# APPLIANCE & HVAC REPORT

Reaching Design Engineers at the OEM Level

October 2021

VOLUME 3 ➢ NUMBER 4




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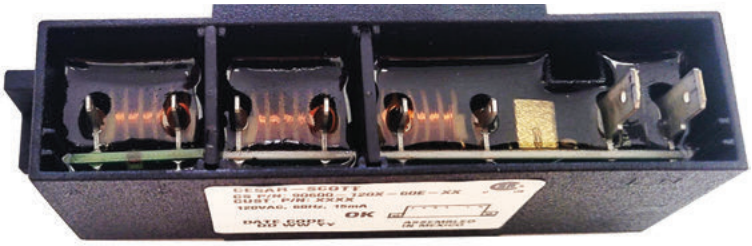



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# Welcome to Our Fourth and Final Issue of 2021



What a year it has been. But happy to say we have remained profitable, thanks to our loyal advertisers and, even more important, our loyal audience. If our readers weren't paying attention to us our advertising base wouldn't continue to support our mission. So thank you readers for helping us succeed.

Part of our revenue stream always goes back into the product. So, for example, we have increased our subscriber base by 20%. We are now at 24,000, primarily US based design engineers who work in our markets.

Care for an espresso? I just read the "single-shot" espresso was created at the turn of the century, the 20th century that is. Milanese inventor Luigi Bezzera patented a machine that forced, or expressed, hot steam through ground coffee beans. Hence the name of this drink.

Recently saw in our local newspaper biz section the following trivia question:

We trace our roots back to 1985 when two guys funded us, aiming to build a strong portfolio of global brands. They succeeded as we now encompass AEG Tools, Dirt Devil, Empire Level hart, Homelite, Hoover, Imperial blades, Milwaukee tool, Oreck, Ryobi, Stiletto Tools and Vax. Some of these brands are more than 100 years old. Hoover began in 1907, Stiletto in 1901 and Empire in 1919. Today we are based in Hong Kong with a market value of almost $33 billion. We specialize (as does ***Appliance & HVAC Report***) in power tools, outdoor power equipment, floor care and appliances. Who are we?

Answer: Techtronic Industries

In the August 7-8 Wall Street Journal, in their Physics column was a piece about grills. Way over my head technically speaking, but since they are appliances I thought I would mention it.

Our whitepaper lineup includes contributions from the following: 3DQue, Henkel, Infineon, JBC Technologies, Littelfuse, Microgroove, Pfeiffer Vacuum, Portescape and Servoflo. We also have a feature on one of the leading woman executives of the commercial appliance industry (you'll have to read it to find out whom) and an article by yours truly.

We will see you in 2022. But if you want to get in contact, and we hope you do, feel free to reach out at **brad@appliancehvacreport.com**. A safe fourth quarter to you and let's hope for a better 2022. How could it not be?

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APPLIANCE & HVAC REPORT
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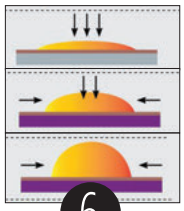
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# October/November

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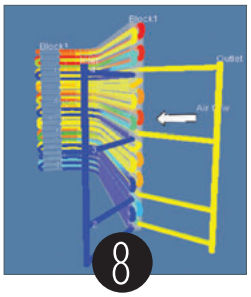
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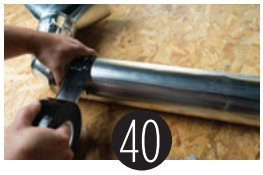
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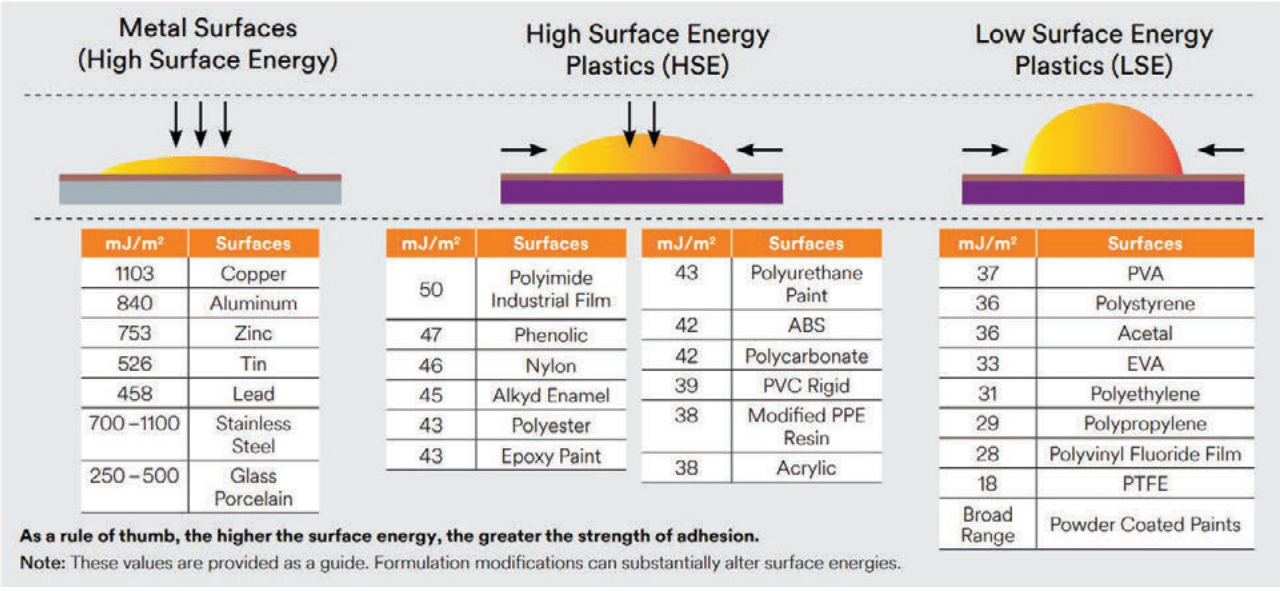
The most common implements of food prep have been through many changes to find their present form. Some of their stories may surprise you.

## DEPARTMENTS

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## Surface energy ranges.

Submitted by 3M




| mJ/m² | Surfaces |
|---|---|
| 1103 | Copper |
| 840 | Aluminum |
| 753 | Zinc |
| 526 | Tin |
| 458 | Lead |
| 700–1100 | Stainless Steel |
| 250–500 | Glass Porcelain |

| mJ/m² | Surfaces |
|---|---|
| 50 | Polyimide Industrial Film |
| 47 | Phenolic |
| 46 | Nylon |
| 45 | Alkyd Enamel |
| 43 | Polyester |
| 43 | Epoxy Paint |

| mJ/m² | Surfaces |
|---|---|
| 43 | Polyurethane Paint |
| 42 | ABS |
| 42 | Polycarbonate |
| 39 | PVC Rigid |
| 38 | Modified PPE Resin |
| 38 | Acrylic |

| mJ/m² | Surfaces |
|---|---|
| 37 | PVA |
| 36 | Polystyrene |
| 36 | Acetal |
| 33 | EVA |
| 31 | Polyethylene |
| 29 | Polypropylene |
| 28 | Polyvinyl Fluoride Film |
| 18 | PTFE |
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**As a rule of thumb, the higher the surface energy, the greater the strength of adhesion.**

**Note:** These values are provided as a guide. Formulation modifications can substantially alter surface energies.

# Specialty Tapes & Adhesives Put the Stick on Low Surface Energy Materials

**BY KATE GLUCK**

Plastics. They're everywhere. Home appliances, consumer electronics, medical devices, even heavy industry – wherever there's a need for improvements in durability, aesthetics, and cost you'll inevitably find plastics. And while thermoplastics like polyolefin (TPO), polypropylene (PP), and high and low density polyethylene (HDPE/LDPE) are incredibly popular with manufacturers they aren't without their design challenges. Due to a phenomenon called low surface energy (LSE), it's often difficult to adhere to them. It's this lack of stick-to-itiveness that can lead to assembly challenges for product design engineers, especially those looking to use adhesives instead of mechanical fasteners.

In this brief article we'll touch on surface energy and what it means in the adhesives world, perform a shallow dive into the pool of adhesive science, and introduce you to an array of pressure sensitive adhesives (PSAs) that have been formulated specifically for use on low surface energy (LSE) materials.

### Adhesives & Bonding: The Basics

Before we get into the nitty gritty of bonding to low surface energy plastics and other specialty materials, we thought we'd take just a moment to cover a few bonding basics. Bond or adhesion strength is the interfacial strength between the adhesive and the substrate and it's typically the most important consideration when designing a strong adhesive-bonded assembly. Cohesion strength is the internal strength of an adhesive, that is the ability of the adhesive to keep itself together under stress. The higher the cohesive strength, the stronger the adhesive. Wetting out is the ability of liquids to spread out across the surface of a material and is a direct measure of how intimately the adhesive will come into contact with different solid surfaces.

**Pressure sensitive adhesives** have a variety of advantages when compared with their mechanical fastener cousins. Among other things, they

- Weigh less
- Distribute loads more evenly across the bonding plane
- Resist vibration, impact, flexing, shock, and heat
- Fill surface gaps more effectively
- Minimize corrosion by sealing joints
- Reduce assembly complexity
- Can be laminated to other materials such as foams, felts, flocks for added benefit
- Can be die-cut into custom shapes and sizes

## Surface Energy: Where Stick Happens (Or Doesn't)

If you've spent any time dealing with adhesives, chances are very good that you've run across the term surface energy. Surface energy is basically the measure of a given surface's ability to interact and form a bond with a liquid – in this case, an adhesive. An adhesive must wet out (spread) effectively across the surface in order to form a strong bond. Most standard adhesives can spread/fully wet out on high surface energy materials, while on low surface energy surfaces, those same adhesives will resist flowing and "bead up" (think of water on a freshly waxed car hood), resulting in either poor bond strength or, in worst cases, bond failure.

In order to achieve full wet out and a secure bond, it's important that the surface energy of the adhesive be as low or lower than the surface energy of the substrate to which it is to be bonded. This requires one of two things - either raising the surface energy of the substrate or using an adhesive that has been specifically formulated for low surface energy applications.

While effective, surface treatments like priming, flame treating or plasma treating are often expensive, can increase production times and, as is the case with primers, can come with EHS regulations. On the other hand, low surface energy tapes and adhesives are engineered to achieve the same objective as mechanical and chemical surface treatments without all the unwanted baggage.

## Low Surface Energy Adhesive Solutions

As consumer demand continues to drive the use of low surface energy substrates so too goes the demand for specialty adhesives and tapes designed specifically for bonding and joining them without the need for primers, promoters or surface treating. At JBC Technologies we have a long history of working directly with some of the world's best adhesives and tapes manufacturers to provide our customers with custom die-cut parts that stick to even the toughest LSE surfaces. In addition to offering a breadth of converting services, we offer material selection assistance, rapid prototyping, and design for manufacturability recommendations. The earlier we get brought in at the design stage of a product, the more assistance we can provide.

Depending on end use case, some of the more common LSE adhesives solutions we recommend include:

**For low profile applications** where a thin bond is required —The 3M™ 300 LSE adhesive series offer high initial bond and shear strength, are resistant to heat, moisture, and solvents and are effective at sealing out water, dust, and chemicals.

**For permanent bonding and noise dampening** — The 3M VHB™ Tape LSE Series which features double-sided acrylic foam tapes that dampen noise and vibration and provide a flexible bond that allows for thermal expansion up to three times its thickness.

**For high-strength bonding and attachment** in appliance & HVAC applications – Avery Dennison AFB 6211 double-coated foam tape with a modified acrylic adhesive can help eliminate the need for mechanical fasteners while offering high adhesion on LSE materials, good shear resistance for shock absorption and stress distribution, and very good all-around environmental performance.

**For foam bonding and** strong performance across a wide range of LSE surfaces — Avery Dennison FT 8327 double-coated polyester features a differential rubber adhesive system that offers high tensile strength, strong resistance to tearing and great die cutting performance, along with excellent bond characteristics across a multitude of low surface energy materials.

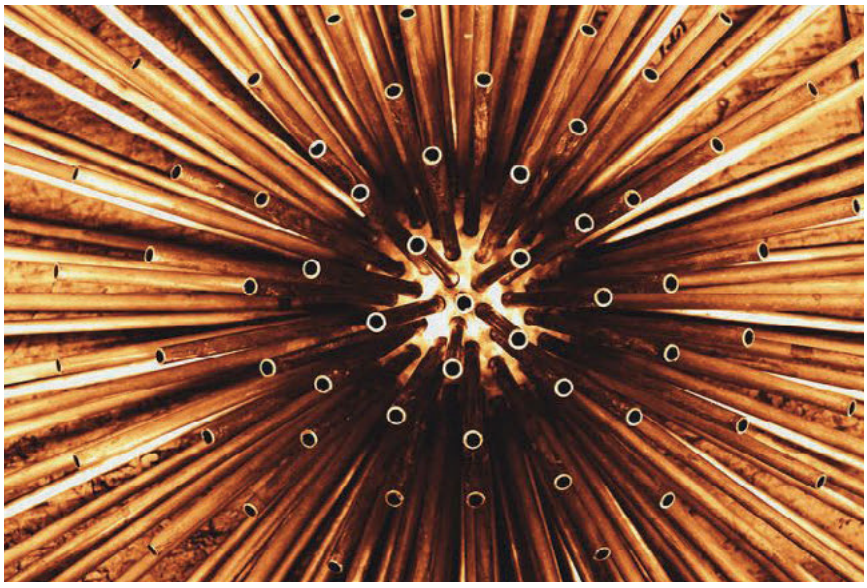
## Turning Rolls of Adhesive into Functional Parts

JBC Technologies excels at transforming pressure sensitive adhesive (PSA) tapes into custom die-cut parts. Our extensive battery of flexible materials converting equipment includes high-speed, tight-tolerance rotary die-cutting presses, hot and cold roll laminators, and both narrow and wide web hydraulic die-cutting machines. For over three decades, we've been putting our engineering and manufacturing expertise to work transforming rolls of foam, insulation, adhesive tape, plastic film, melt-blown fabric, and even metal foil, into custom die-cut parts that have helped thousands of manufacturers solve critical design challenges. ●

For more information about JBC Technologies, we invite you to explore our website at www.jbc-tech.com and, when you're ready, to give us a call at 440.327.4522. Let us help turn your challenges into solutions.



