficiency
- Must operate on performance map
 - Flow too low or pressure too high = surge
 - Flow too high or pressure too low = choke
 - Performance varies with air density
- Summer (high loads, low air density)
- Winter (low loads, high density)

HOW TO SELECT THE MOST EFFECTIVE BLOWER TECHNOLOGY FOR WASTEWATER APPLICATIONS

- Turbo blowers are ideal for applications where they can run at the same speed all day — they are less efficient when used in applications with regular fluctuations. The best way to optimize a system is to combine a turbo (for base load) with a hybrid (for peak load and low flow conditions).
- It is critical that the turbo is able to tolerate the introduction of the hybrid without surging. The idling feature and the current-based inverter control easily facilitate this combination.
- It is also critical that the PD or hybrid be equipped with pulsation attenuation, to minimize the disturbances in the system while operating with the turbo.
- Overall energy efficiency can be higher with this approach, and the overall turndown range can be extended to 6:1 or more.

WWTP Application Examples

The following case studies illustrate results that can be achieved by implementing turbo, hybrid, and combination blower technologies in WWTPs.

Turbo Blower: Blue River WWTP

Overview: Built in 1974, the Blue River Wastewater Treatment Plant in Silverthorne, Colo., provides wastewater services to the communities of Silverthorne, Dillon, Dillon Valley, Buffalo Mountain, and Mesa Cortina. A conventional activated sludge plant with extended aeration capabilities and a design capacity of 4 million gallons per day (MGD), the Blue River WWTP serves resort communities with high variation in usage, both seasonally and between midweek and weekends during the peak season.

Average demand ranges from approximately 1.5 to 2 MGD. Given the variation in basin levels and the limitations on turndown in the multistage centrifugal blowers, the plant operators were frequently over-aerating, resulting in energy loss and lowered overall blower efficiencies. Engineers experimented with adding VFDs to the old blowers to reduce energy consumption, but it proved difficult to protect the centrifugal blowers from surge.



Aerzen TB100 turbo blowers at the Blue River Wastewater Treatment Plant (Silverthorne, Colo.)

Objective: Reduce rising energy costs and replace the aging multistage centrifugal blowers with new technology that would reduce energy consumption and provide steady and reliable operation.

Results: The Silverthorne-Dillon Joint Sewer Authority (JSA) selected the Aerzen TB100, a 100-horsepower turbo blower for its ability to meet the plant's maximum design aeration requirements of 1,400 cubic feet per minute (CFM) at a pressure of 7.5 psi. The TB 100 runs on a permanent magnet motor specifically designed for the high frequency and high speed requirements of a direct drive turbo application.

An immediately apparent benefit was the drastic reduction in noise, eliminating the need for hearing protection. The plant has averaged 20 percent greater energy efficiency than with its predecessor blowers, which translates to annual savings of approximately \$6,500. Another energy benefit is the heat recovery from the blower's cooling system. The warm air is used to heat the facility during the cold winter months, and

a separate cooling air connection vents the heat outdoors during the summer months. Since the blowers use airfoil bearings that are lubricated by air instead of oil, the plant has also reduced its maintenance costs.

Hybrid Blower: City Of Anacortes WWTP

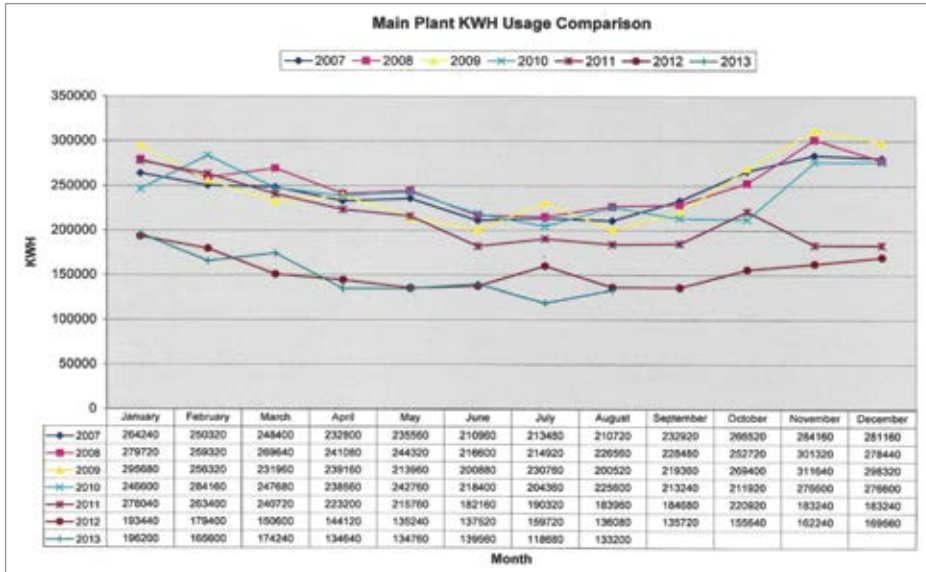
Overview: The City of Anacortes WWTP is located in the state of Washington off the coast of Puget Sound, which is home to a variety of wildlife and aquatic life. Its WWTP processes 2 MGD and was using three 150 hp multistage centrifugal blowers with a minimal air flow rate of ~1750 standard cubic feet per minute (SCFM) — far more than required to maintain adequate dissolved oxygen (DO) in the basin.

Objective: Improve efficiency of the aeration system and reduce operating costs and energy consumption/costs by investing in more efficient blower technology.

Results: After evaluating hybrid and turbo technologies, the plant selected the Aerzen Delta Hybrid model D 62S with a 75 hp motor for two reasons: 1) lower initial and operating costs and 2) broad range of operating conditions, specifically greater turndown capacity. The new Delta Hybrid operates between 1,450 SCFM at peak flow and 600 SCFM during the night, for a power savings of 30 to 55kW.hr, depending on the time of day.



