White Paper

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by Gardner Denver

Selecting Modern Chemical & Pharmaceutical Process Vacuum Systems

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The choice of a vacuum pump system for a chemical or pharmaceutical processing application is an extremely important decision, because the system can directly influence production. Vacuum affects the quality, unit cost, environmental impact, energy costs and safe handling of many materials. Vacuum issues are especially problematic with processes that involve flammable, corrosive or toxic vapors, or which generate significant amounts of effluent.

Comparing different technologies is a key step when evaluating modern vacuum pump systems. Whichever vacuum system is selected, it should be the one with the most economic benefits after all the related costs are taken into account. Each process application will naturally have unique priorities, and an analysis of total cost of ownership should consider all of them.

The contents of this paper present why many modern chemical and pharmaceutical plants are making the switch to dry vacuum systems.

Dr. Don Collins
Global Applications Manager, Dry Tech
Gardner Denver Nash, LLC.

Traditional Approaches

For generations, engineers in chemical processing industries have relied on "wet" vacuum equipment – pumps which include liquid in the vacuum chamber to serve as a lubricant or seal. Wet vacuum systems include steam ejectors, liquid ring pumps, (LRPs), oil-sealed pumps and vapor boosters.

Wet vacuum pump systems have historically been popular choices because they have delivered dependable solutions for all process vacuum applications. However, wet vacuum technology can pose disadvantages in certain situations.

Traditional wet pump vacuum systems have the potential for process contamination. Wet systems are affected by condensed vapor in oil-sealed pumps or the vapor pressure of the sealing fluid in liquid ring pumps.

LRPs will cavitate as the process pressure approaches the vapor pressure of the seal fluid. The temperature of water may affect the performance of the inter-stage condensers in steam ejector systems.

Other concerns with wet vacuum pump systems are corrosion and effluent. Wet systems often produce large amounts of effluent, which can then require expensive treatment and disposal. Throughout the world, the question of waste generation has become a bigger issue in recent years. As government agencies gain more regulatory power, affected industrial plants have to incur additional expenses to stay within mandated compliances.

Those problems can be avoided with dry pump systems, as explained throughout this article.

The Advantages of Dry Vacuum Pumps

Today, many engineers throughout modern chemical and pharmaceutical industries are converting to dry vacuum pumping for a number of reasons. Dry vacuum pump technology – especially variable pitch screw chemical dry pumps -- can offer clear, measurable advantages over traditional wet systems in a wide variety of essential applications. Dry vacuum systems include air ejectors, mechanical boosters and dry backing pumps.

The single most important feature of dry pumps is that they do not use water, oil or any other liquid for sealing or lubrication of the vacuum stages. This eliminates the risk of process contamination, effluent generation and corrosion, due to always pumping in the vapor phase. Dry pump systems are independent from the vapor pressure of seal fluid in LRPs and inter-stage condensers for steam ejectors. Dry vacuum pump systems offer significant process and economic benefits throughout their lifecycles. They generally represent the best cost of ownership in their operating range, due to lower installation expenses, easier maintenance, lowest running cost and reduced environmental impact. Dry systems also provide more flexible vacuum. They easily adapt to changed processes and operating pressures.

A broad spectrum of advantages and disadvantages can be present by selecting different CPI vacuum technologies, as shown below.