***Kate Gluck*** *is the Vice President of Business Development for JBC Technologies. Prior to this Kate was JBC's Director of Sales and Marketing and was responsible for all of the company's sales and marketing operations, including end-to-end management of JBC's online presence and advertising, estimating and sales activities, and service and support in all markets. Kate's current mission is to partner with industry experts and leading suppliers to uncover new opportunities for profitable, sustainable growth for JBC's custom and branded products.*



# Virtual Conferences Focus on Energy Efficient Heating and Cooling

**BY YORAM SHABTAY AND KERRY SONG**

### Advanced Technology Lowers the Demand for Energy

The energy efficiency of heating and cooling appliances and equipment steadily increased in recent years, partly thanks to the use of smaller diameter copper tubes in heat pumps, air conditioners and refrigeration systems. Efficient appliances and building systems already are helping to draw down greenhouse gas (GHG) emissions and there is still plenty of room for improvement.

Research and development on energy efficiency were presented in 2021 at ACEEE's Hot Water Forum and the Purdue's International Refrigeration and Air Conditioning Conference. Both conferences took place virtually this year and high quality presentations and papers were delivered at both.

What follows are some highlights from each of these two conferences, emphasizing the energy efficiency of heating and cooling systems.

### Cheers for HPWHs at Hot Water Forum

The 13th Hot Water Forum featured more than 60 speakers presenting on a wide range of topics. Of course, participants were especially eager to learn about the use of heat pumps water heaters (HPWHs) as a means to fight climate change. Grid decarbonization and electrification of homes and commercial buildings were central to many of the presentations. Emerging HPWH technologies were also discussed, including first looks at models that use low-GWP refrigerants and natural refrigerants.

Indeed, heat pumps for water and space heating represent a tremendous opportunity for "doing more with less." HPWHs allow for the electrification of water heating, and they are multiple times more efficient than electrical-resistance water heaters. High-efficiency HPWH can play a pivotal role in drawing down GHG emissions from fossil fuels.

#### GETTING THE WORD OUT

The Advanced Water Heating Initiative (AWHI) within the New Buildings Institute made the case for heat pump water heaters. The session titled "All Boats Rise on Heat Pump Water Heaters" included an overview of an advertising campaign that promoted HPWHs in the northwestern region of the United States. The campaign was developed in Partnership with the U.S. Department of Energy to stimulate the market for HPWHs and possibly be adopted by manufacturers and utilities nationally.

According to the AWHI Playbook and Progress Report (February 2021): https://newbuildings.org/nbi-key-markets/advanced-water-heating-initiative/

"No single region can move the national market on its own, and it will take a concerted and coordinated effort to drive HPWHs into the mainstream."

#### MULTIPLE MODE OPERATION

The session on "Advances in Heat Pump Water Heaters" included a presentation by Greg Pfotenhauer, who is a data scientist from Franklin Energy. Pfotenhauer described experiments on a Rheem HPWH that has three modes of operation, including Heat Pump Only, Energy Saver, and High Demand modes. Pfotenhauer examined usage data and made general recommendations for design.

## LOW GWP REFRIGERANTS

In the same session, a presentation was given by researchers from Oak Ridge National Laboratory. Kashif Nawaz, Jeff Munk, Bo Shen, Ahmed Elatar and Walt Hunt delved into the consequences of using R1234yf refrigerant in a HPWH. They noted that future work would involve an optimized HPWH using a new evaporator with the system optimized for R-1234yf charge.

## COPPER TUBES IN HPWHs

The session "Modeling and Optimizing Tanks, Heat Exchangers, and Controls" was of special interest to users of efficient small diameter copper tube MicroGroove technology. Yoram Shabtay from Heat Transfer Technologies and Kerry Song from International Copper Association reported on "Optimization of Copper-tube Coils for Energy Efficiency and Charge Reduction in Heat Pump Water Heaters."

Tank type water heaters are the most common water heaters and are very promising for reducing peak demand because of their large energy storage capacity. Modeling of the tank, the heat exchanger, and controls were explored in the presentation by Shabtay and Song. The slideshow is posted online at https://microgroove.net/hxsim. Qualified end-users are welcome to download a fully working copy of HXSim courtesy of ICA.

## MORE MODELING FROM GTI AND ORNL

In the same session, Divya Thiagarajan and Jonathan Harrison of Gamma Technologies Inc. (GTI) introduced a physical model of buoyancy and flow phenomena within the tank itself.

The third presentation from ORNL and the Department of Energy describes a method to minimize electricity cost during time-of-use electricity pricing. Authors Kadir Amasyali, Jeffrey Munk, Kuldeep Kurte, Teja Kuruganti, and Helia Zandi detailed how controls could be used to save 11 to 33 percent in electricity costs compared to the baseline. https://www.energystar.gov/products/water_heaters/high_efficiency_electric_storage_water_heaters/how_it_works

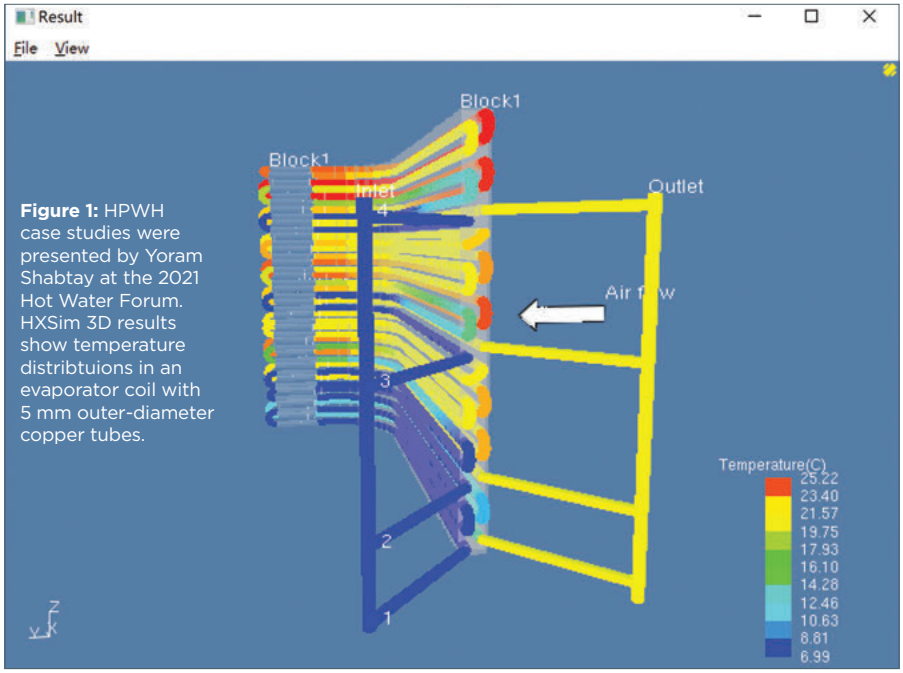



**Figure 1:** HPWH case studies were presented by Yoram Shabtay at the 2021 Hot Water Forum. HXSim 3D results show temperature distribtuions in an evaporator coil with 5 mm outer-diameter copper tubes.

## WEEK TWO PLENARY: COMPELLING STATISTICS

The 2021 Hot Water Forum consisted of four sessions per day for four days spread over two weeks. The second week was kicked off by a plenary from the New Buildings Institute (NBI) and Advanced Hot Water Initiative (AHWI). This presentation featured excellent statistics making the case for HPWHs and fully capturing the magnitude of the mission and goals of NBI-AHWI.

## NOT ONLY RESIDENTIAL

The third session on day three (i.e., session "S11") was on Next-Gen Commercial Water Heating Products. These are large WHs, including some with large evaporators split from the large hot water tank.

Ryan Hamilton of Nyle Water Heating Systems described diverse products as well as experiments with alternative and natural refrigerants in split systems, including split outdoor evaporators.

In the same session, Lynn Mueller, Matt Wardlow and Elisa Kimus from the SHARC Energy Systems demonstrated an interesting way to save energy by optimally arranging water tanks in a commercial setting. SHARC is an incubator company associated with the Electric Power Research Institute (EPRI).

Last but not least, Cain White described a 40 kW HPWH that uses carbon dioxide (R744) as a refrigerant in commercial applications. These modules can be stacked to provide hot water for large commercial applications. The helical gas cooler with copper tubes was especially noteworthy in the design. White is the director of Commercial Product Management at Mitsubishi Electric Trane HVAC US.

## HPWH PRODUCT ROUNDUP

Amruta Khanolkar from the New Buildings Institute kicked off the final day of the Hot Water Forum by comparing residential HPWHs from Bradford White, Rheem, A.O. Smith, GE, Nyle, and SanCO2; and also commercial (central) HPWHs from SanCO2, Nyle, Colmac, Mitsubishi, AERMEC, Mayekawa and an unnamed US manufacturer that will release a new product in 2022.

CO2 systems from Sanden, Mitsubishi, and Mayekawa were among the commercial systems described and compared by Khanolkar.

All told, the 2021 Hot Water Forum exceeded expectations. The importance of this forum is underscored by the fact that water heating ranks third in terms of energy usage for domestic applications, exceeded only by space heating and space cooling.

### A Virtual Gathering at Purdue 202ONE

The organizers of the Purdue Conferences were forced to postpone the biannual conference that normally would have occurred in July 2020; although there were aspirations to meet live in 2021, a decision was made to go "virtual only" for the rescheduled event, which was dubbed "202One."

## DESTINATION GATHER TOWN

The chosen "virtual setting" (i.e., "Gather" or "Gather Town") was well suited for Purdue 202One. Papers and presentations could be viewed in advance and participants used an avatar to virtually "walk the floor" of Gather Town, striking up live video chats with authors and other attendees. Upon entering a virtual conference room in Gather Town, one could readily view the featured slideshow and paper and spontaneously interact with the original investigators as well as the assembled group.

The range of topics was quite extensive. Of possible interest to heat-exchanger engineers and appliance designers are papers on the following topics.

- Tube and fin research
- Coil circuitry (including distributor design)
- Refrigerants
- Appliance design

There were several papers about the properties of tubes, including copper tubes, and in some cases specifically on MicroGroove smaller-diameter copper tube technology.

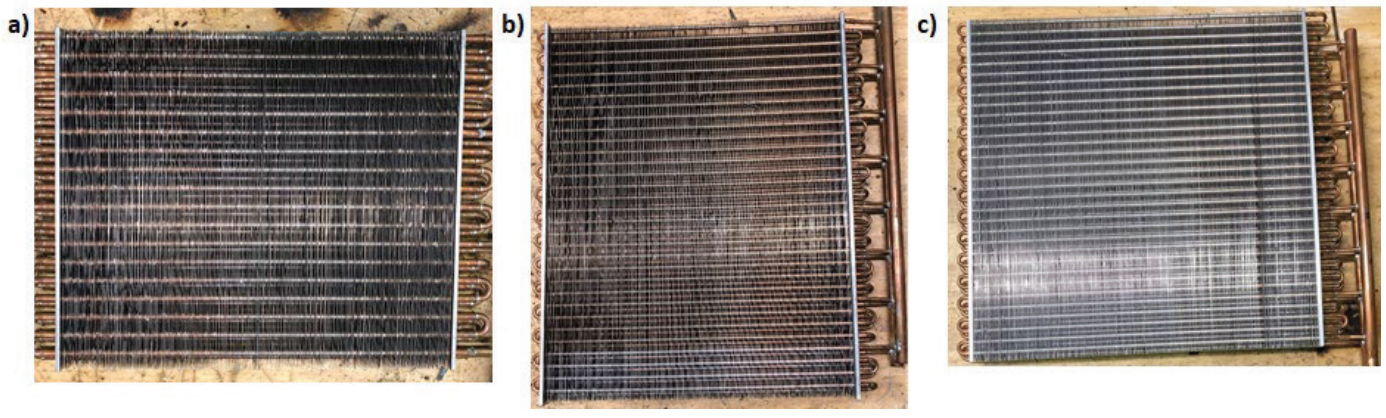
NOTE: Purdue 202One papers can be accessed online from this webpage. https://docs.lib.purdue.edu/iracc/ Search 2021 papers using paper number, author(s), company or the title of the paper.

## A PRIZE WINNING TECHNIQUE

Min Che and Stefan Elbel from the University of Illinois Urbana presented on "Experimental Evaluation of Local Air-Side Heat Transfer Coefficient on Single Fins" (Paper 2176). The paper won first place for doctoral candidate Min Che in the student competition. https://mechse.illinois.edu/news/40254.

Che described new experimental methods for visualizing and quantifying Heat Transfer Coefficient (HTC) distributions on fin surfaces. The technique involves spraying a thin yellow coating (20 μm) on the fins and placing them in a wind tunnel. Tracer quantities of ammonia are present in the wind tunnel airflow, causing the color of the surface of the fins to change from yellow to blue. By correlating the rate of local color change with the rate of local mass transfer (and hence also heat transfer) local HTCs on the fin surfaces can be quantified.

**Figure 2:** Simulation results for MicroGroove copper tubes were verified by wind tunnel tests on actual heat exchangers: ***(a)*** coil with 5 mm tubes and 19 fins per inch (fpi); ***(b)*** 3 mm tubes and 21 fpi; ***(c)*** 3 mm tubes and 28 fpi.



## FIRST 3 mm DIAMETER TUBE HEAT EXCHANGER

The paper on "Design Optimization of 3mm and 5 mm Copper Tube and Flat Fin Air-to-Water Heat Exchangers with Experimental Validation" (Paper 2195) is of particular interest to followers of MicroGroove Technology.