The City of Anacortes replaced a 125HP multistage centrifugal blower (right) with an Aerzen D 62S 75HP hybrid blower (left)



The City of Anacortes experienced a significant decrease in energy use with the Aerzen Delta Hybrid blower.

The new blower also enabled the plant to turn off two channel air blowers, which alone saved ~\$11,700/year. All told, the new aeration system saved the city ~\$56,155/year in energy costs and demand fees, which their utility provider charges industrial customers based on consumption. Payback was achieved in 22 months. In addition, the plant was able to use existing maintenance staff to service the new aeration blowers, eliminating the potential costs associated with service and maintenance agreements.

The City of Anacortes experienced a significant decrease in energy use with the Aerzen Delta Hybrid blower.

**Combination Blower Technology:
Bremervörde Sewage Treatment Plant**

Overview: The Bremervörde sewage treatment plant in Germany has an overall design capacity of 30,000 Einwohnergleichwert (EGW, or population equivalents) — a measurement of the total pollution load divided by the individual pollution load of one person. Operating at approximately 29,000 EGW, the plant is nearing full capacity, processing up to 3,000 cubic meters of wastewater per day. However, weekend turndown can result in

load fluctuation from 1,200 to 1,500 cubic meters. During the week, the plant processes a nearly constant 1,500 cubic meters per day using two existing Aerzen Delta PD blowers. Approximately 75 percent of the plant's energy consumption goes toward generating process air, which represented a significant operating cost reduction opportunity.

Objective: Optimize energy use by implementing a fully automated blower system that would meet process air requirements within the operating range of 50 to 100 percent.

Results: The plant selected the Aerzen AT 100 turbo blower. The new turbo blower serves as a base load generator for process air, operating at a capacity range from 35



Figure 1 Aerzen AT turbo blower and two PD blowers processing air at a Bremervörde, Germany WWTP.

to 80 cubic meters per minute (1200 to 2800 SCFM). The two existing PD blowers are connected to the new system and automatically start when needed to handle peak loads or serve as redundant blowers. Adding the new turbo blower resulted in cost savings on the order of 20% to 25%.

Summary And Conclusion

WWTP plant managers have more opportunities to optimize energy efficiency and reduce operating costs thanks to a variety of aeration blower technologies and application concepts. A thorough understanding of the overall process, operating conditions, and interplay of aeration and process controls is key to a successful implementation.

Often, technologies are misapplied due the promise of high energy efficiency, failing to consider operational variables that will ultimately cause the machine to run outside its intended range. New concepts of applying established and more recent technological advances within the context of the entire WWTP system have proven effective in maximizing the benefit of each technology. The result is an improvement in the overall operating efficiency of the WWTP in terms of overall equipment effectiveness (OEE), energy efficiency, and reduced operating and maintenance costs.

Learn how your plant can optimize energy efficiency and operating effectiveness with Aerzen's An Engineer's Mini Guide to Blower Technology Selection or contact your local Aerzen application specialist to discuss your application today (610) 380-0244. **BP**

For more information contact Tom McCurdy, Environmental Manager, Aerzen USA, tel: 610-656-1683, email: tmccurdy@aerzenusa.com, or visit www.aerzenusa.com.

To read more **Blower Technology** articles, please visit www.blowervacuumbestpractices.com/technology/blowers.



Process Air Solutions Blows Away Safety and Quality Issues at a Cannery

By Clinton Shaffer, Editorial Associate, Blower & Vacuum Best Practices

► Many manufacturing processes are like offensive linemen. When everything is running smoothly, nobody tends to notice. But, when an application starts creating a hazardous work environment (think too many blindsided sacks), or the products start spoiling (think shutout or a losing season), you best believe someone will start paying attention.

We recently spoke with Greg Cannon, National Sales Manager at Process Air Solutions, and he discussed just such a situation.

Cannon told us about a food processing company that was experiencing some critical quality and safety issues due to their blower system. In an effort to address those problems, Cannon and Bob Endress, Western Sales Representative at Process Air Solutions, retrofitted the system with new blowers, air nozzles and air knives. In addition to eliminating the original issues associated with the blower application, the team at Process Air Solutions helped the manufacturer save tens of thousands of dollars in annual energy costs.

Caution: Slippery (and Costly) When Wet

The blower system retrofit that Cannon discussed involved a canning facility. While this particular food processing company places a high priority on sustainability, they did not initially approach Process Air Solutions to improve their energy efficiency. Rather, there were some fundamental flaws with their blower system, and those flaws were

resulting in dangerous working conditions and an alarming number of product defects.

The cannery uses blowers on their production lines to dry cans as they come out of a cooling system. The cans are jettisoned onto the conveyor belt at a rate of roughly 600 cans per minute. That is a lot of cans to dry in a small timeframe. The conveyors then transport the cans to the palletizing area of the facility. Depending on the production line, a can's journey to palletization could be a quick trip or a long trek throughout the factory. This facility has 26 production lines, and each line had a dedicated blower for drying the wet cans.

The problems with the blower system were most noticeable in the palletization area. Because the blowers were not drying the cans effectively, water would drip from the cans and pool on the floor, causing slip hazards that required constant attention from maintenance personnel. In addition, the water that collected on the cans would cause rusting, which led to rejected products. According to Cannon, the company recorded \$100,000 worth of rejects in one 4-month production season, prior to installing their new blower system. Had the manufacturer operated on a yearlong basis, the costs to the company could have been three times as large.

“[That] was really the initial reason for us coming in to look at the facility. It was to evaluate their lines because there were quality issues

and the slip hazard issue,” Cannon explained. “The quality issue was that the cans would rust. The cans go back to palletize in their warehouse until someone calls in a request. They would have rusty cans because water was left on the cans from the inadequate blowers. At that point, they can’t sell them.”

Blower System Retrofit

The existing blower system was antiquated, ineffective and inefficient. As noted previously, the manufacturer has 26 production lines in operation. Those lines each had a dedicated blower that ranged from 20 to 30 hp. The air was delivered at 1.3 psi through an array of low-pressure aluminum air knives with 0.035" slot gaps.