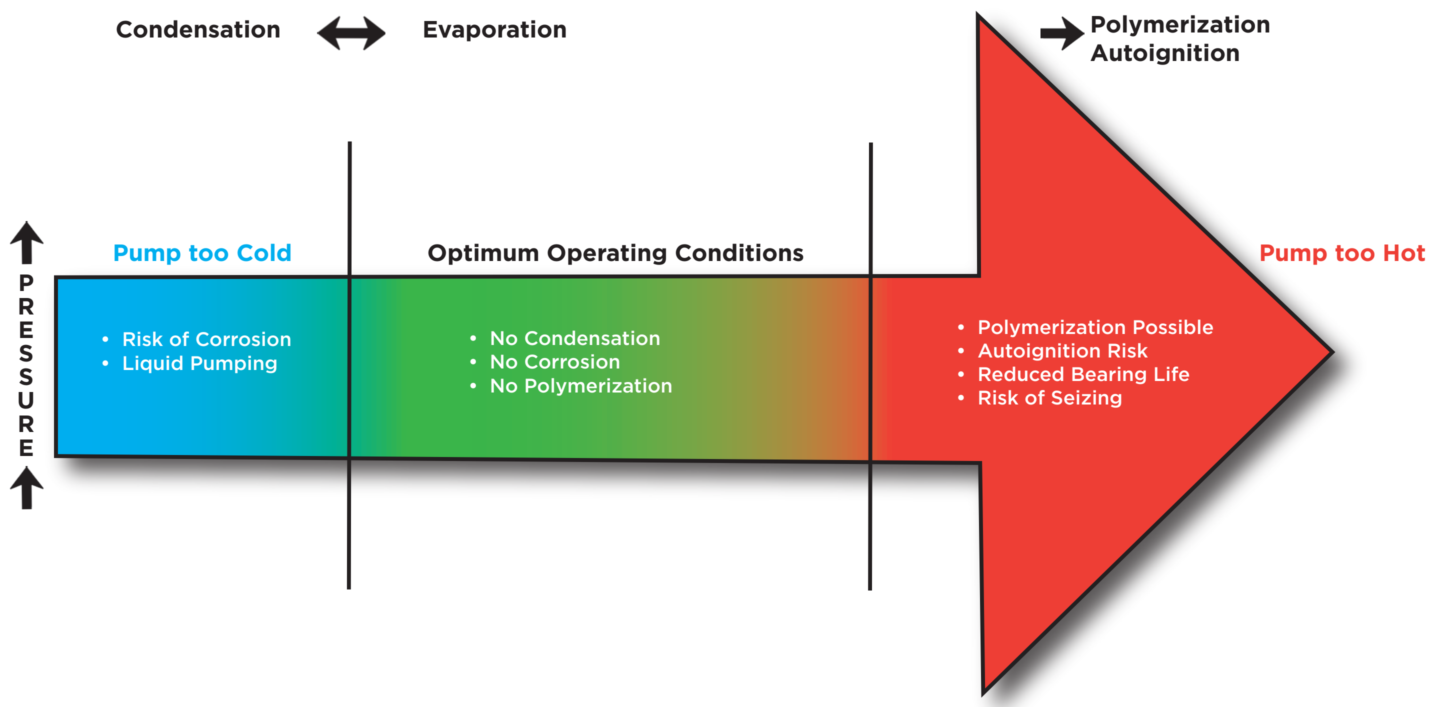
ADVANTAGES AND DISADVANTAGES OF DIFFERENT CPI VACUUM TECHNOLOGIES

	TECHNOLOGY	ADVANTAGES	DISADVANTAGES
WET	STEAM EJECTORS	- No moving parts, compact, simple to operate - Pump flammable vapors safely - Reliable – low maintenance costs - Good vacuum levels when multistaged, (10^3 to 10^{-3} mbarA) - High pumping speeds, (10 – 2,000,000 m^3h^{-1}) - Fairly insensitive to suction temperature - Wide choice of construction materials - Traditional CPI vacuum technology	- High capital & operating costs - Single stage provides only low vacuum - Potential process contamination - Inflexible operating parameters - Hard to troubleshoot - Can block, erode and corrode - Ice formation below 4 mbarA - Can be noisy
	LIQUID RING PUMPS (LRPs)	- Simple, reliable construction - only one moving part - Handles flammable vapours safely - Can condense vapors and handle high vapor temperatures - Good liquid and solids handling - Varying seal fluids aid solvent recovery or reduce effluent - Low operating temperatures, motor speeds, noise & vibrations - Wide choice of construction materials. Low capital cost in cast iron. - Traditional CPI technology	- Seal fluid supply - Can use large amounts of cooling water - Non-recoverable condensate, generally - High effluent treatment or disposal costs - Potential process contamination - Vapor pressure limiting - Potential cavitation - Corrosives require special materials
	OIL-SEALED PUMPS	- Improved vacuum levels - Constant volumetric capacity - Low specific power, (kW/[m^3h-1]) - Simple machines - Relatively low capital cost - Reliable on clean applications – not so good for process - Traditional CPI vacuum technologies	- Constant seal fluid supply for one-through pumps - Process contaminated waste oil - High effluent treatment or disposal costs - Potential process contamination at low pressures - High maintenance & service costs - Not normally explosion-tested
Dry	DRY VACUUM PUMPS	- No effluent, no pollution, less waste disposal costs - Clean, flexible vacuum - no contamination of process streams - Immediate solvent recovery at pump exhaust - Can pump corrosive and explosive gases safely - Deeper vacuum; (to <0.001 mbarA with mechanical boosters) - Capacities not limited by cooling water temperatures - Tolerant to high heat loads - Non-contacting mechanisms - no wearing internal parts - Lower total cost of ownership	- Newer technology - Typically higher capital costs than wet pumps in standard MOC - Small clearances can lead to cold seizures & damage - Often need accessories to handle solids and liquids - Risk of condensation, polymerization or autoignition outside design operating range - Limited primary pump sizes. (Use mechanical boosters for more pumping speeds).
	ROOTS MECHANICAL BOOSTERS	- Similar to Dry Vacuum Pumps above - Multistage combinations with wet or dry backing pumps - Small footprint - Reliable and proven - Easy maintenance - Low capital and operating costs	- Require primary backing pump - Low capacities at high inlet pressures, (> ~ 100 mbarA)