Authors included Daniel Bacellar, Dennis Nasuta, Song Li and Cara Martin from Optimized Thermal Systems, Inc. Beltsville, Maryland as well as Dale Powell of the Copper Development Association. The simulation results were validated by building prototype heat exchangers.

According to the authors, to the best of their knowledge, the experimental work is the first that performed experimental tests on a heat exchanger using 3 mm diameter copper tubes. The numerical optimization illustrated how, under equivalent geometry characteristics, a 3 mm diameter tube offers advantages with respect to thermal-hydraulic performance.

## LABORATORY VALIDATION OF FIN-AND-TUBE HEAT EXCHANGER SIMULATIONS

Researchers claim they can validate computer simulations to a high degree of accuracy, using a novel experimental apparatus that includes a small wind tunnel.

Results were presented in a paper titled "Development of Novel Experimental Infrastructure for Collection of High-Fidelity Experimental Data of Refrigerant to Air Heat Exchangers" (Paper 2222). The paper was authored by Saad Saleem, Craig R. Bradshaw and Christian K. Bach from Oklahoma State University; and Omer Sarfraz from Johnson Controls.

The data collection apparatus collects high fidelity experimental data for fin-and-tube heat exchangers for three operating modes: (1) single-phase refrigerant, (2) evaporator, and (3) condenser mode. The pumped refrigerant loop can control refrigerant test conditions as well as the flowrate to each individual heat exchanger circuit. The apparatus has been sized to test heat exchanger coils up to a capacity of 5 tons (17.5 kW).

The first test of the apparatus was carried out on a typical copper tube coil with aluminum fins. This four circuit coil could also be simulated with HXSim simulation software from the International Copper Association.

## NOVEL TUBE SHAPES

A memorable technical article on novel tube shapes is titled "Experimental Study of a Novel Shape-Optimized Air-to-Refrigerant Heat Exchanger under Evaporator Conditions" (Paper 2539). The paper was authored by Ellery Klein, Vikrant Aute and others from University of Maryland and Yoram Shabtay from Heat Transfer Technologies.

Using the novel tube shape, a finless heat exchanger was designed with a 25 percent reduction in volume, 20 percent reduction in face area, and an 8 percent reduction of internal volume compared to a state-of-the-art, air-to-refrigerant heat exchanger; yet it was designed to have the same air-side pressure drop and a capacity equal to or greater than the conventional heat exchanger. The predicted and measured values show good agreement, with the performance verified under dry and wet evaporator conditions using R 410A as the refrigerant.

## AUGMENTING NUCLEATION ON COPPER TUBES

Numerous researchers have found that surface roughness can enhance pool boiling heat transfer. Most recently magnetic abrasive finishing (MAF) was used to augment the activated nucleation sites on the internal surfaces of copper tubes. The technique provided higher heat transfer coefficients for the in-tube flow boiling as expected.

"Heat Transfer and Pressure Drop Characteristics of Water Flow Boiling in Internally Enhanced Tubes" (Paper 2685) delivers the results from three laboratories. Three authors from Oak Ridge National Laboratory (Cheng-Min Yang, Kashif Nawaz, and Anthony Gehl) collaborated with two from the University of Florida, Gainesville (Hitomi Yamaguchi and Fang Xu) and one from Texas A&M University (Jorge Alvarado) to develop and test a copper tube internally enhanced using the MAF technique.

## BALANCING RTPF WITH MCHX

Moving beyond studies focused on tubes, several papers addressed tube circuitry and maldistribution.

As an indicator of the continued importance of such research, Khaled Ibrahim Alghamadi and Christian Konrad Bach from Oklahoma State University endeavored to balance a system that uses microchannel tubes in the condenser and 10 mm round tubes in the evaporator. Their results are given in a paper titled "Dynamic Modeling of Packaged Air Conditioner with Microchannel Heat Exchanger Condenser" (Paper 2267).

The reasons for using round tubes in the evaporator have to do with the maldistribution of refrigerant that can occur with microchannel heat exchangers. After reviewing the literature on modeling the system balancing, the authors point out that little work has been done on systems that include a combination of microchannel tubes and round tubes.

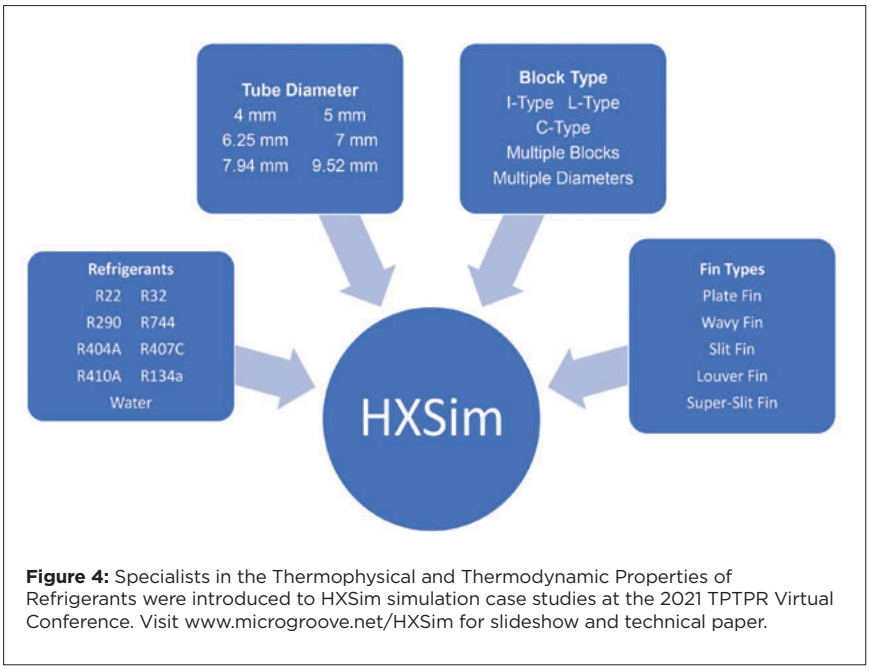



**Figure 4:** Specialists in the Thermophysical and Thermodynamic Properties of Refrigerants were introduced to HXSim simulation case studies at the 2021 TPTPR Virtual Conference. Visit www.microgroove.net/HXSim for slideshow and technical paper.

## OPTIMIZING THE DISTRIBUTORS

Although the details of the research are beyond the scope of this overview, several papers on flow distribution are noteworthy.

Yufang Yao and Pega Hrnjak, from University of Illinois and Creative Thermal Solutions, respectively, presented a two-part paper on refrigerant distributors (Paper 2464). Part one (10 pages) is titled "Effect of flow regime before distributor on two-phase flow distribution" and part two (9 pages) is titled "Effect of orientation on performance of the refrigerant distributor."

Their research demonstrates the effect of the flow regime at the distributor inlet on the uniformity of two-phase flow distribution. The flow regime is determined by mass flux, quality, and distance from the expansion device. A high-speed camera is used to visualize the two-phase flow regimes between the expansion valve and distributor; and also to interrogate the flow regime inside the distributor. A close study of both of these papers provides insights into the design of distributors and circuitry for evaporators.

Similarly, Saugata Sarkar, who is a senior thermal system engineer with Triumph Group Integrated Systems, provides insights into evaporator designs through modeling of ideal distributors in a paper titled "Computational Fluid Dynamics (CFD) Modeling of Two Phase Refrigerant Flow in Evaporator Distribution System" (Paper Search Term: Triumph).

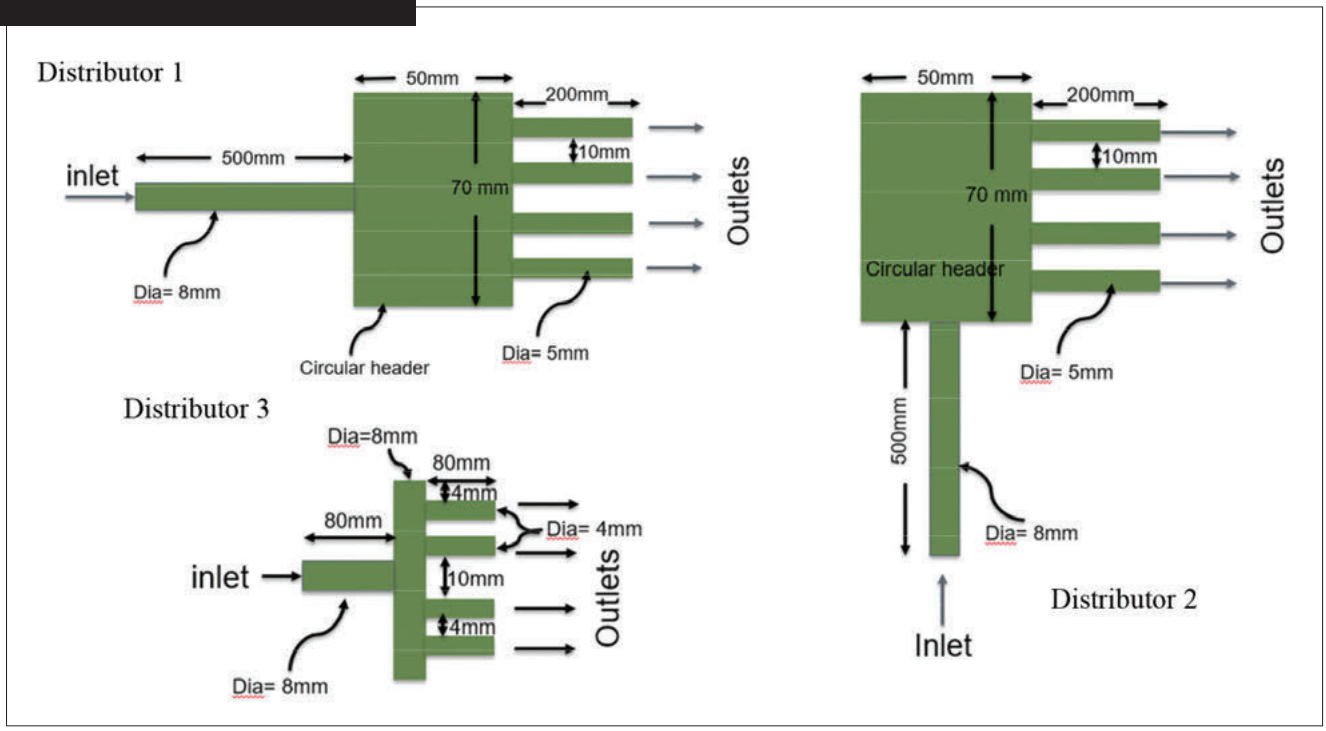



**Figure 3:** The performances of these three ideal distributors were simulated by Saugata Sarkar, a senior thermal system engineer with the Triumph Group. (Illustration used with permission.)

The more general topic of how to simulate distributors was tackled by Zhenning Li from ORNL and Vikrant Aute from University of Maryland. They outlined their algorithm for the optimization of circuitry in evaporators in a paper titled "Enhanced Integer Permutation based Genetic Algorithm for Optimization of Tube-Fin Heat Exchanger Circuitry with Splits and Merges" (Paper 2574). According to their case studies, optimal designs obtained using their algorithm exhibit higher capacity, lower pressure drop and better manufacturability compared to baseline designs.

## RESEARCH ON REFRIGERANTS

Refrigerant blends are on the minds of heat exchanger designers everywhere as OEMs strive to reduce the GWP of refrigerants in AC, heat pump and refrigeration applications. The use of blends allows designers to make tradeoffs between GWP, flammability, cost and performance.

Ternary blends obtained mixing hydrofluorocarbons (HFC) and hydrofluoroolefins (HFO) have recently been proposed as substitutes for high global warming potential (GWP) fluids employed in refrigeration and air-conditioning. Several papers from the Purdue Conference give a preview of what is to come.

Ternary blends were also a hot topic on the program of the Thermophysical Properties and Transfer Processes of Refrigerants (TPTPR), an international conference that takes place every four years. This year TPTPR was a virtual event from September 1-3, 2021. A paper on heat-exchanger simulations was presented at TPTPR 2021 by Yoram Shabtay, Kerry Song and Frank Gao of HTT and ICA. The TPTPR presentation and the paper titled "Simulation of the effects of copper tube diameter on refrigerant charge reduction in split AC systems and refrigerated cabinets" are available online at https://microgroove.net/hxsim.

## PADOVANS LOOK AT R455A AND R452B

The University of Padova is renowned for its work on the thermophysical properties of refrigerants. Marco Azzolin, Arianna Berto, Stefano Bortolin and Davide del Col recently conducted research on two different zeotropic ternary mixtures: R455A, which is a mixture of R32, R1234yf and R744 (21.5/75.5/3.0% by mass composition); and R452B, which is mixture of R32, R1234yf and R125 (67.0/26.0/7.0% by mass composition).

They measured condensation and flow boiling heat transfer coefficients inside a minichannel (0.96 mm diameter) and inside a conventional tube (8.0 mm diameter) for these blends. The results of these methodical laboratory measurements were reported in a paper titled "Two-Phase Heat-Transfer of Low GWP Ternary Mixtures" (Paper 210049).

## ORNL DOUBLES DOWN ON REFRIGERANT BLENDS

Researchers from Oak Ridge National Laboratories (ORNL) described a novel framework for optimizing low-GWP refrigerant mixture compositions. Using this framework, new refrigerants can be matched to the system. The condenser and evaporator circuitry configurations can be optimized simultaneously with the mixture compositions.

The case studies using an experimentally validated R410A Roof Top Unit (RTU) show that the proposed optimization approach can generate new binary and ternary mixtures and new circuitry designs to improve system EER, reduce refrigerant flammability, and maintain a low GWP.

This paper is titled "Optimization of Refrigerant Compositions for Low-GWP Refrigerant Mixtures Using Segment-by-segment Heat Exchanger and Detailed System Models" (Paper 2614). The ORNL authors are Zhenning Li, Bo Shen, and Kyle Gluesenkamp.