According to Cannon, the original blower installation was far from ideal, especially at the point of use. In order to effectively dry cans, an air knife system should be installed within 2 to 3 feet of the conveyor belt. In many instances throughout the facility, this wasn't the case. Additionally, due to the speed and number of the cans moving through the conveyor lines, more pressure was required to dry the cans adequately.

Process Air Solutions was able to significantly improve the blower system, in regards to both system performance and energy efficiency. The improvements began with the installation and consolidation of the air blowers. At each line, Process Air Solutions replaced an old 20- or 30-hp blower with a new Vortron 20-hp Z40e centrifugal blower. In instances where there were adjacent production lines, they were even able to eliminate a blower entirely by replacing two blowers with one. Not only did this improve energy efficiency, but it also freed up space in the motor control room and reduced the time spent maintaining superfluous machines. Overall, the company was able to reduce the number of blowers installed at the facility from 26 to 18.



Image 1: Sample installation of the Vortron Z40e centrifugal blower

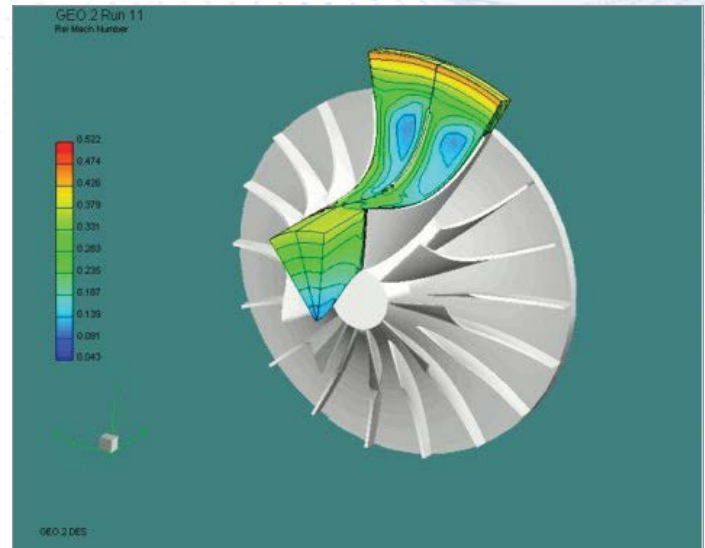


Image 2: Design software illustrating the flow characteristics of the Vortron Z40 impeller

The new blowers were dramatically more efficient than the older blowers. According to Cannon, the best-case scenario for the original blowers was an operating efficiency of roughly 36 or 37 percent. In contrast, the Vortron Z40e blower can achieve a peak operating efficiency of up to 80 percent.

“Our blowers came out to be about twice as efficient,” Cannon said. “The difference is in the overall compressor stage design, which is backswept. It is much more dynamic than other stage designs. If you look at the cut, it’s like designing a fan for a jet engine that has 20,000 pounds of thrust as opposed to one with 10,000 pounds of thrust. Our design software shows the flow characteristics of that impeller design.”

Mapping Demand, Customizing Solutions

Process Air Solutions did not simply install the new, more efficient Vortron blowers. According to Cannon, the company takes a comprehensive look at a facility’s blower demand to determine the optimum system design, from the blowers down to the air delivery fixture. When evaluating a facility’s blower system, they provide their clients with a “compressor map,” which provides flow-to-pressure operating points and efficiency islands.

“When we talk about efficiency and we look at an operating point, we want to know how efficient the blower is at that operating point,” Cannon explained. “We’ve mapped every one of these blowers on a gas compressor stand, which takes a lot of hours to do. So, hypothetically, when we say that a blower is going to provide 1000 cfm at 3 psi and

PROCESS AIR SOLUTIONS BLOWS AWAY SAFETY AND QUALITY ISSUES AT A CANNERY



Image 3: Sample installation of an air delivery system from Process Air Solutions

it's going to take 19.68 hp to do that, it's going to take exactly that.” (Figures are corrected to site conditions).

Along with the compressor map, Process Air Solutions customizes the air delivery fixture for the given application. Part of the problem with the original blower system was that it only provided 1.3 psi of air to dry the cans. With approximately 600 cans moving through the conveyor every minute, there was just not enough air pressure to dry the cans with an air knife.

To address the issue, Process Air Solutions designed a more holistic air delivery system that dried the cans from every angle. It was at this stage of the process that Endress' expertise came into play.

“Bob Endress was really instrumental in the design and implementation of the air delivery fixture,” Cannon said.

Process Air Solutions installed an 8-nozzle array at the top of the line, a 2-nozzle array to dry the bottoms of the cans, and two 12” air knives on the sides. The system also provided air at a higher pressure, blowing off the cans at 3.1 psi with a volume of 1194 scfm. Since the installation, there have not been any product rejects, and the slip hazards have been completely eliminated.

Return on Investment

To make the results of the new installation more tangible, Cannon quantified the manufacturer's overall return on investment (ROI).

TABLE 1: SIMPLIFIED RETURN ON INVESTMENT						
PROJECT DESCRIPTION	ENERGY SAVINGS (KWH/YEAR)	COST SAVINGS (\$/YEAR)	PROJECT COST ¹	INCENTIVE	NET PROJECT COST	ROI
Blower Retrofit	394,812.17	\$67,118	\$209,000	\$50,484	\$158,516	42.3%

¹ Blower project costs are estimated based on a firm equipment value of \$174,438 plus assumed installation costs of \$50,000.

However, it is important to note that this facility only operates 4 months out of the year. To put the results in context, we provide the ROI figures as if the plant ran continuously throughout the entire year (Refer to Table 1).