Even though dry pumps are made from ductile cast iron, corrosion is not a threat.

Corrosion is essentially an ionic reaction requiring water or some other liquid to be present to allow ionic separation to take place. When operating in the vapor phase, the pressure and temperature profile inside the pump is maintained above the dew point of the process media. Similarly, there are few polymerization reactions in the vapor phase. With dry pump systems, there are no problems of compatibility with process gases.

Traditionally, wet pump systems would have to be constructed of expensive materials when corrosion was an issue. That necessity is removed with dry vacuum systems, which means the screw chemical dry pumps can be made of more affordable ductile iron. That difference further enhances the lower cost of ownership of a dry system and ensures its reliable pumping of highly corrosive media.

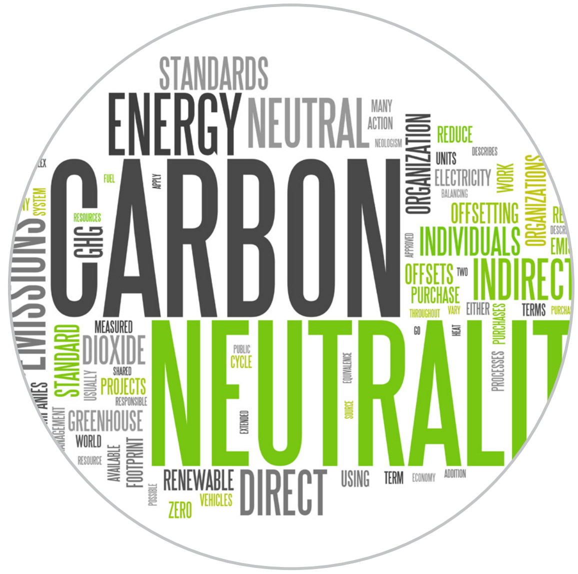


Screw chemical dry pumps can be protected from liquid ingress by the correct use and design of knock-out pots (KOPs), condensers, filters, scrubbers, etc., and must operate with the correct internal temperature profile to avoid condensation. KOPs and dust filters can also protect dry pumps from solids, and any solids which do accumulate in the pump can be dealt with by solvent flushing or soaking using a suitable solvent, technique and strategy.

Dry pumps have very similar performance characteristics to oil-sealed pumps, typically covering the pressure range 1000 to 1 mbar at near constant volumetric efficiency, with ultimate pressures of 10^{-1} to 10^{-2} mbar. Their operating range can be extended with the addition of one or two roots pump stages, thereby increasing the pump capacity to many thousands of m^3h^{-1} and decreasing the ultimate vacuum capacity to 10^{-3} or 10^{-4} mbar.

Less Environment Impact & Reduced Carbon Footprint

The choice of a vacuum pump system must also address environmental questions, including energy consumption and the possible repercussions of ever-tightening regulations on pollutants. Dry vacuum pump technology offers advantages in those categories as well.



With a dry system, valuable solvents can be recovered relatively easily by inlet or exhaust condensation, and recycled without any need for further purification.

Stricter environmental standards have added scrutiny to the use of oil in oil-sealed pumps. A large oil-based vacuum system can consume significant quantities of fresh oil in each pump for lubrication and sealing, all of which must be disposed of in accordance with local regulations.

Did you know?

Chemical dry vacuum pumps lower a plant's carbon footprint by operating more energy-efficiently than comparable traditional wet technology.