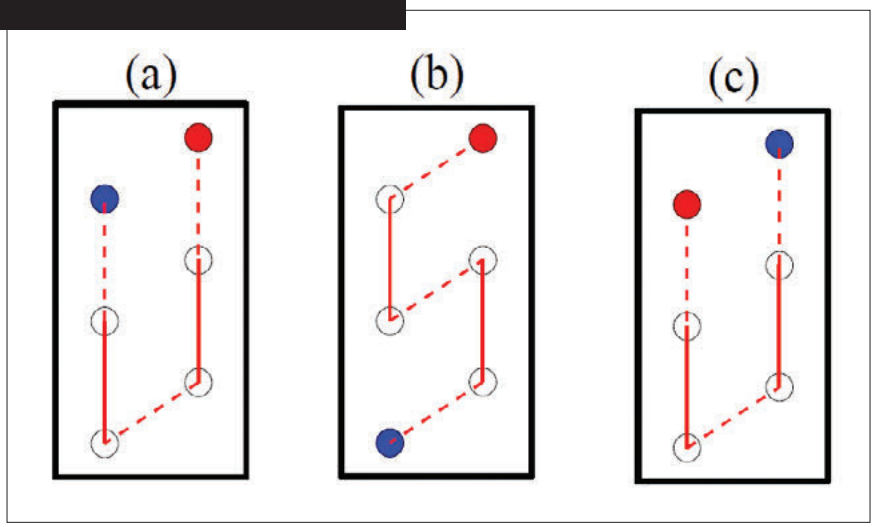



**Figure 5:** Shen and Li from ORNL describe these three basic types of tube circuitry a paper about low-GWP refrigerants. (Illustration used with permission.)

## EMERSON WEIGHS IN ON LOW-GWP OPTIONS

The new refrigerant blends and the optimized heat exchangers must work in harmony with the compressors. Emerson weighed in on new refrigerant mixtures with a paper titled "HVAC Systems with Low Global Warming Potential Refrigerants: A Case Study" (Paper 2144) by Vijay Bahel, Rajan Rajendran, Brian Butler and Drew Welch, from Emerson, Dayton, Ohio.

The Emerson paper provides an excellent overview of things to come with respect to refrigerant blends. In the conclusion, the authors state key takeaways as follows: (1) we can conclude that R-32 and R-454B, two popular R-410A replacement candidates with a GWP below 750, both have system performance equal to or better than R-410A; (2) refrigerant options with a GWP below 300 all underperform versus R-410A. The authors also found electronically commutated motors (ECM) to be more efficient than permanently split capacitor (PSC) condenser fans and evaporator blower motors.

## EFFECTS OF MICROFINS ON BLENDS

Ethan P. Matty and Brian M. Fronk from Oregon State University compared the condensation heat transfer and pressure drop for zeotropic refrigerant R454C and its individual components in a horizontal microfin tube with a 4 mm outer diameter. According to these authors, microfin tubes enhance heat transfer by several mechanisms: the microfins increase the internal surface area of the tube, the fins drain condensate from the fin tip to the trough region, and the microfins produce secondary flow structures.

Noting the limited data on HFO/HFC mixtures in microfin tubes, Matty and Fronk conducted experiments on the complete condensation of R454C, R1234yf and R32 for saturation temperatures of 40, 50 and 60 °C and mass fluxes from 100 to 600 kg/m$^2$s. They compared their results on heat transfer and pressure drop to correlations from the literature; and they also calculated heat transfer enhancement factors and pressure drop penalty factors for each refrigerant. Their paper is titled "A Comparison of Condensation Heat Transfer and Pressure Drop for Zeotropic Mixture R454C and its Components, R32 and R1234yf, in a Horizontal Microfin Tube." (Paper 210068)

## THE MULTIPLE BENEFITS OF LESS CHARGE

No matter the HFC/HFO blend, lowering the refrigerant charge has the dual effect of reducing the system GWP and also the amount of flammable refrigerant in the system. Costantino Guzzari, Marco Azzolin, Sandro Lazzarato and Davide del Col from the Università degli Studi di Padova addressed this issue in the paper titled "Effect of the refrigerant charge on the system performance and mass distribution in air-to-water systems" (Paper 210064).

These authors analyzed the influence of refrigerant charge on the system performance and on the mass distribution in an air-to-water reversible heat pump working with R32. They used a mathematical model to predict the refrigerant charge within the heat exchangers. The results show that most of the charge is stored in the condenser and that an optimal charge can be found to maximize the system COP. The same model can be used to compare various refrigerants in terms of direct and indirect impact on the greenhouse effect.

## CONCEPTS IN APPLIANCE DESIGN

Many of the results mentioned above directly apply to the development of optimized heat exchangers for improving the efficiency of appliances, including heat pumps for space heating and water heating; as well as air conditioners and refrigeration equipment. There were also papers specifically on heat pumps for clothes dryers and dishwashers.

Examples of papers on clothes dryers include a paper titled "Experimental Investigation of a Heat Pump Tumble Dryer with a Zeotropic Refrigerant Blend" (Paper 1012) from the Technische Universität Dresden; and a paper titled "Thermodynamic Analysis of Thermo-vacuum Clothes Drying Operation" (Paper 2406). The latter paper is a collaboration between Wilson Engineering Technologies, Inc., the Gas Technology Institute (GTI), and ORNL. It examines the intriguing concept of drying clothes in a vacuum in which case the speed of drying could be increased and the energy consumption decreased by the vacuum.

A dedicated heat pump for producing very high temperature water for a commercial dishwasher is described in a paper titled "Development of a High Temperature Water Heat Pump in Vent-Less Dishwasher Application" (Paper 2341) by Daqing Li and Suresh Shivashankar, who are both from Emerson Commercial & Residential Solutions, in Sidney, Ohio, USA.

This brief synopsis paints a picture of ongoing research from national laboratories, universities, industry suppliers and OEMs. As fundamental research advances, it is clear that there is much room for improvements in the efficiency of heating and cooling appliances and equipment.

Scientific research on the refrigeration cycle, the thermophysical properties of refrigerants and the optimization of heat exchanger designs gives appliance designers new tools and technologies for efficient heating and cooling in residential, commercial and industrial applications.

## Countdown to 2021 UN Climate Change Conference

As we look ahead to COP26, an important question looms: What can be done to further improve the energy efficiency of heating and cooling systems?

The 2021 UN Climate Change Conference (COP 26) is scheduled to take place in the city of Glasgow, Scotland from October 31 to November 12, 2021.

Although the conference was delayed by the global pandemic for one year, expectations are high as world leaders, policy makers and scientists gather for what promises to be a turning point in addressing climate change.

Aggressive-yet-realistic targets for the reduction of greenhouse gas (GHG) emissions will be deliberated in Glasgow. Progress has been made since the Paris Agreement was negotiated at COP 21 in 2015 but much more progress is needed to avert climate catastrophes in our lifetime.

Energy production by solar and wind has increased significantly in the past 20 years. In many instances, it is now less costly to generate electricity from solar and wind rather than fossil fuels. The technology exists.

What is still lacking is the willingness to put the technology into action and scale up clean technologies by a few orders of magnitude if we are to be successful in scaling down reliance on fossil fuels.

Drawing down usage of fossil fuels such as coal, oil and gas is the key to reaching sustainability goals of the Paris Climate Treaty. Renewable energy resources such as wind and solar can replace coal-burning power plants. Simultaneously, in transportation and buildings, the use of oil and gas can be drawn down through the electrification of automobiles and heating systems.

This transition will be facilitated by the use of smaller-diameter copper tubes in high-efficiency heat exchangers, which allow for the development of systems that consume less energy. ●



***Yoram Shabtay**, President of Heat Transfer Technologies, has extensive background in heat exchangers development and production and has been working with the ICA for over two decades.*



***Kerry Song** is a Project Manager with the International Copper Association. He is also the Secretary-General of Refrigeration and Air-conditioning Heat Exchanger Technology Alliance in China.*

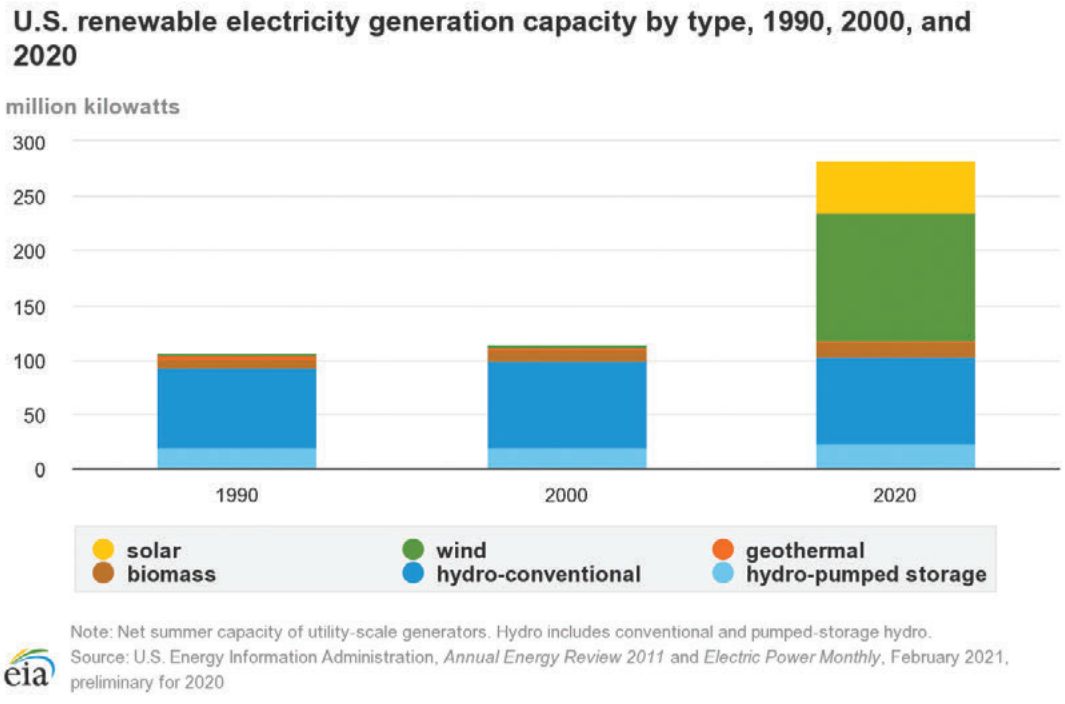
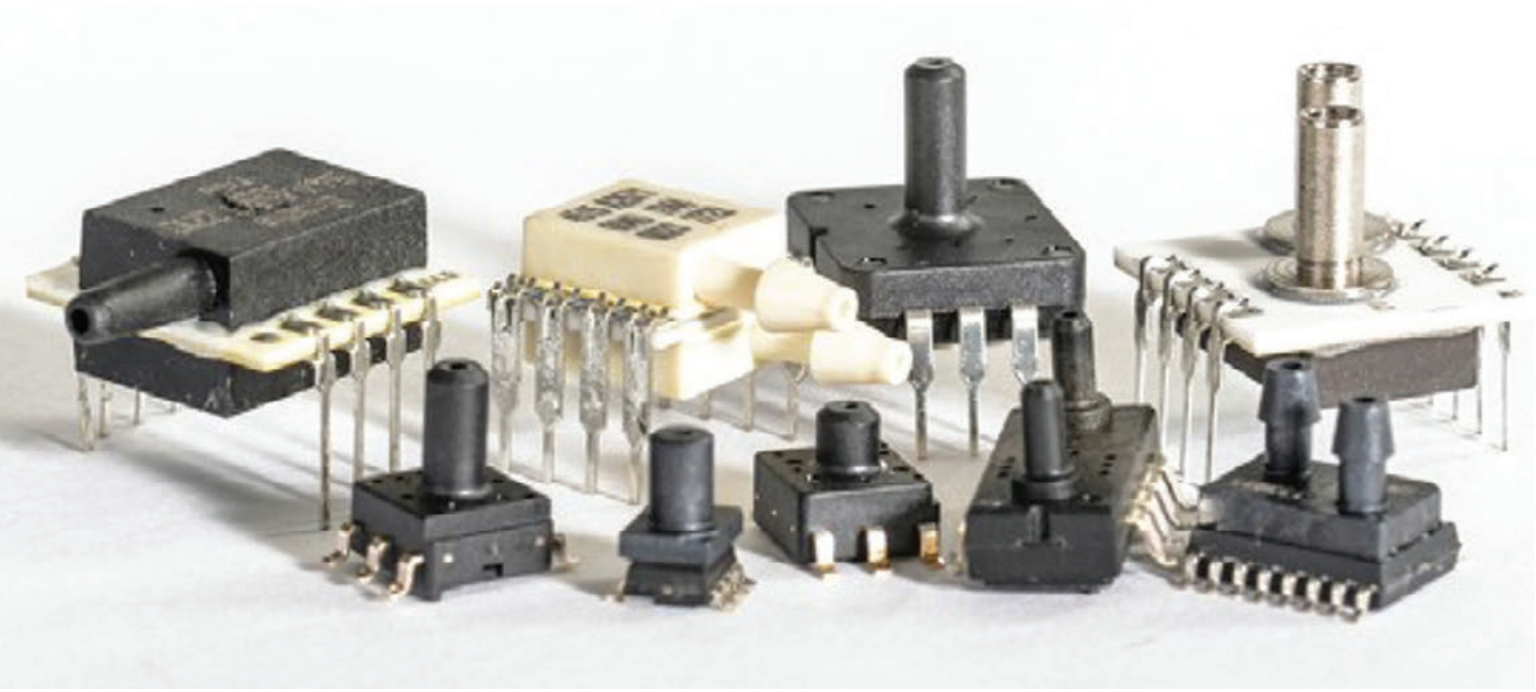



**Figure 6:** All eyes will be on Glasgow this Fall for the UNCCC (COP 26).



# How to Choose A Board Level Pressure Sensor

**BY DAVID EZEKIEL**

The advent of microelectromechanical systems (MEMS) technology has resulted in a wide range of pressure sensor style and performance options, allowing for use in an equally wide range of applications, including industrial instrumentation, medical monitoring, HVAC equipment, consumer devices, and many others.