In essence, there was a 10-month payback on the investment in the new blowers and the associated equipment, which includes the annual energy savings and an energy rebate from the utility company. While that means that it will take this particular manufacturer 2.5 years to achieve its ROI, a typical manufacturing plant that operates yearlong could achieve an ROI with this type of installation in less than one year.

“It really was a straightforward job. The ROI is rather large because there were so many blowers, but it really worked out well,” Cannon elaborated. “This past production season was their most profitable, and they have traced that back to being more efficient in the way they do it. Obviously this project was a big part of their efficiency initiative.” **BP**

About Process Air Solutions

Founded in 2006, Process Air Solutions is an independently run company based in Fenton, MO. The company is the exclusive packager of Vortron centrifugal blowers for the industrial market, and their standard offering includes 3- to 75-hp oil-free blowers.

Process Air Solutions commonly works with air compressor distributors, and they also work with original equipment manufacturers (OEMs), especially with manufacturers of bottling and food processing machinery. They are also the only blower company approved by the military to provide ground support equipment for cooling avionics.

The Vortron oil-free centrifugal blowers boast an 80,000 hour design life, and routinely outlast that mark. This is largely due to a proprietary, permanently lubed and preloaded spindle assembly on the bearing cartridges. According to Cannon, the blowers are extremely durable and maintenance-free.

For more information about the companies discussed in this article, contact Greg Cannon, National Sales Manager at Process Air Solutions. He can be reached by telephone at (636) 343-2021 and by email at greg.cannon@processairsolutions.com. You can also visit <http://www.processairsolutions.com>, or www.vortron.com.

To read similar articles on **Blower System Assessments** visit www.blowervacuumbestpractices.com/system-assessments/vacuum-blowers.

A VACUUM SYSTEM CONSOLIDATION AUDIT

Tim Dugan, P.E. President, Compression Engineering Corporation

► Vacuum systems are considered “black magic” by most plant engineers, even more so than compressed air. Terms like icfm, cfm, torr, and Nm³/hr get bandied around and confuse us all. What plant engineers know is what works. If they run vacuum pump X at vacuum level Y, everything works. That is a hard thing to change if there are inefficiencies in the system, even when an audit is recommending change. One of the biggest opportunities I run into for savings is the consolidation of multiple vacuum systems running at a lower absolute pressure (higher vacuum) than is really needed. Therefore, educating the customer is critical.

Vacuum System Basics

Before I launch into the actual audit, let me define a couple of key terms relating to vacuum systems:

Capacity: As with compressors, this is the inlet flow volume that the vacuum pump pulls in at a given vacuum and speed. For positive-displacement vacuum pumps, which are evaluated in this audit, capacity is fairly constant (at constant speed). It is measured in ft³/min, and called icfm in Imperial units, and m³/hr in SI units.

Vacuum: This is the gauge pressure that the inlet is at, relative to the atmospheric pressure. Usually this is in inches of Mercury (0" Hg) in Imperial and mbar or torr in SI units.

Free Airflow: This term is used less often, but is critical to understanding consolidation. This is the air, in scfm (Imperial) or Nm³/hr (SI), that the process pulls into the system — if it is at sea level. Free airflow is directly proportional to inlet absolute pressure, assuming a constant capacity. In other words, at 20" Hg vacuum (about 10" Hg absolute pressure), the vacuum pump's free air delivery will be at 33 percent of its capacity. At 22" Hg vacuum (20" absolute), it will be at 26.7 percent. The change in capacity from 22" to 20" Hg is $26.7/33.3 = 0.80$, a 20 percent decrease in required capacity.

System Curve: The process is merely an orifice, with atmospheric pressure on the front end and vacuum on the other. Like an orifice, the relationship between vacuum and flow that the system requires is “second order.” That is, vacuum is proportional to the square root of flow, and flow is proportional to the square root of vacuum. Thus, lower vacuum will require less flow in scfm. Running at 20" Hg instead of 22" Hg will require $(20/22)^{0.5} = 0.95$, or about 5 percent less delivered air.

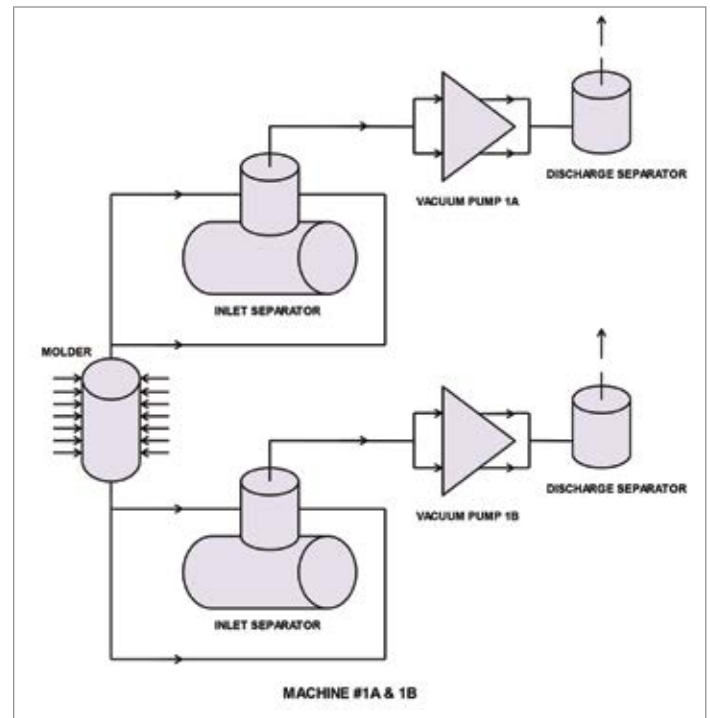


Figure 1: Vacuum Piping Schematic for Machine One (A & B)