Screw chemical dry pumps also lower a plant's carbon footprint by operating more energy-efficiently than comparable traditional wet technology. Specifically, by requiring less burning of fossil fuel, dry vacuum pump systems help reduce emissions of greenhouse gas that contributes to global warming. Some facilities have even combined their energy-saving vacuum systems with abatement programs that remove greenhouse gases, resulting in a "negative carbon footprint."

Using less energy is also a direct economic advantage for the facility's operating expenses and the vacuum system's total cost of ownership.

In certain applications, a dry vacuum pump system can cost up to 90 percent less to run than its steam ejector equivalent. Similarly, compared to a liquid ring pump system, the operating cost of a dry pump system can be dramatically lower. Not only does the dry system use significantly less energy when running, it can be switched off between cycles (unlike a steam ejector) or run at low speeds using an inverter to save power.

In general, when compared over their entire lifecycles, a dry vacuum pump system will have measurable energy-saving and associated environmental advantages over a similarly sized wet system.

Perception vs. Reality of Dry Pump Systems

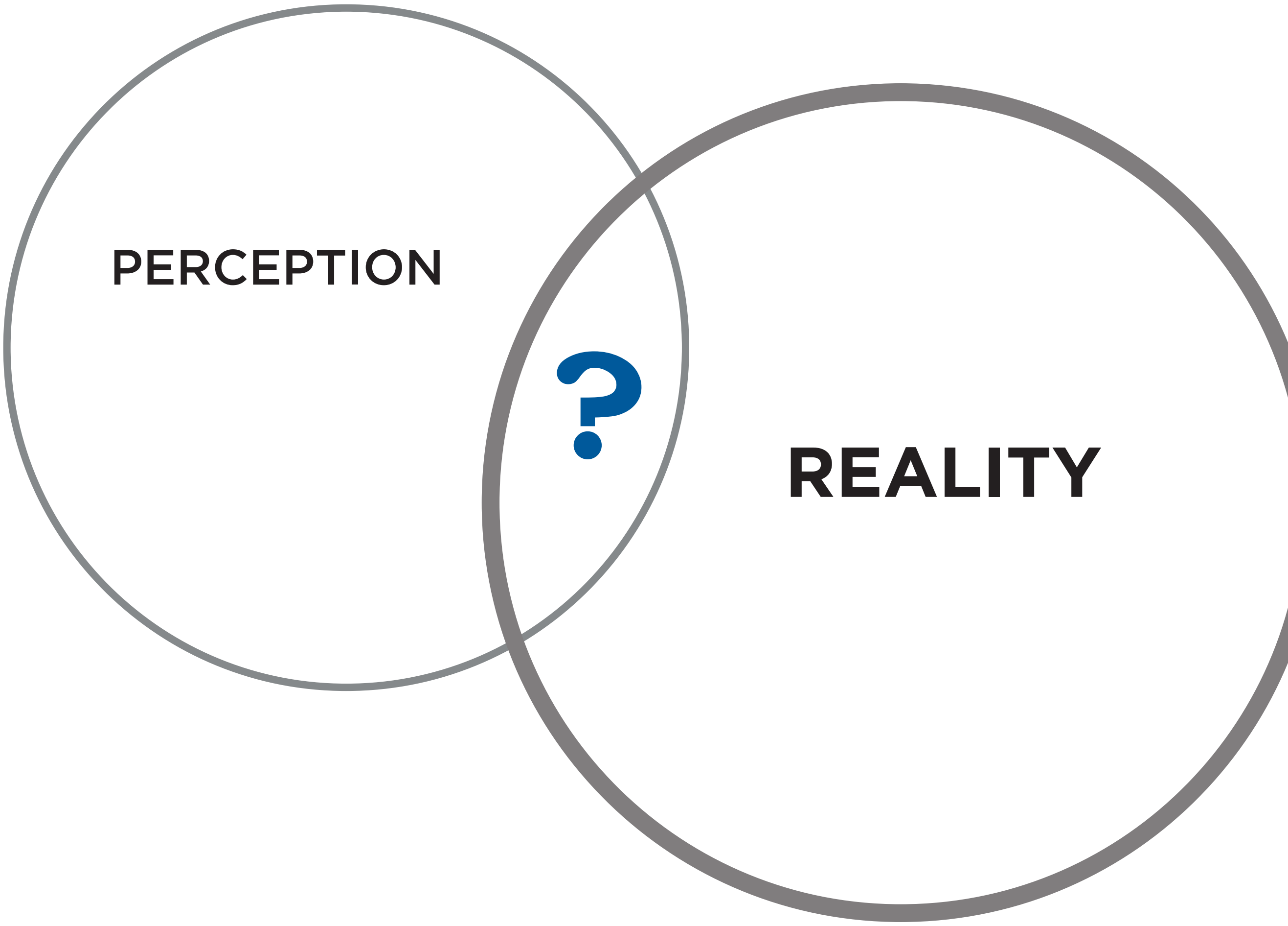
Considering the many clear, valuable advantages of dry vacuum pump technology, it may be logical to ask:

Why are wet vacuum systems still so common throughout modern chemical process industries?

That is a good question, and there are many good likely answers. For one thing, wet vacuum systems have performed admirably and successfully for many, many years. The technology is proven, well-known and makes operators comfortable.

Plant managers, engineers and other stakeholders naturally want to avoid downtime, so they are content with running wet vacuum pumps as long as the system continues to do an acceptable job -- and as long as the plant stays within environmental guidelines. The fact that converting to a dry vacuum pump system could be more economical does not even warrant consideration while everything else is satisfactory.

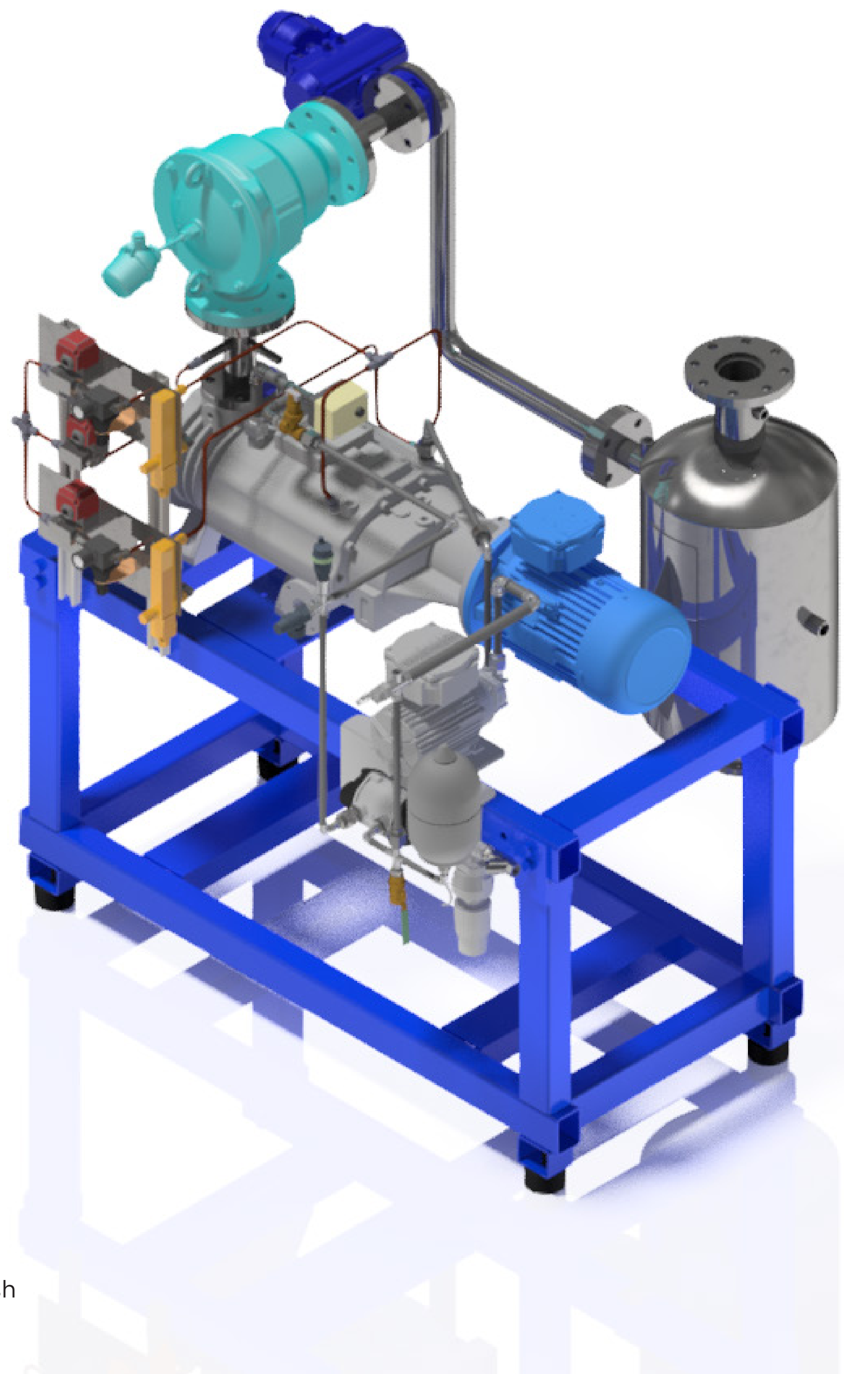
Another possibility for slow adoption of dry vacuum technology is that some engineers have heard stories about dry systems failing, or at least not living up to expectations. While such cases do exist, they can usually be explained very easily. The problems most often result from improper installation during a wet-to-dry system conversion, or they are caused by incorrect operation.