With so many different pressure sensor models, accuracies, and features available from a variety of manufacturers, it's easy to get overwhelmed and choose an inappropriate pressure sensor model that either underperforms or overperforms based on the measurement requirements of the application. Both of these scenarios will result in higher costs; an underperforming sensor requires supporting additional components and labor while an overperforming sensor costs more money than is necessary.

We've created this eBook to help you evaluate your options and avoid unnecessary expenditures. Below are some key considerations to keep in mind when selecting a pressure sensor for your specific project.

## Defining Your Application

Different types of sensors are ideal for different industries and applications. Sensors are available in common- off-the-shelf (COTS) varieties or as fully packaged transducers, and can also be modified (or even customized) for your specific needs. To narrow the scope of your prospective purchase, you'll first need to define your application requirements.

### Sample Applications

HVAC

Critical Containment Units Cleanroom Management VAV Control
Indoor Air Quality/EMS Systems
Data Center Sensors Refridgerant Monitoring
Filter Blockage
Duct Pressure Measurement

INDUSTRIAL

Barometric Pressure Liquid Level Sensing Leak Testing
Tank Level Measurement Vacuum Sensing Instrumentation Altimeters
Pressure Transducer Development

MEDICAL

Respirator & Breath Detection Equipment Sleep Apnea
Oxygen Concentrators/Conservers
Infusion Pumps
Blood Pressure Measurement Air

Mattresses & Cushions DVT Machines Wound Therapy

### Material Selection

If the media in your application is clean air between 0-85 °C, a board-level pressure sensor — one that's mounted to a printed circuit board (PCB) — is likely the best option unless special packaging requirements are needed.

Liquids, extreme temperatures, and harsher media call for ceramic sensors or other media-compatible options.

### Measuring Range

Selecting the right pressure sensor measuring range will ensure that your measurements offer optimal accuracy (precision) and resolution (smallest detectable change in pressure) while also maintaining any safety boundaries the application requires. To select the correct range, you must determine three factors:

• **Nominal operating pressure of the system** — Under general operating conditions, what is the highest pressure at which you need a meaningful measurement? What is the lowest pressure at which you need a meaningful measurement? Often, a nominal pressure range starts at 0 pressure units (such as psi, kPa, mmHg, etc.) and ends at a positive, higher pressure. However, pressure ranges can also be negative (vacuum) or compound (ranging from the vacuum range to the positive pressure range). Defining this optimal pressure range is a critical step in sensor selection.

• **System dynamics** — Once you've determined the nominal pressure range, consider any system dynamics that could affect operation, such as the impact of starting or stopping pumps and opening or closing valves, as well as sensor response time and the level of accuracy needed during these events.

• **Any additional circumstances that might impact system operation** — These circumstances may include significant changes in operating temperature and potential for overpressure. Many sensors require a ''safe overpressure'' range to keep from bursting or weakening during these times.

### Measurement Type

There are three basic types of pressure measurement. Each offers a reference pressure to the application's applied pressure.

• **Absolute pressure** — Absolute pressure sensors compare the applied pressure to the reference pressure of a perfect vacuum. You may choose an absolute sensor if you want your measurement to be affected by changes in barometric pressure or if it is not possible to provide a reference pressure in the ambient environment of your measurement. For example, changes in barometric pressure affect measurements in some medical applications. Also, submersible sensors may not be able to be exposed to the ambient pressure requiring their own internal references.

• **Differential pressure measurement** — This type of measurement compares the difference between two applied pressures. Either pressure could be larger than the other or one of the pressures might always be larger than the other. Examples include pressures from either side of an air filter, pressures from either side of a flow orifice, or two independent pressures that need to be monitored simultaneously. In the past, it was difficult to measure very low differential pressures due to technological limitations. Now, advances in the silicon sensing element combined with better bonding techniques that reduce mechanical stress susceptibility have allowed for ultra-low differential pressure sensors which can measure down to a few inches of water in small, low-cost packaging.

• **Gauge pressure measurement** — A subtype of differential pressure measurement, a gauge pressure measurement compares the ambient atmospheric pressure to the applied pressure. Changes in atmospheric pressure do not affect the measurement. Thus, when the applied pressure is zero, the sensor will have an output corresponding to the lowest end of its specified range. The applied pressure may be positive or negative (vacuum). Generally, gauge pressure measurements are the most common, such as pump pressures, gas pressures in a pipe, or refrigerants in an HVAC system. Most gauge pressure measurements are ''vented,'' meaning the reference pressure is the ambient atmospheric pressure. Sometimes, venting to the atmosphere is not possible; the sensor manufacturer must then provide a known reference by sealing the reference side of the pressure element within a ''chamber.'' This is called a ''sealed gauge'' sensor. Sealed gauge pressure sensors are typically used in high-pressure applications in which the effect of altitude on pressure measurement is negligible.

### Calibration

While some standard sensors are suitable for simple plug-and-play operation for noncritical functions, applications demanding higher accuracy require sensors that are calibrated to their unique systems. After extended use, especially, systems often require recalibration or need to be reset to zero to safeguard their reliability. As an example, think

of a mechanical scale application in which the user must ensure the scale is reading zero when no weight is on it. Users often build in auto-zero capability into their complete product design to allow the end user to auto-zero in the field.

No two sensors — even if they're from the same manufacturer — will produce the exact same readings. It's therefore crucial that sensors employed in critical-use applications are set up in line with the system's distinct environmental factors, including temperature, humidity, and shock. When determining whether or not to calibrate pressure sensors, users have three options:

- **Uncalibrated, uncompensated, and unamplified** — Subject to user's own calibration process; weighs trend of price and performance over accuracy; auto zero is possible and preferable. These sensors are good for tracking trend over precision.
- **Calibrated, compensated and unamplified** — While still requiring amplification, these versions are not as flexible when it comes to modifying pressure ranges or adjusting total error band.
- **Calibrated, compensated, and amplified** — Simpler calibration process; prioritizes reading accuracy; accounts for entire pressure range; some can be used with high-resolution A/D. Most flexible for modified pressure range and adjusting total error band. Fastest time to market for the end design. Amplified, calibrated, and compensated pressure sensors also provide the designer with more output options (voltage or digital output). In these scenarios, design considerations revolve around resolution, total system accuracy, and, in some cases, total power consumption. Generally, this allows designs to be created using the minimum number of total components, keeping the bill of material costs as low as possible.

At the factory, amplified, calibrated, and temperature-compensated sensors can be modified to meet specific performance targets of sensitivity, resolution, and accuracy. This is especially useful in keeping noncomponent costs as low as possible since little or no user calibration will be required.

When choosing an amplified sensor, regulated supply voltage is an important factor; it's good practice to have the sensor and the microprocessor running off the same supply voltage rail. Supply voltage must be considered when optimizing power consumption of the total system. Warm-up time and processing time, especially for digital output sensors, should also be considered.

One final consideration is mechanical packaging. Some manufacturers provide the same electrical performance in a range of mechanical configurations. Connecting the pressure source to the sensor can be done by tubing or connecting directly to a manifold and sealing with an O-ring; other similar strategies may also be employed. Mechanical design considerations are as important as electrical performance needs.

Combining all of these factors may lead a designer to request a more complex assembly; for example, adding cables, flex circuit, and connection schemes may be possible. The ultimate goal is to minimize space usage, component count, and labor content for their application.

### What Makes a Good Sensor and a Good Sensor Supplier?

A good sensor provides just the right level of capability at just the right cost for the specific intended application. Standard data sheets and suppliers often cannot provide this level of optimization.

A good supplier will work closely with designers to determine where the ideal sensor lies on the price and performance spectrums.

Additional Considerations When Evaluating Sensor Manufacturers:

- **Current Trends** - Some consolidation of manufacturers
- **Many options to choose from** - Sources are all over the world
- **Lead-times** - How to make sure you can get parts when you need them
- **Price**
- **Technical Support**
- **2nd Source Requirements** - Sounds easy on paper but are there pin-to-pin replacements
- **Focus on what the application requires versus datasheet claims** - don't overdesign
- **Focus on cost of measurement**, not cost of component

**UNDERSTANDING THE TRADE-OFFS BETWEEN...**
Sensor Cost, Accuracy Requirements, and Calibration Effort Needed If You Choose an *Unamplified* Sensor

| UNCALIBRATED, UNCOMPENSATED AND *UNAMPLIFIED* | CALIBRATED, COMPENSATED AND *AMPLIFIED* |
|---|---|
| Own calibration process | Simpler calibration |
| Trend over accuracy | Accuracy is important |
| On/off single point | Whole pressure range is important |
| Auto zero possible | Can be used with high res A/D |

**Summary**

After reviewing your application basics (type of media, potential contaminants, pressure range, operating temperature, accuracy within a temperature range, overpressure, system accuracy, calibration, and any regulatory considerations such as UL, FDA, and CE), there are still a few more factors to consider regarding application mechanics, electricity, and assembly — all of which are interrelated.

- Shape and size (SMT or thru-hole)
- Supply voltage (3V, 3.3V, 5V, 10-36 VDC)
- Resolution and response time
- Port configuration and orientation
- Output
- Accuracy over temperature
- Mechanical connections
- Electrical connections
- Overall system accuracy required
- Robustness — burst and overpressure
- Power consumption
- Customized accuracy over a defined pressure range and operating environment

**Making a Final Decision**

Although some manufacturer consolidation has occurred over time, the sheer amount of sensor design options can easily overwhelm customers. Above all, it's critical to focus on the cost of measurement — what your application actually requires — rather than what a data sheet claims your component should cost.

For over 30 years, Servoflo Corporation has been helping companies across industries meet their pressure sensing needs. We offer a full line of pressure sensors and transducers, environmental sensors, mass flow sensors, and micropumps for a variety of applications, and specialize in helping engineers find the right solution at the right time — at a fair price. ●



***David Ezekiel*** *is Vice President of Servoflo Corporation*

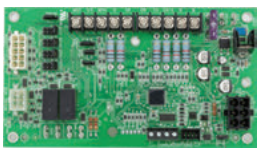
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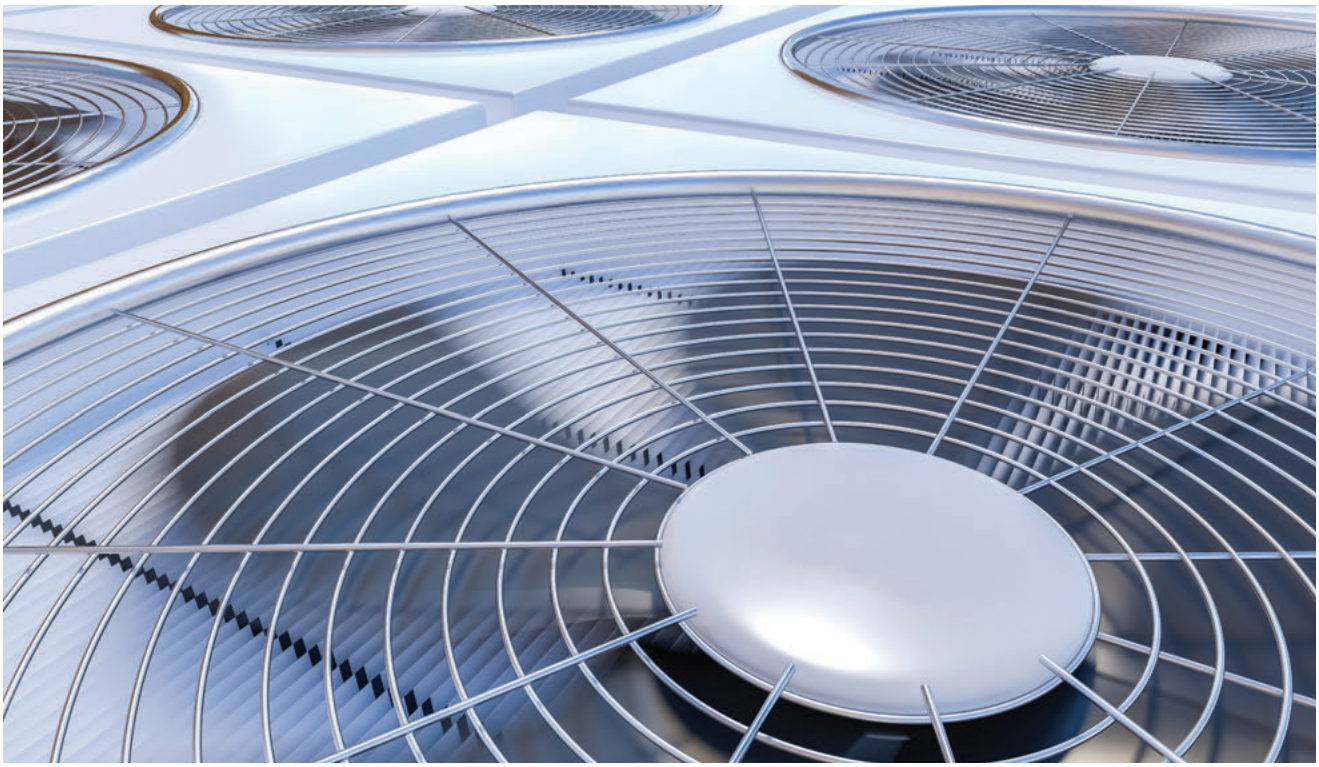


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# Leak Testing of Refrigerant Circulation Systems: Important For People, Nature and Economy

**BY DENNIS HARDER**

Regulations governing the leak tightness of refrigerants are becoming increasingly strict. No wonder, since the immense potential of refrigerants to generate greenhouse gases is increasingly in the spotlight in the context of global warming. To meet regulations and reduce carbon emissions, there is a growing demand for improved, energy-efficient HVAC-R (heating, ventilation, air conditioning and refrigeration) systems and their quality and productivity standards. These demands are supported by modern leak detection systems that precisely ensure the leak tightness of cooling and refrigeration circuits.