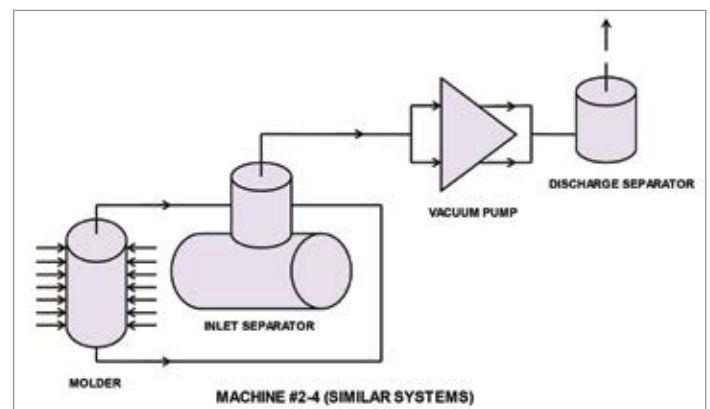


Figure 2: Existing Vacuum Piping Schematic for Machines Two Through Four

Thus, reducing vacuum reduces the required capacity in two ways. First, it reduces the free air (by the square root of the vacuum ratio). Secondly, there is less capacity required to deliver that reduced free air (linearly by the ratio of the absolute pressure). Changing vacuum level from 22" Hg to 20" Hg can drop the required capacity by about 24 percent $(1.0 - 0.80 \times 0.95)$. If one was to consolidate a system of

A VACUUM SYSTEM CONSOLIDATION AUDIT

Savings and Cost Summary

Utility Rate:		\$8.000 /kW-m		\$0.05000 /kWh				
Measure No.	Description	EEM Life Expectancy (yrs)	Peak Power Savings (kW)	Demand Reduction (kW)	Annual Electric Savings (kWh/yr)	Annual Electric Savings (\$/yr)	Installed Cost (\$)	Pre-incentive Payback (yrs)
1A	Option A. Integrate Vacuum Systems	15	0	0	1,259,380	\$62,969	\$475,640	7.6
1B	Option B. Install VFDs on Each Pump	15	0	0	711,428	\$35,571	\$184,250	5.2
1C	Option C. Change V-Drive Speed on Each Pump	15	0	0	437,340	\$21,867	\$13,750	0.6

Incentive Summary

Capital Incentive Cap, % of Project Cost		70%					
Capital Energy Incentive Rate		\$0.15 /kWh					
EEM No.	Description	Incentive Structure (-)	Cost Incentive Cap (\$)	Energy Incentive Cap (\$)	Final Incentive (\$)	Customer Cost After Incentive (\$)	Customer Final Payback (yrs)
1A	Option A. Integrate Vacuum Systems	CAPITAL	\$332,948	\$188,907	\$188,907	\$286,733	4.6
1B	Option B. Install VFDs on Each Pump	CAPITAL	\$128,975	\$106,714	\$106,714	\$77,536	2.2
1C	Option C. Change V-Drive Speed on Each Pump	CAPITAL	\$9,625	\$65,601	\$9,625	\$4,125	0.2

Table 1: Savings, Cost and Incentive Summary

VACUUM PUMP NO.	(3) 200HP VPs LOAD-SHARING	(2) 200HP VPs LOAD-SHARING	(1) 200HP VP	LINE 1	FLOW RANGE (ACFM)	
ACFM	12469	8312	4156	2280	FROM	TO
1			T		0.0	4156
2			T	B	4156	6436
3		T			6436	8312
4		T		B	8312	10592
5	T				10592	12469
6	T			B	12469	14749

*T = "trim," or partly-loaded
*B = base-load, or fully loaded

Table 2: Vacuum Pump Staging

four vacuum pumps with that drop in vacuum, one vacuum pump could be shut off for a majority of the time. That is the basis for the consolidation savings in this proposed project.

Initial Vacuum System Description

Refer to Figures 1 and 2 for simplified diagrams of the four systems. Three are identical 200-hp, 4000 acfm, liquid-ring vacuum pump systems, supplying machines two through four. They currently run

continuously at 23" Hg, except during brief shutdowns. Machine One is a smaller, 75-hp duplex system, approximately 2300 acfm. It runs about 25 percent of the time for special orders, at about 20" Hg. Total system demand is 10,000 icfm at 21" Hg, or about 2450 scfm.

Energy Efficiency Measures

Three multiple, mutually exclusive options for energy efficiency improvements have been considered for the vacuum system. These

options were developed to provide alternatives if the theoretical customer, let's say Customer ABC, has limited funding. In our view, Measure 1A is superior.

Measure 1A: Integrate the Vacuum Systems

Currently, the four systems (Machines One through Four) run separately. The vacuum level is uncontrolled, seeking its own on the vacuum pump curve at a level in excess of what is needed. The combined flow demand from all lines can be significantly dropped if vacuum is dropped. However, when operating separately, the individual vacuum pumps can't be turned down enough to match the reduction opportunity possible through vacuum set point reduction. With the connecting pipe, the vacuum pumps can be optimally controlled at the reduced vacuum/flow. A large vacuum pump can be shut off most of the time if an automation system can manage the vacuum pumps.

This project includes piping, variable frequency drives (VFDs) and controls to optimally run the system at one common vacuum level. Flexibility is built into the recommended system design to allow for segmentation of the system, if future products would require different vacuum levels. Energy efficiency will not be compromised if that occurs.

Measure 1A offers the most flexibility and savings. The system can be run at the same vacuum level or at multiple levels. It can meet very high and very low demands, while still maintaining efficiency. Additionally, one or more vacuum pumps will be off most of the time to accommodate maintenance or standby.

Measure 1B: Install VFDs on Individual Vacuum Pumps

This is a lower-cost alternative to Measure 1A. This measure adds VFDs to each 200-hp vacuum pump (Machines Two through Four), keeping them separate. It has some of the flexibility of Measure 1A, but it does not yield as much savings.

Measure 1C: Change V-Drive Speeds of Each Vacuum Pump

This measure consists of changing sheaves and possibly belts, so that each vacuum pump operates at the target vacuum level. Just the three larger units (Machines Two through Four) would be changed.