Assuring an Ideal Conversion to a Dry Vacuum System

Converting a vacuum system from wet to dry requires more than simply installing a dry pump where the wet one was. Engineers who have replaced wet pumps in the past are often familiar with just putting a new unit in and having all processes continue as they were before. Given such successful prior experience, it may not automatically occur to some converting engineers that liquid being allowed to drain into a dry pump can destroy it.

Consequently, most problems with wet-to-dry conversions occur when a liquid ring pump or steam ejector is replaced with a dry pump without any other modifications being made. The dry pump needs to stay dry, which means the pipework and other system components must be changed as well, or at least adapted to be compatible, both at the inlet and the exhaust.



When engineers hear stories about conversions failing, they naturally tend to be reluctant about pursuing the dry technology.

However, those failures are avoidable. They often occur because the buyer-seller collaboration wasn't followed through completely, or because the customer didn't clearly understand the system operation. A supplier must provide applications input all the way to the end – including installation and controls – and then the customer must be familiar enough with what needs doing.

When considering a wet-to-dry conversion, it is strongly recommended that you work with a manufacturer who has thorough knowledge of CPI process technologies and significant experience in dry system design and installation. Dry vacuum pump systems designed by reputable suppliers and experienced dry pump applications engineers perform with excellent reliability and long life.

The High Cost of Complacency

It's not hard to understand why some plant managers and process engineers are hesitant to convert from their existing wet vacuum pump to a dry system, especially when things appear to be running smoothly. But those good feelings can be deceptive.

A deeper analysis of the plant's overall operating costs will often demonstrate the many economic advantages of converting a current wet vacuum process to a higher-efficiency dry pump system. Another essential factor to address is the environmental impact of the plant's wet pump, and how new regulations might force a change in protocol.

Forward-thinking manufacturers need to evaluate their processes and ask themselves critical questions such as how much they're spending to deal with a lot of effluent, or could they reduce their energy consumption, or what are their competitors doing to lower their unit costs? Although it's reassuring to be comfortable when things seem to be working trouble-free, that's not how progress and improvements are made.

Dry Vacuum Pumps Can Enhance Processing Efficiency and Profitability

In conclusion, dry vacuum pumping can offer major benefits over traditional wet technologies for pharmaceutical and chemical processing where the size range makes selection economically sound. Dry pumps eliminate problems associated with the oil or water in wet pumps, such as possible contamination, effluent disposal and corrosion. Dry pumps consume less energy and save money. They are clean, reliable, provide low to high vacuum, and require minimal maintenance.

All of those impressive advantages make screw chemical dry pumps a viable alternative to comparable wet equipment, especially when they prove to be more cost-effective in a particular application. Through lower cost of ownership, a dry system often pays for itself very quickly.