## Basic Operation of Refrigeration and Air Conditioning

A cold beer from the fridge or a pleasant 20 degrees (70°F) in the office: people encounter refrigeration and air conditioning every day. While the refrigerator cools a small, insulated space, air conditioners keep our home, office space or a supermarket at a comfortable temperature. This is due to a physical principle that has been known for a long time: the alternation of gaseous and liquid states of aggregation.

Liquids that expand into a gaseous state extract heat from the surrounding material or surface. In an industrial setting, this process is facilitated by refrigerants. These evaporate or boil at much lower temperatures than water and enable heat to be extracted more quickly from their surroundings. In a nutshell, the refrigeration cycle essentially consists of a compressor, evaporator, condenser, expansion valve and various connection points. It also includes, for example, welds and bolted connections between the individual components. Each of these components must be leak tested to ensure that the complete system functions efficiently and sustainably throughout its life cycle. The significant global warming potential (GWP) of refrigerants is the basis for increasingly stringent regulations and standards in refrigeration and air conditioning.

## Rules and Standards For Refrigeration and Air Conditioning

The leak tightness of refrigeration and cooling systems is described by means of a loss in mass that occurs over a certain time. In refrigeration and air conditioning technology, the loss of refrigerant in a system is measured in grams per year (g/y). In homes and smaller restaurants and stores, refrigerant loss of 2 to 5 g/y is tolerated. If the refrigerant loss is converted to an equivalent leak rate with a tracer gas concentration of 100%, this corresponds to a leak rate of 1-5 10-5 mbar l/s. This defines a leak rate limit in the leak testing process in production. In commercial applications, such as hotels, office buildings and hospitals, the systems differ in size and complexity from residential applications. As a result, these systems have a higher susceptibility to leakage. In sum, a maximum refrigerant loss of 5 to 15 g/y is allowed here. In the industrial sector, the sum of potential leakage is a refrigerant loss of 15 to 30 g/y. This relates to chemical processes that use large-scale process cooling, such as in the production of food or pharmaceuticals.

To adhere to the requirements of regulations and standards, refrigeration circuits must be kept as leak tight as possible. Even the smallest leaks of 10 µm (by comparison: a human hair has a cross-section of 40 µm) can cause immense damage. Consequences may include:

- Reduced system performance
- Increased energy demand
- Overheating
- Compressor damage and failure

This damage increases downtime as well as operating costs in relation to refrigerants, servicing and electricity – to name but a few. In addition, it can have negative effects on sales, the corporate image and above all: the acceleration of climate change.

At the same time, increasingly stringent regulations and standards present the industry with an ever greater challenge. The Kigali agreement is applicable at an international level. In Europe, the European F-Gas Regulation – EU No. 517/2014 applies. This is the origin of the various regulations and includes the restriction of various refrigerants that have a high GWP. By 2030, a number of refrigerants will be banned through a step-by-step reduction, which will entail a great effort on the part of suppliers and manufacturers: the entire system needs to be revised to ensure efficient and at the same time cost-effective operation of the overall system.

## Call For Higher Quality and Productivity Standards

Improved, more energy-efficient HVAC-R systems are required to meet the regulations. In addition, the demand for more stringent quality and productivity standards is growing, so leakage control already plays an important role in the production process. Therefore, two essential manufacturing steps are required before actual leak-detection testing: drying and leak testing of the systems. These have a direct impact on the service life and performance of the equipment.

To ensure that leaks can be detected and repaired at an early stage, all components that come into contact with the refrigerant are tested individually. The requirements for the leak-detection testing process depend not only on the leak rate limit, but also on the tracer gas used and its concentration, the test duration, the degree of automation, and whether the test method is localizing or integral. In order to comply with the required leak rate limit, a leak test is carried out in a vacuum or an accumulation chamber after a gross leak test, using air-based test methods for example. In addition, a sniffing test can be used to localize the leak.

In order to comply with the required leak rate limit, a leak test is carried out in a vacuum or an accumulation chamber

Once the testing of the individual components has been successfully completed, the next production step is to assemble the individual components into a system and weld them together. After an optional gross leak test with air, the refrigeration circuit is simultaneously evacuated and vacuum-dried.




**Leak detector with sniffer probe**

## Evacuation and Vacuum Drying For Greater Longevity

Evacuation and simultaneous drying of the system have an essential influence on the subsequent efficiency and reliability of the system. Particular attention is paid to drying the residual moisture: the challenge is to remove the thin layer of moisture adhering to the internal surfaces of the compressor, condenser, evaporator, valves and tubing. If the system is

not actively dried, residual moisture remains, which can freeze during operation and cause failures in the expansion valve or closing pipe. In addition, water reacts with the refrigerant to form acids that can corrode or may also form deposits, threatening overall system failure.

Vacuum drying is therefore crucial for successful long-term operation of the system. It reduces residual moisture on the internal surfaces of the components and improves both the subsequent leak testing process and the filling operation with refrigerant. Typically, oil-sealed rotary vane pumps with a pumping speed of 10 to 30 m3/h are used for this purpose. The low pumping speed prevents residual moisture from freezing in the system, and oil-sealed rotary vane pumps achieve a stable ultimate vacuum.

Once the refrigeration circuit has been evacuated and vacuum dried, a tracer gas, such as helium or hydrogen is introduced. The test pressure should correspond to the subsequent working pressure of the system in order to reproduce a leak test under real conditions. To save costs in relation to the tracer gas, tracer gas concentrations of 100% are often not used. For the tracer gas to be distributed effectively in the system, the system must offer optimum conditions. This means: an airless space, without any humidity or other gases. Tracer gas recovery systems are ideal for systems with a large refrigeration circuit volume.

## Reliable Leak Testing With The ASM 306 S Leak Detector

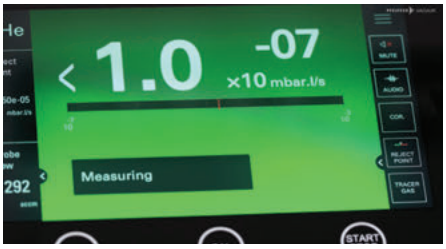
A sniffer leak detector is then used to test the individual welded and soldered joints, and the valves and connections. Leak tests with helium or hydrogen sniffers are far superior in terms of response time, accuracy and sensitivity to conventional leak detection methods, such as the water bath method or the pressure rise test. With the ASM 306 S leak detector, Pfeiffer Vacuum offers a state-of-the-art product that supports this application. This is because the helium and hydrogen sniffer leak detector is designed for 24-hour use, even in harsh environments. With its high sensitivity of 0.2 g/y it enables precise and error-free measurements that meet the stringent requirements of air conditioning and refrigeration applications. Designed to perform fast and repeatable measurements, this instrument offers short recovery times, even in the event of large leaks, ensuring maximum operational availability coupled with low maintenance and reduced service costs. Users therefore benefit from longer maintenance intervals and easier replacement of wear and tear parts.

The sniffer leak detector is not only convincing in terms of its accuracy and economy, its user-friendliness and intuitive operation also support efficiency due to the lightweight and ergonomic sniffer probe. The ASM 306 S achieves easy and precise results even from a large working distance and guarantees fatigue-free work on every working shift. In addition, the intuitive operation of the high-resolution 7-inch touch screen ensures easy operation, which is supported by color LEDs. Depending on the signal strength, these light up on the sniffer probe and ensure error-free readability in real time.

The ASM 306 S is available with different hose lengths for various applications. The compact design and low space requirements also make it easy to integrate in the production line.

The tracer gas leak detector covers all industrial sniffing applications and has proven itself particularly in leak testing of refrigeration and air conditioning units. The robust design of the ASM 306 S ensures low maintenance and operating costs with reliable use around the clock. ●

**Intuitive menu for easy operation**





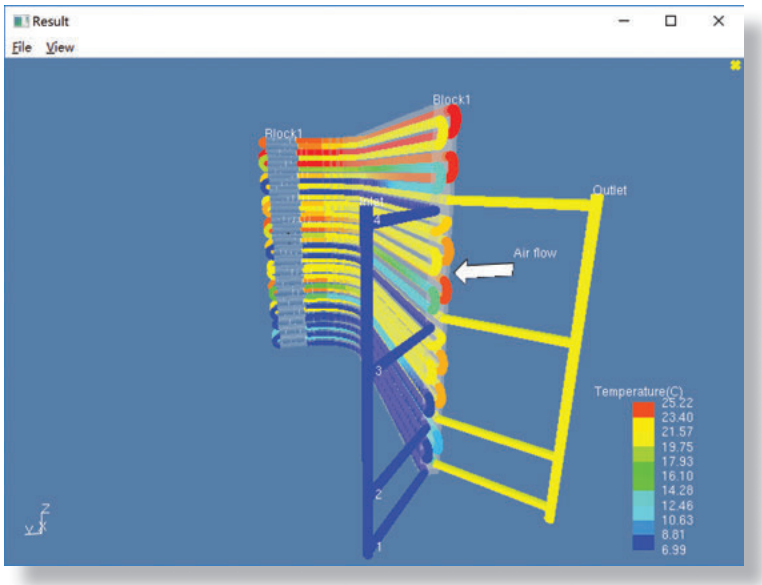


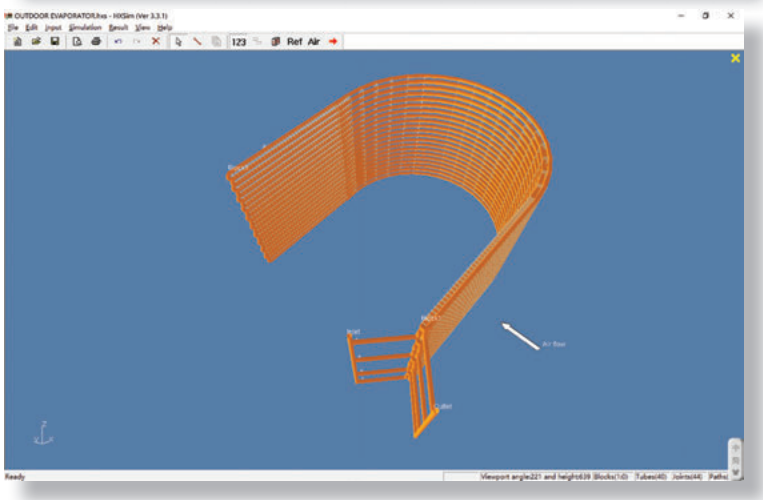
**The sniffer probe has a built-in calibration device and 5m cable**

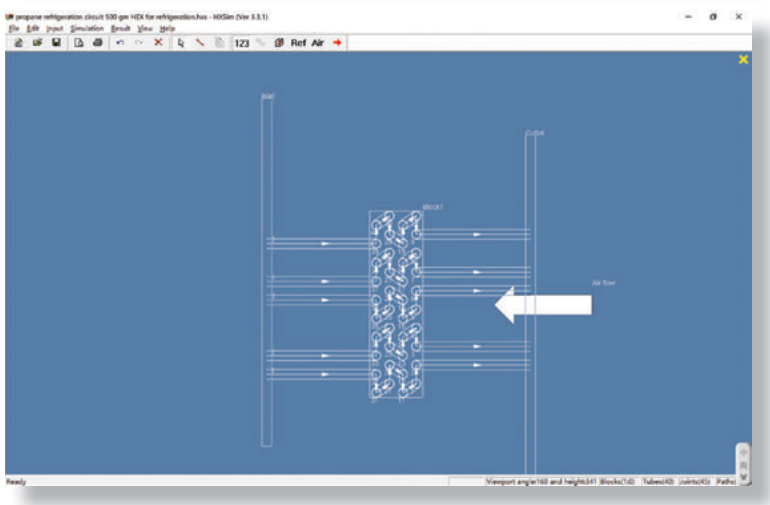


***Dennis Harder*** *has been with Pfeiffer Vacuum since 2017. After his dual studies in industrial engineering with a focus on mechanical engineering, he has been working in the Industry market segment since December last year. There, he is responsible for business development in the field of refrigeration and air conditioning technology (HVAC-R). Dennis Harder, Pfeiffer Vacuum GmbH, Berliner Strasse 43, 35614 Asslar, Germany, Tel.: +49 6441 802-1180, E-Mail: Dennis.Harder@pfeiffer-vacuum.de, www.pfeiffer-vacuum.de*

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# SPOT

## Women of The Commercial Appliance Industry

Historically, the commercial appliance industry has been largely male-dominated. Today, although it is still a male-dominated industry, there are countless opportunities for females. Women are generally good communications, problem solvers, listeners and multi-taskers, which are all important and valued skills in the industry.

In this issue, we are spotlighting ***Jenny Repfennig***, a female leader finding great success in the commercial appliance space. Repfennig acts as the Marketing Manager for Miele Professional's NAN region, spanning USA, Canada, Australia and New Zealand. Miele is a leading manufacturer of professional-grade appliances for industries using commercial dishwashers, commercial laundry technology and laboratory, medical and dental technology.

Repfennig is an engineer who has dedicated her career to marketing commercial appliances at Miele Professional since 2015. During her time at the organization, she was nominated to Miele Global's International Young Management Program, where she was one of ten participants from around the world. The two-year program from 2017-2019 was dedicated to supporting the next generation of managers with a heavy focus on diversity and inclusion. She presented a project to the Miele management board about the importance of empowering women to be a part of the leadership team.

We asked Jenny some questions about her experience working in the commercial appliance industry.

# LIGHT

**Q** What is your favorite part about your job at Miele Professional?

**A** **Jenny:** I really like to deliver on market needs, bring ideas and collaborate across the organization to develop the best possible services and other solutions for Miele customers. I enjoy working closely with the different departments in the factory, as well as the service, marketing, logistics, sales, back office, and training departments. I really take great pride and joy in communicating with people to bring all the puzzle pieces together to make our products and services "Immer Besser," meaning "Forever Better" in German.

**Q** What are you most proud of in your career in the commercial appliance industry?

**A** I've improved Miele's internal processes and utilized resources both in our US headquarters, but also from an international perspective. For example, I've pushed hard to promote the use of our training department and to really strengthen our product trainings for the sales team and the dealers. That helped make our training platform more available and more professional, and ultimately, increases the knowledge of our sales partners and leads to better sales results.