Economic Summary

Table 1 provides a summary of the estimated costs, benefits and potential incentives for the custom energy efficiency measures evaluated in this report. The potential utility incentives for capital-intensive, custom measures are calculated as \$0.15 times the total project energy savings (in kWh), subject to project-level caps. The incentive shall not exceed 70 percent of the eligible project cost or the amount that results in a one-year payback based on energy cost savings.

The optional measures reduce system energy use by 19 to 33 percent, depending on the option selected, and produce a simple payback of 0.2 to 4.6 years after the potential utility incentive.

Electrical savings are much higher if the vacuum system can be run at a lower level. For instance, at 17" Hg, savings from Measure 1A are over 2,050,000 kWh/yr, yielding a project payback of less than 2 years. An initial test was successfully run at 17" Hg on Machine Two. However, subsequent testing showed that additional gas usage in the dryer would be needed for vacuum levels lower than about 20" Hg, which would have been "fuel switching." This type of trade-off was not cost-effective, and would disqualify the project from potential utility incentives.

However, if Customer ABC could run the system at lower than 20" Hg without additional gas, the savings would be approximately 320,000

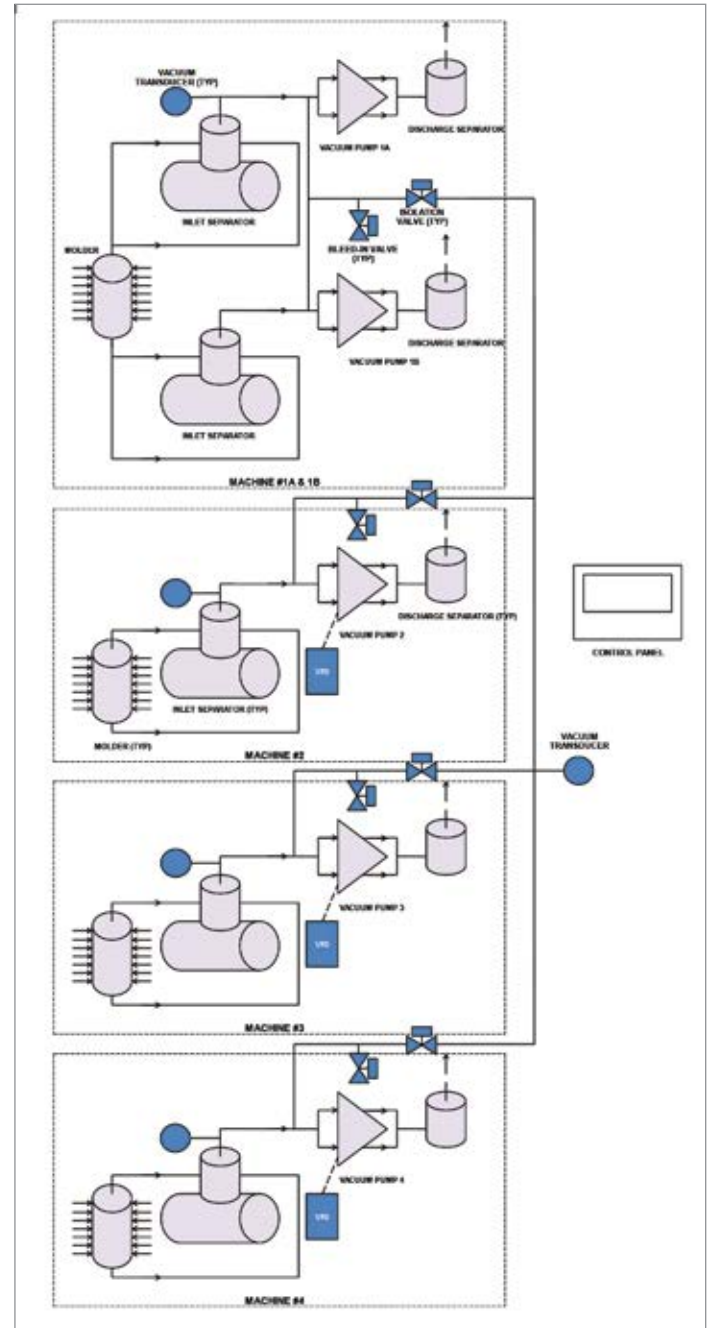


Figure 3: Recommended System Diagram for Measure 1A

kWh/yr more for each 1.0" Hg lower than 20" Hg, down to 18" Hg, and 240,000 kWh/yr more to get to 17" Hg. The incentive would increase by \$0.15/kWh for Measure 1A (\$48,000) per every 1" Hg down to 18" Hg. For this reason, and the additional reliability, flexibility and controllability provided by Measure 1A, we would recommend this measure if Customer ABC had enough capital.

A VACUUM SYSTEM CONSOLIDATION AUDIT

DETAILED DESCRIPTION OF PROPOSED EQUIPMENT AND OPERATION

Measure 1A: Integrate Vacuum Systems

Source of Energy Savings

The measure combines the four systems, controls the number of vacuum pumps running, and runs them at their most efficient speed. This saves energy in four ways:

1. Operating a vacuum system at a lower vacuum (higher absolute pressure) significantly reduces the excess flow requirement at the vacuum pump inlet to achieve a given mass flow requirement. If a system can operate at 20" Hg (9" Hg absolute in Yakima, WA), and operates at 23" Hg (6" Hg absolute), it requires 9/6 the acfm volume to develop the same scfm real-system demand.
2. Operating at a deeper vacuum than needed also requires more mass flow of air than needed — about 7 percent more in the above example.
3. These vacuum pumps are more efficient at lower speed, likely due to less hydraulic losses.
4. Running fewer vacuum pumps in a combined system allows the speed optimization to occur. Instead of running pumps at maximum speed or at minimum speed with too much capacity for the demand, the right number of pumps as a set will be running.