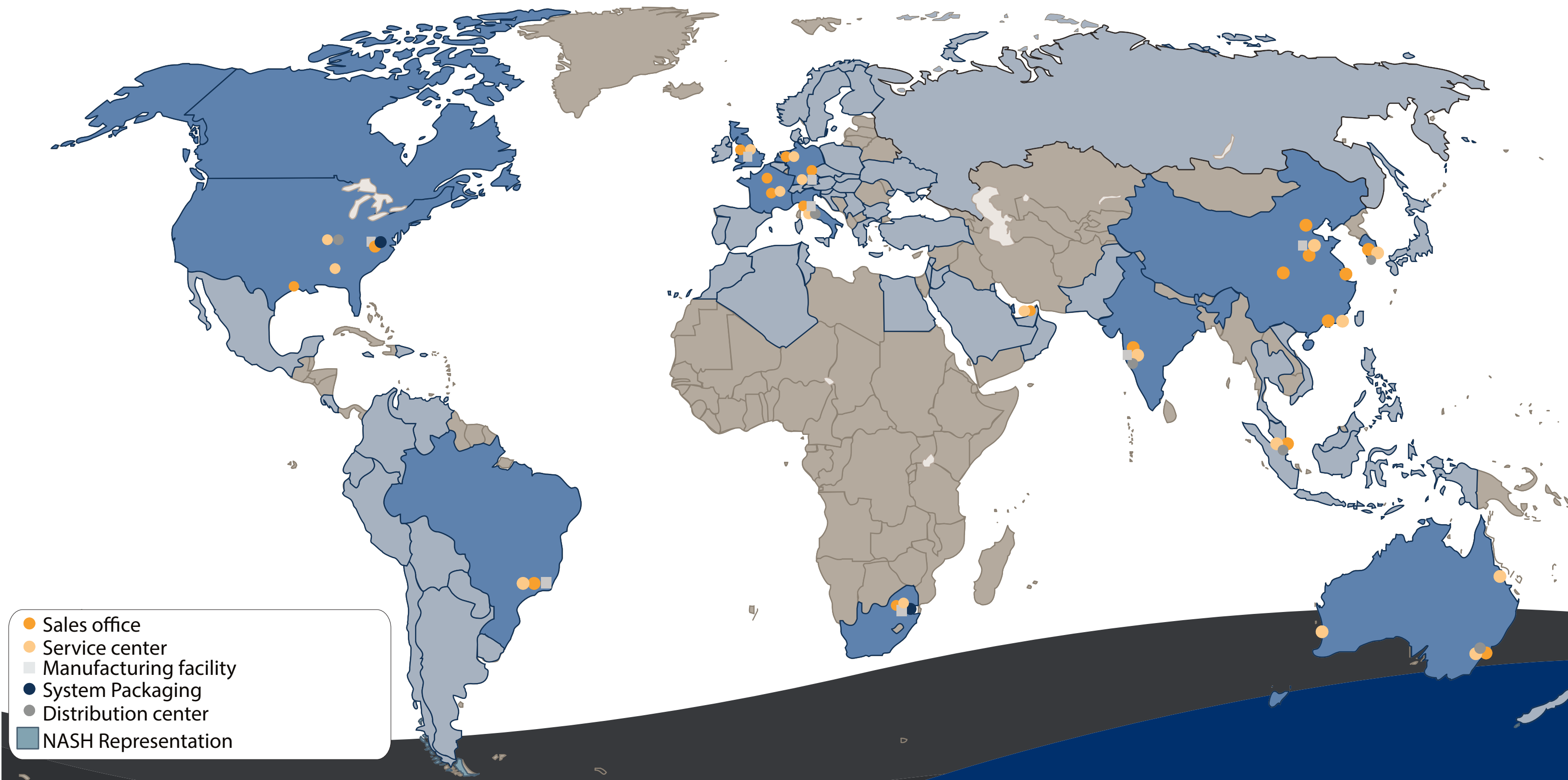
Get the Advice of a Proven & Experienced OEM

When evaluating the benefits of a dry vacuum system, an excellent starting point is to consult manufacturers' websites and marketing materials. It is also advisable to focus your search on suppliers which have a long history of success with vacuum systems for chemical and pharmaceutical processing industries.

As a good case in point, the manufacturer Gardner Denver Nash has the product portfolio and engineering expertise to design and deliver safe, reliable dry vacuum systems for all types of chemical and pharmaceutical process applications. Gardner Denver Nash has consistently demonstrated the added value of its background and capabilities when it comes to solving the most demanding vacuum pump challenges.

The choice of equipment affects the economies of any vacuum process. As with every complex system, it is crucial that each element is selected and combined to not only realize, but also maximize, the anticipated reliability, efficiency and total cost of ownership. Implementing the appropriate vacuum system is a critical part of minimizing production costs and environmental impact.

More information about Nash vacuum pump systems, either wet or dry, can be readily obtained at www.GDNash.com.



To find out more about Nash solutions for the Chemical & Pharmaceutical Industries visit www.GDNash.com

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