**Q** What would you say are your biggest strengths and accomplishments thus far in your career?

**A** I am a strong problem solver and always try to deliver new strategies to grow a business. Because of my international experience, I'm able to see things from different perspectives and share those across different organizations and departments. I've worked hard not only to strengthen communication between our North American region and our headquarters in Germany, but also to harmonize our U.S. and Canadian products. As a result, the North American region collectively has more input into the product development process. It has also eliminated extra work, streamlining product marketing into a single North American approach.

**Q** What is it like being a female leader in a very male-dominated industry?

**A** I don't like to see myself as a woman in a male-dominated industry. I'm engineer with 14 years of experience in marketing and product development. I love my job, and I'm good at (and I enjoy!) working with people and finding improved solutions and processes to bring the best possible products to our markets and customers.

**Q** What is your advice for other women in the industry?

**A** Believe in yourself. Raise your hand and make your voice and opinion heard.


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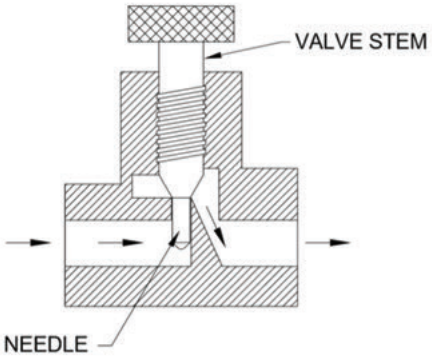
# Select the Right Motor for Your HVAC Gas Valve Actuator

**BY MAHESH DUNDAGE & SAJAL KUMAR**

HVAC systems that regulate temperature and air quality to keep enclosed areas warm in wintertime typically depend on natural gas combustion to sustain boilers, pumps, radiators, meters and other components. The burning gas heats air or water for circulation around the enclosed space. Gas and liquid flow must be controlled and metered accurately using various sensing and modulating elements such as flow control valves or isolation valves — also known as shut-off valves — or both.

## How Flow Control Valves Work

Flow control valves have a valve stem that moves up or down inside the valve body, causing the needle, or sealing element at the end of the stem, to restrict the flow of fluid to a desired level. Another valve type — a stem-and-ball valve — is designed with a ball ball that rotates around the valve stem. The ball has an opening that allows full flow at one position and variable flow as the stem rotates to the shut position. The valve stem may be designed to allow an operator to adjust a screw-needle position, or an actuator can move the stem with control from a motor and drive system.




## Types of Electric Motion Systems for Gas Valve Actuators

Brushed DC or stepper motors fit the performance and cost requirements of the gas valve actuator. While both can deliver the necessary torque and speed for the application, designers must decide how to configure the overall motion system which includes both a motor and a positioning system.

For the gas valve actuator, a combination of motor technology, motion type and positioning system will determine the overall motion system's complexity and costs. Options for the motion system are:

• Brushed DC motors, which provide rotary motion, or linear motion with the addition of an external lead screw to convert rotary to linear motion. In both cases, an encoder is needed to provide closed loop operation.

• Stepper motors that produce rotary motion, or linear motion with the addition of an external lead screw. In both cases, the driver can provide direct open loop control.

• Linear stepper motors have an integrated lead screw as part of a single robust package to deliver direct linear motion output, with the driver providing open loop control.

## Motor Technology Overview

**DC Motor**—Thanks to its simplicity, a DC motor does not require complex electronics to drive the motor. However, if the application calls for linear motion, the DC motor will require an additional lead screw and gearing system to convert the rotational motion to linear motion. It will also need a feedback mechanism like an optical sensor or encoder for accurate linear position control. Because the rotor has high inertia, consider adding a braking system.

**Stepper Motor**—This DC motor rotates in several small, equal and discrete increments called steps. Driving a stepper motor requires a dedicated control unit. The stepper motor's construction and design offer some inherent benefits. For example, the motor can operate in open loop with good accuracy when properly sized thanks to the discrete steps that provide built-in positioning control. Its design also makes possible the use of detent torque to provide holding position, and the motor offers an excellent response for start, stop and reversing operations. If linear motion is required, an additional lead screw and gearing system are necessary to convert rotational motion to linear motion.

Typically, stepper motors can be used for output speed up to 1,000 rpm and torque up to 170 millinewton-meters. Actual torque and speed also depend on whether the driving mode is full step, half step or micro-step. Depending on the working load point of the application, designers can add gearbox and lead screw systems.

**Stepper Linear Actuator**—This compact device combines a can stack stepper motor with a threaded rotor and an integrated lead screw to provide direct linear motion. The stepper linear actuator lead screw moves up and down in discrete step increments when electrical pulses are applied. Because a stepper linear actuator can be controlled accurately in an open loop system, no expensive feedback device or braking system is needed for positioning.

Typically, linear actuators can be used for output speed up to 80 millimeters per second, and they provide up to 100 Newtons of force. Actual force and speed also depend on lead screw efficiency and driving mode — full step, half step or micro-step. Depending on the working load point of the application, a gearbox can be added.

## Key Considerations

Gas valve applications vary by valve stem type, desired operation and precision. When selecting a motor, keep these considerations in mind:

• Maximum and running torque and force required

• Speed requirement: Typically, force and torque is required at low speeds for valve applications.

• Overall price of the system

• Control system: Typically, closed loop control is not required.

• Temperature of the application environment

• Type of motion needed for actuation: rotary or linear motion

• Expected lifetime of the system before replacement

• The required linear or rotary resolution

• Maximum current and voltage available

Based on the motion options available and HVAC requirements, a stepper motor is well-suited for a rotary application, and a linear step motor is desirable for a linear application. ●

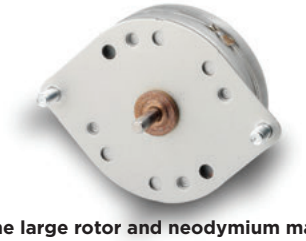



***Mahesh Dundage*** *lead design engineer and* ***Sajal Kumar****, product line manager, Portescap*






**This DC coreless motor can deliver a torque up to 5 mNm continuously, reaching up to 80% efficiency while maintaining a long lifetime. Can be customized; from shaft lengths to mounting holes.**

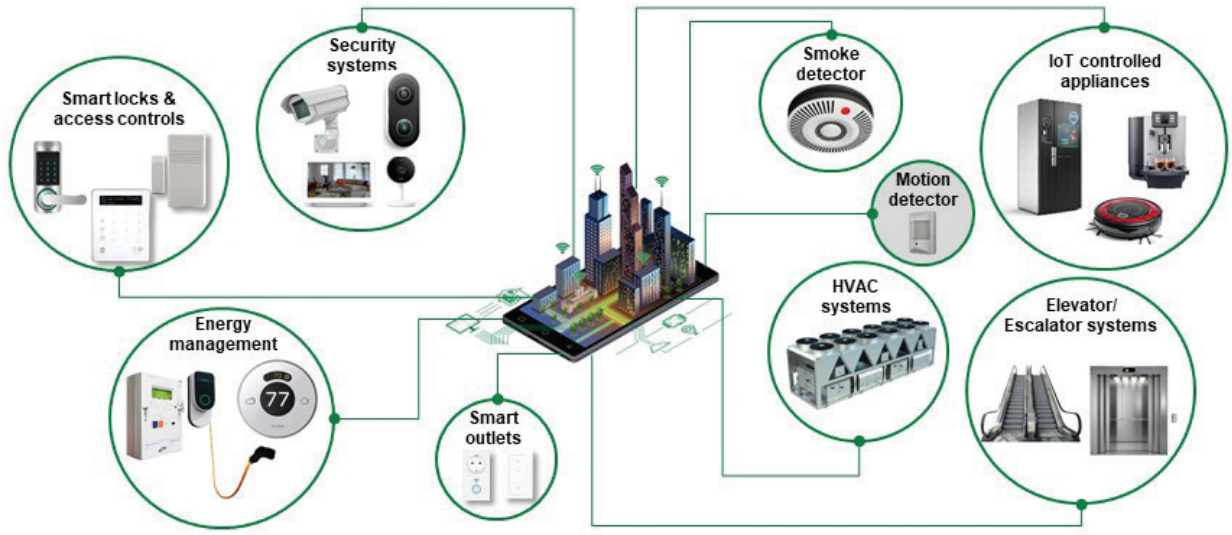


**The large rotor and neodymium magnets provide up to 18.5 oz-in (131 mNm) of holding torque and is optimal for high torque applications. The 48 steps per revolution results in a 7.5 degree step which increases the positional resolution. It is available in 5 or 12 volt windings, and in unipolar or bipolar designs.**



**This is a non-captive high performance linear actuator that provides a long stroke length and up to 110 oz of linear force in a 20 mm frame size.**

**Figure 1:** Intelligent devices that enable security, convenience, safety, and efficient energy management in homes and buildings




# How to Develop Robust Motion Detectors for Smart Home & Building Applications

**BY RYAN SHEAHEN**

Today's smart buildings—from residential homes to commercial structures—are benefitting from intelligent technologies that enable them to be more convenient, safer, and energy-efficient. The wide range of products available for smart building applications is shown in Figure 1. Both home consumers and building management personnel can automatically monitor and control these devices remotely, even when not on-site.

Infrared motion detectors are one product that combines convenience, safety, and energy conservation. An infrared motion detector senses occupancy in an area and can then activate lighting, the HVAC system, or an alarm. If the motion detector provides security functionality, it




**Figure 2:** Passive infrared motion detector showing recommended protection, control, and sensing components

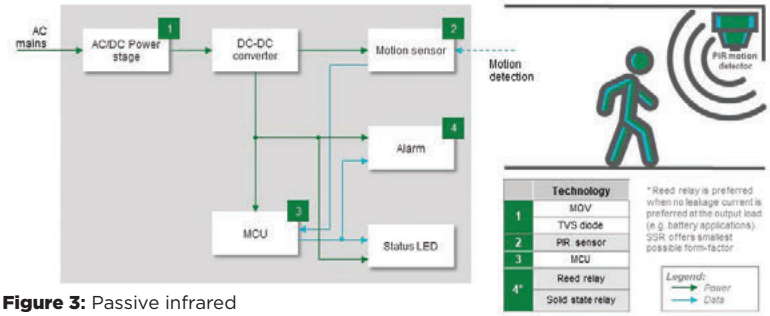



**Figure 3:** Passive infrared motion detector block diagram

needs to operate reliably 24 hours/7 days a week without downtime.

Passive infrared is the leading technology for motion sensing due to the combination of reliable performance and low cost. Factors driving the market's healthy compound annual growth rate, which is over 13% and will likely exceed $3.5 B in 20251, include:

• Residential demand for security using surveillance

• Reduced installation costs with wireless connectivity and IoT networks

• Government initiatives for energy conservation that are being adopted in the public and commercial sectors.

This article addresses concepts that ensure your design will be robust to external disturbances. In addition, it presents an infrared detector assembly that significantly reduces your design's parts count while improving product performance and reliability.

## Protection, control, and sensing components for passive infrared motion detectors

Since passive infrared motion detectors may be used for either interior or outdoor monitoring, these products must be robust to environmental disturbances. If the detectors are powered by the AC line, they need to withstand current overloads and voltage transients that can propagate on the AC power line. In addition to robust circuit protection, efficient control and reliable sensing performance are essential for a quality end product. An example infrared motion detector (see Figure 2) defines several recommended protection, control, and sensing components that enhance both product reliability and performance.

The block diagram (see Figure 3) shows a passive infrared motion detector, identifying in which circuits the recommended protection, sensing, and control components should be placed. The following sections discuss each block in which components are recommended.

### AC/DC Power Stage

The AC/DC Power Stage provides the DC power for the other circuits. Because this circuit interfaces with the AC power line, it is subject to overcurrent surges and overvoltage transients. Overvoltage transients and current surges can result from lightning strikes, inductive spikes from motor turn-on and turn-off, and transients from power line voltage variations. Against these potential disturbances, a metal oxide varistor (MOV) is recommended as the first line of defense for the AC/DC power stage board. Locate the MOV as close as possible to the entrance of the AC voltage on the circuit to minimize the propagation path for AC line transients on the circuit board. Select an MOV with these characteristics:

• Safe absorption of up to 10 kA peak surge current or 150 J of pulse energy to protect downstream circuitry from a lightning strike

• Low clamping voltage which will not damage downstream circuitry

• An operating temperature range to ensure the component will function over the detector's specified environmental range (versions of MOVs with phenolic coating can operate safely up to 125 °C)

• UL- or IEC-recognized to reduce qualification time by a nationally recognized standards lab.

At the output of the AC/DC Power Stage, consider using a transient suppressor (TVS) diode for further protection of all the load circuits on the power supply. The TVS diode will minimize transient stress on the power components in the various load circuits. The TVS diode offers these benefits for circuit protection:

• Absorbance of as much as 600 W of peak pulse power or 100 A of peak surge current

• ESD protection that can be as high as 30 kV either from through-the-air strikes or direct contact

• Ultra-fast response, under 1 ps, to a transient

• Versions that have clamping voltages as low as 10 V

• UL or IEC component recognition

TVS diodes can be bi-directional, using two series diodes in a package, or uni-directional, with a single diode (Figure 4). In addition to their protection features, TVS diodes consume a small amount of power. In normal, disturbance-free operation, the component draws under 1 µA. Finally, surface mount versions of TVS diodes are available for conserving printed circuit board (PCB) real estate.