Specific Equipment Recommendations

Refer to Figure 3 for a system sketch:

- Install VFDs on the three 200-hp vacuum pumps (Machines Two through Four).
- Install vacuum transducers at each of the four inlet separators.
- Install a 12" stainless steel header, with four branch lines to connect the inlets of all four systems to

the header. The branch lines are on the vacuum pump side of the vacuum-regulating valves.

- Install four 12" automatic butterfly valves on the individual branch

lines for isolation from the header, normally open.

- Install four 6" automatic butterfly valves at the vacuum pump inlets, on tees to atmosphere,

BASELINE										
		FULL LOAD INLET CAPACITY, ACFM	AVERAGE INLET FLOW, ACFM	AVERAGE FREE AIR FLOW, SCFM	AVERAGE VACUUM, "HG	AVERAGE ABS. PRESSURE, "HG	AVERAGE POWER, KW	PEAK POWER, KW	SPECIFIC PERFORMANCE, ACFM/KW	ENERGY CONSUMPTION, KWH/YR
VP2	Nash 904-M2	3915	3634	761	22.5	6.4	149.6	361.8	24.22	1,269,445
VP3	Nash 904-M2	3073	3411	830	21.6	7.3	137.0	360.8	24.91	1,153,721
VP4	Premier P501M2	3853	3586	672	23.3	5.6	138.4	353.5	25.73	1,173,940
VP1A&B	Sih (unknown models)	2280	569	170	20.0	8.9	24.0	96.0	23.71	202,127
TOTAL		14020	11190	2463	21.9	7.1	490.0	666	24.87	3,790,233
AFTER MEASURE 1A										
		FULL LOAD INLET CAPACITY, ACFM	AVERAGE INLET FLOW, ACFM	AVERAGE FREE AIR FLOW, SCFM	AVERAGE VACUUM, "HG	AVERAGE ABS. PRESSURE, "HG	AVERAGE POWER, KW	PEAK POWER, KW	SPECIFIC PERFORMANCE, ACFM/KW	ENERGY CONSUMPTION, KWH/YR
VP2	(3) 200HP VP's LOAD-SHARING	12469	121	36	20.0	8.9	5.4	464.9	22.23	45,746
VP3	(3) 200HP VP's LOAD-SHARING	8312	6197	1821	20.0	8.9	225.3	325.4	27.11	1,897,365
VP4	(1) 200HP VP	4156	469	140	20.0	8.9	21.5	360.4	21.90	181,245
VP1A&B	Sih (unknown models)	2280	1106	330	20.0	8.9	46.3	96.0	22.91	406,496
TOTAL		14749	7892	2326	20.0	8.9	308.5	770	25.97	2,530,853
MEASURE 1A SAVINGS										
		FULL LOAD INLET CAPACITY INCREASE, ACFM	AVERAGE INLET FLOW REDUCTION, ACFM	AVERAGE FREE AIR FLOW REDUCTION, SCFM	AVERAGE VACUUM REDUCTION, "HG	AVERAGE ABS. PRESSURE REDUCTION, "HG	AVERAGE POWER REDUCTION, KW	PEAK POWER REDUCTION, KW	SPECIFIC PERFORMANCE INCREASE, ACFM/KW	ENERGY DIFFERENCE, KWH/YR
TOTAL		728	3288	127	1.9	-1.9	148.5	0	1.10	1,259,380
AFTER MEASURE 1B										
		FULL LOAD INLET CAPACITY, ACFM	AVERAGE INLET FLOW, ACFM	AVERAGE FREE AIR FLOW, SCFM	AVERAGE VACUUM, "HG	AVERAGE ABS. PRESSURE, "HG	AVERAGE POWER, KW	PEAK POWER, KW	SPECIFIC PERFORMANCE, ACFM/KW	ENERGY CONSUMPTION, KWH/YR
VP2	Nash 904-M2	4156	2471	737	20.0	8.9	115.4	158.0	21.41	972,221
VP3	Nash 904-M2	4156	2680	799	20.0	8.9	108.0	156.0	24.83	909,283
VP4	Premier P501M2	4156	2085	622	20.0	8.9	115.6	154.9	18.83	973,749
VP1A&B	Sih (unknown models)	2280	618	184	20.0	8.9	26.5	96.0	23.29	223,551
TOTAL		14748	7854	2341	20.0	8.9	366	464	21.48	3,078,805
MEASURE 1B SAVINGS										
		FULL LOAD INLET CAPACITY INCREASE, ACFM	AVERAGE INLET FLOW REDUCTION, ACFM	AVERAGE FREE AIR FLOW REDUCTION, SCFM	AVERAGE VACUUM REDUCTION, "HG	AVERAGE ABS. PRESSURE REDUCTION, "HG	AVERAGE POWER REDUCTION, KW	PEAK POWER REDUCTION, KW	SPECIFIC PERFORMANCE INCREASE, ACFM/KW	ENERGY DIFFERENCE, KWH/YR
TOTAL		728	3336	111	1.9	-1.9	84.5	0	-3.38	711,428
C										
		FULL LOAD INLET CAPACITY, ACFM	AVERAGE INLET FLOW, ACFM	AVERAGE FREE AIR FLOW, SCFM	AVERAGE VACUUM, "HG	AVERAGE ABS. PRESSURE, "HG	AVERAGE POWER, KW	PEAK POWER, KW	SPECIFIC PERFORMANCE, ACFM/KW	ENERGY CONSUMPTION, KWH/YR
VP2	Nash 904-M2	3860	2471	737	20.0	8.9	127.8	132.9	19.33	1,076,710
VP3	Nash 904-M2	3860	2680	799	20.0	8.9	124.1	139.6	21.66	1,044,962
VP4	Premier P501M2	3860	2085	622	20.0	8.9	122.1	127.4	17.07	1,028,731
VP1A&B	Sih (unknown models)	2280	569	170	20.0	8.9	24.0	96.0	23.66	202,471
TOTAL		13861	7965	2327	20.0	8.9	398	496	19.61	3,352,873
MEASURE 1C SAVINGS										
		FULL LOAD INLET CAPACITY INCREASE, ACFM	AVERAGE INLET FLOW REDUCTION, ACFM	AVERAGE FREE AIR FLOW REDUCTION, SCFM	AVERAGE VACUUM REDUCTION, "HG	AVERAGE ABS. PRESSURE REDUCTION, "HG	AVERAGE POWER REDUCTION, KW	PEAK POWER REDUCTION, KW	SPECIFIC PERFORMANCE INCREASE, ACFM/KW	ENERGY DIFFERENCE, KWH/YR
TOTAL		-169	3386	126	2.4	-1.9	61.9	0	-5.26	437,340

Modeling Results

for unloaded starting and testing, normally closed.

- Install a master control system to control the following:
 - Vacuum level at each machine, and vacuum at the main header
 - Vacuum pump speed
 - Vacuum pump start and stop, based on a flow-based algorithm, running exactly the right combination of vacuum pumps in every flow range. This controls vacuum at the header.
 - Isolation butterfly valve operation
 - Bleed-in valve operation
- Interface the controls with the plant supervisory control and data acquisition (SCADA) system and/or PI system for data collection and trending.
- Preliminary staging is shown in Table 2.

Performance Indicators Recommended to Achieve Optimal Energy Efficiency

- Target a common vacuum of 20" Hg to start. Lower vacuum creates more savings. However, we don't recommend going much lower due to the need to add more natural gas in the drying section.
- Run the vacuum pumps in a "load-sharing" algorithm, running multiple units at as low a speed as possible. The minimum speed is 300 rpm, which is about 85.7 percent of full speed.

Additional Assumptions Behind the Savings Estimate

- The vacuum pumps operate according to the manufacturer's pump curve.
- The VFD's efficiency is 97 percent.
- Motor efficiency is constant throughout the operating range of the VFD.

- Pipe length and elevations used in analysis are accurate estimates.

Measure 1B: Install VFDs on Individual Vacuum Pumps

Source of Energy Savings

The sources of savings are the same as the first three for Measure 1A. Savings are less because a vacuum pump can't be completely shut down until the line goes down.

Specific Equipment Recommendations

- Install VFDs on the three 200-hp vacuum pumps (Machines Two through Four) and the two 75-hp

vacuum pumps (Machine One, A & B).

- Install vacuum transducers at each of the four inlet separators.
- Install controls at each line to control the following:
 - Vacuum level
 - Vacuum pump speed
- Interface the controls with the plant SCADA and/or PI system for data collection and trending.

Performance Indicators Recommended to Achieve Optimal Energy Efficiency

- Target a vacuum of 20" Hg to start. Lower vacuum creates more

1A Option A. Integrate Vacuum Systems				
Item	Description	Price Ea	Qty	Qty Price
1	304SS 12" Sch10S piping, material & labor	\$ 170,000	1	\$ 170,000
2	12" Valves & Actuators	\$ 4,200	8	\$ 33,600
3	6" Valves & Actuators	\$ 700	4	\$ 2,800
4	200hp VFDs, Controls & Instrumentation	\$ 171,000	1	\$ 171,000
7	Electrical installation	\$ 40,000	1	\$ 40,000
8	Engineering	\$ 10,000	1	\$ 10,000
9	Commissioning	\$ 5,000	1	\$ 5,000
	Contingency		10%	\$ 43,240
Total CM1 - Option A				\$ 475,640

1B Option B. Install VFDs on Each Pump				
Item	Description	Price Ea	Qty	Qty Price
1	200hp VFD	\$ 30,000	3	\$ 90,000
2	75hp VFD	\$ 11,250	2	\$ 22,500
4	Controls & HMI	\$ 25,000	1	\$ 25,000
5	Electrical installation	\$ 15,000	1	\$ 15,000
6	Engineering	\$ 10,000	1	\$ 10,000
7	Commissioning	\$ 5,000	1	\$ 5,000
	Contingency		10%	\$ 16,750
Total CM1 - Option B				\$ 184,250

1C Option C. Change V-Drive Speed on Each Pump				
Item	Description	Price Ea	Qty	Qty Price
1	New Sheaves & Belts	\$ 1,500	5	\$ 7,500
2	Commissioning	\$ 5,000	1	\$ 5,000
	Contingency		10%	\$ 1,250
Total EM1				\$ 13,750

Cost Estimates

A VACUUM SYSTEM CONSOLIDATION AUDIT

savings. However, we don't recommend going much lower due to the need to add more natural gas in the drying section.

- The minimum speed is 300 rpm, or 85.7 percent of full speed.
- Additional Assumptions Behind the Savings Estimate
- The vacuum pumps operate according to the manufacturer's pump curve.
- The VFD's efficiency is 97 percent.
- Motor efficiency is constant throughout the operating range of the VFD.

Measure 1C: Change V-Drive Speeds of Each Vacuum Pump

Source of Energy Savings

The sources of savings are the same as numbers one through three, as outlined in Measure 1A, but at a lower level.

Specific Equipment Recommendations

- Change the V-belts and sheaves of each of the vacuum pumps so that they can operate at about 21" Hg at full production. This gives some additional head room since there is no drive to increase speed. The preliminary speeds are as follows:

- Machine Two: 338 rpm
- Machine Three: 344 rpm
- Machine Four: 331 rpm

Performance Indicators Recommended to Achieve Optimal Energy Efficiency

- Target a vacuum of 21" Hg to start. Lower vacuum creates more savings.
- The minimum speed is 300 rpm, or 85.7 percent of full speed.

Additional Assumptions Behind the Savings Estimate

- Same as Measure 1B, except for VFD losses **BP**

For more information, contact Tim Dugan, P.E., President, Compression Engineering Corporation by phone at (503) 520-0700, by email at Tim.Dugan@compression-engineering.com, or visit www.comp-eng.com.

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