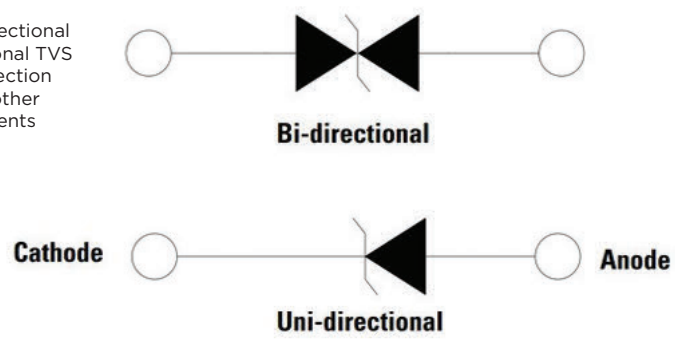
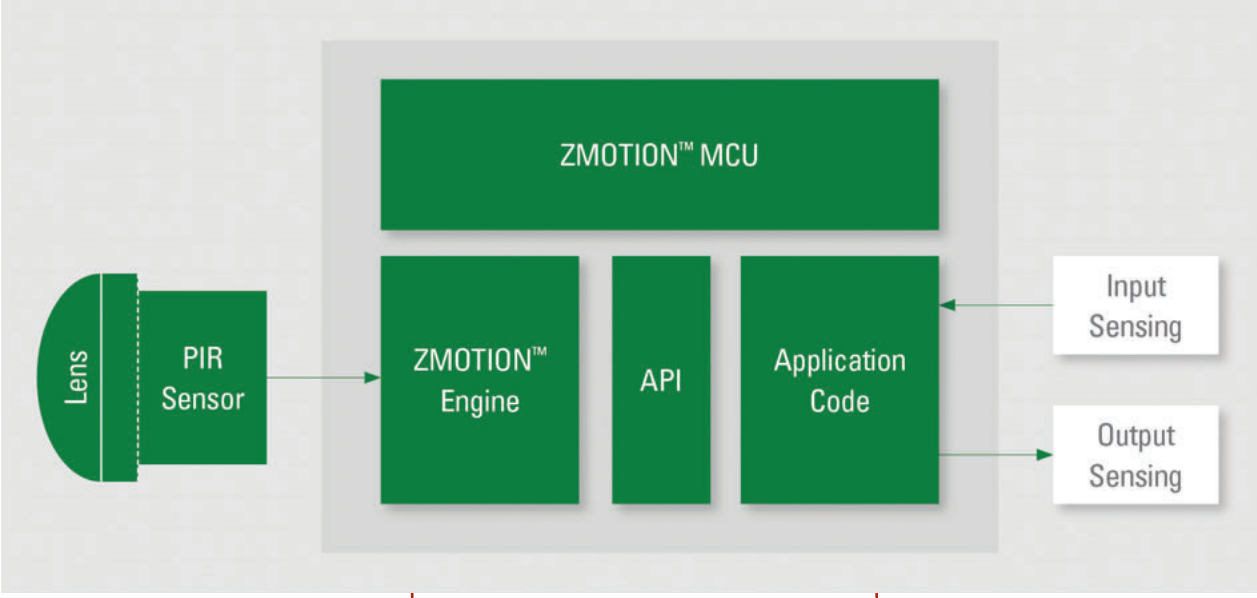



**Figure 4:** Bi-directional and uni-directional TVS diodes for protection from ESD and other electrical transients

**Figure 5:** Combination lens, sensor, and microcontroller assembly block diagram




## Motion Sensor and MCU

The primary elements of the passive infrared detector are the infrared radiation sensor and the microcontroller unit. Be aware that complete packages are available that include a sensor, a lens, and a microcontroller unit (see Figure 5). A complete package offers:

- Reduction of the design's bill of material since the sensor connects directly to the microcontroller chip.
- A microcontroller that contains all the circuitry needed for a complete design for the detection and processing electronics. The microcontroller contains the CPU, RAM, timers, comparators, A/D converter, communication interface, and the firmware for the sensor.
- 2-element or a 4-element sensor that, combined with a lens, can offer numerous options for different fields of vision.
- Designs that allow the use of lower cost and smaller ceramic capacitors compared with typical usage of electrolytic capacitors which have higher leakage and a shorter product life
- Advanced motion detector algorithms that provide sensitivity, range, and field of detection management
- Flexibility in the microcontroller to allow implementation of user-defined application features.

To save power during long periods of inactivity, look for an assembly that incorporates a low power mode when no motion is detected. Figure 6 shows an example infrared motion detector package. The combination of an integrated package with fewer components and no electrolytic capacitors improves overall product reliability, saves PCB space, and reduces cost.




**Figure 6:** Example lens-sensor-microcontroller infrared motion detector assembly from Zilog. The lens and sensor are on top of the PCB. The microcontroller is underneath the sensor.

## Alarm

The alarm circuit activates when the infrared sensor detects an appropriate amount of motion. Typically, the circuit drives a flashing LED light or a combination of an LED light and a speaker. The alarm circuit will need a control component to energize the external device. Consider either a reed relay or a solid-state relay, both of which will provide galvanic isolation of the high-power drive from the low power logic circuitry. A solid-state relay offers longer life for the output drive contacts, while a reed relay offers lower power consumption.

Reed relays are available in compact single-in-line packages. You can also get reed relays with built-in back EMF suppressor diodes to protect the coil drive circuit and with magnetic shield options to prevent the coil EMI from entering the control circuitry. In addition, reed relay contacts have a longer life than conventional electromechanical relays, and they are relatively immune to wide ranges of environmental temperatures.

Solid-state relays optically couple control between an input LED and an output photodetector transistor.

**Table 1:** Standards that govern safety and operational requirements for passive infrared motion detectors

| Standard | Title | General scope | Region |
|---|---|---|---|
| IEC 63180:2020 | Methods of measurement and declaration of the detection range of detectors–Passive infrared detectors for major and minor motion detection | Provides a methodology and test procedures to be able to declare and verify the detection area for motion detectors using passive infrared technology | Global |
| UL 639 | Standard for Intrusion–Detection Units | Requirements cover intrusion-detection units intended to be used in burglary-protection signaling systems. These units are intended to be used in indoor or outdoor locations to automatically indicate the presence of an intruder by actuating electrical control circuits. | North America |
| IEC 62368-1 | Audio/video, information and communication technology equipment–Part 1: safety requirements | This part of IEC 62368 is a product safety standard that classifies energy sources; prescribes safeguards against those energy sources; provides guidance on the application of, and requirements for, those safeguards | Global |

Solid-state relays can have as much as 1500 Vrms isolation between input and output. Many are designed to eliminate EMI/RF generation with logic that initiates switching at zero voltage crossings. Versions of solid-state relays can have a low off-state output leakage current of under 1 µA to minimize power consumption. They are available in space-saving, surface-mount packages.

Your choice of drive component will depend on ensuring the contacts or the output have sufficient drive capacity for the types of outputs that will be used. Size, power consumption, and cost will be other factors that you will want to factor in your choice of drive component.

## Safety Standards for Passive Infrared Motion Detectors

Table 1 lists critical standards that your design needs to conform to so that it can be certified and obtain market acceptance. Adhering to these standards as part of the development process will reduce certification costs as well as certification time. Complying with the IEC standards will permit sales of your product in all worldwide regions.

## Summary

Robust, reliable designs can have a low component count and low development costs.

Bottom line: For an infrared detector design, a robust design requires only a few protection components. You can take advantage of a lens/sensor/microcontroller package to reduce parts count and maximize product reliability. Be sure to include standards compliance as an important element of the development project to save certification time and costs.

When available, it is wise to take advantage of a manufacturer's applications expertise to help save time when selecting the necessary protection and control components, which can also help save significant design time. The manufacturer can also provide guidance on which standards apply to the design and how to ensure compliance. These recommendations will help you achieve a robust, reliable design that will result in fewer field failures and a more cost-effective and profitable product.

## References

[1]Occupancy Sensor Market. Markets and Markets. July 2020.

***Additional Reference Literature available at Littelfuse.com:***

- Circuit Protection Selection Guide
- Sensing Products Selection Guide
- Power Semiconductor Selection Guide
- Zilog ZMOTION™ Detection Module Datasheet



***Ryan Sheahen*** *is the Global Market Manager at Littelfuse. For additional information, use the QR code to download a copy of the Building & Home Automation Application Guide, courtesy of Littelfuse.*



Quinly automation upgrade for Prusa MK3S

# How Does Automating 3D Printers Change the Break-Even Volume for Spare Parts?

**BY STEVEN MCCULLOCH**

In order to increase the lifespan of appliances, in many parts of the world, right-to-repair laws now require appliance manufacturers to stock spare parts for 10 years after releasing a new product. With some product life spans as low as 2 years, this is a dramatic change for some suppliers, leaving them scrambling for solutions. The current inventory solution is crude…miles of warehouses with millions of spare parts.

3D printing has typically been used as a prototyping tool, but with advancements in automation technology, high-volume 3D-printed production is a real possibility. Large batches of parts can be produced in-house with minimal human labor.

The typical method to produce plastic parts is injection molding, and for good reason. Injection molding is well known for being the most efficient way to produce large quantities of custom plastic parts. For an initial production run, it makes a lot of sense to use injection molding to produce thousands of plastic components, but for spare plastic parts, it can be prohibitively expensive and wasteful. This is where the benefits of 3D printing start to appear.

Plastic components typically fall into the category of parts that rarely need to be replaced yet make up a large percentage of the total inventory. Vast sections of warehouse space are therefore being used to stock thousands of parts which simply collect dust. At the end of the 10-year lifespan, any remaining stock is waste and must be disposed of. It can be hard to predict how often certain components will fail, so manufacturers will overproduce spare parts, in effect guaranteeing some level of waste.

Imagine a future where plastic parts are made to order. In the middle of the night, as a new order arrives, a 3D printer immediately activates and begins printing a seldom-requested plastic latch component. In the morning, the part is ready to be collected and sent out to the customer. No warehouse, no waste.

## What About Automation?

3D printing is well known for being a slow manufacturing process, however the main bottleneck for 3D printing in mass-production is not the print speed. In fact the requirement for intermittent manual labor is the main concern. When a print is finished someone must walk up to the printer, remove the part, and start the next print. If this is not done soon, prints can sit idle, sometimes for hours, especially if prints finish in the middle of night.

The bottleneck has been solved with advancements in automation

technology. 3DQue has developed an FFF/FDM 3D printing automation system known as Quinly. With Quinly, 3D printers can automatically eject parts from the build plate and begin the next print. This allows the production of 3D printed components to continue 24/7, only interrupted by the need to reload material once per week, per printer.

It is still true that 3D printers are slow, however that is just a single machine. For the cost of an average injection mold, spare parts suppliers could instead invest in multiple 3D printers which can manufacture anything in their inventory that is suitable for 3D printing. Since there is minimal human labor involved, automated 3D printing is highly scalable, and there are multiple logistical benefits as well.

## Benefits of a Digital Inventory

### FREEDOM IN DESIGN

When 3D printing a part, there are much fewer design constraints compared to injection molding. Due to this, multiple injection molded parts can be combined, reducing part count. Any design changes can be seamlessly accommodated, and many parts designed for injection molding are easily adapted for 3D printing.

### MINIMUM ORDER QUANTITY: 1

Injection molding comes with high tooling costs, making it impractical for short runs of parts. Typical molds start at $10k. 3D printers can be used to create any part at all, and in any quantity. Imagine your supply of parts runs out at year 9, and you need to supply an extra year's worth of components. Do you fork over the cash to do a small batch of injection molded parts? Now it is possible to simply 3D print your parts to fill any gaps in the inventory.

### SMALLER WAREHOUSES

Since 3D printers are small, there exists the real possibility of re-working an area of a warehouse to become a small 3D print lab. Due to the power of automation, just a few 3D printers working 24/7 can be sufficient to meet the spare-parts demand for hundreds of components. Spare parts are usually ordered in small quantities, so it is reasonable to expect that 3D printers will have sufficient capacity. If production needs to be increased, it's as easy as adding a few more printers.

### SUSTAINABLE

As the climate crisis continues, it is extremely important to look towards sustainable technology that reduces carbon emissions. 3D printing reduces emissions from shipping as operators can 3D print many of their parts in-house, avoiding shipping from overseas contract manufacturers.

## Common Concerns

By now, you might have come up with a few counterarguments against 3D printing as a viable alternative to injection molding, and I don't blame you. We're talking about a paradigm shift here, diverging from a tried-and-true method that has worked, and will continue to work for the foreseeable future. The big question is, can we do better? Should we even try? We're human after all, so the answer should be yes! Here are some common concerns with 3D printing, so you don't have to write in, asking us about them.

### LOOK & FEEL

Let's face it. 3D printed parts have layers. This is the most common concern, but it really shouldn't be. The look of layers is completely inconsequential for internal components that rely solely on functionality. And external components? 3D printing has come a long way in the past few years, and it is entirely possible to create beautiful parts that are strong and functional, with layers that are smooth and consistent, and sometimes even unnoticeable.

### STRENGTH

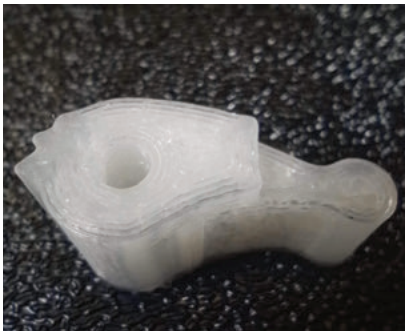
As material properties may change during the printing process, the strength of 3D printed parts is often put into question. However, when following "design for additive" guidelines, the majority of 3D printed parts are perfectly suitable as end-use parts. Just as parts need to be designed specifically for injection molding, parts properly designed for 3D printing can almost always be printed in an optimal orientation that negates the inherent weakness of the layer lines. Engineering-grade materials such as carbon-fiber nylon and polycarbonate are widely used in high-strength 3D printing applications.

### MATERIAL CHOICES

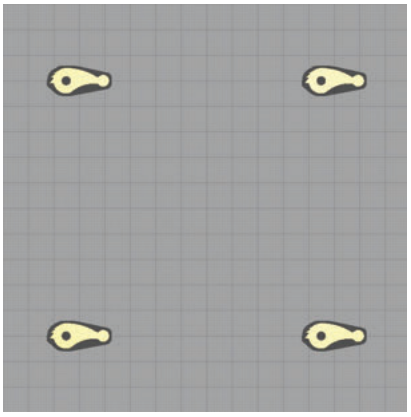
There is also concern that 3D printing materials lack chemical and heat resistance. Yet, there are many new materials for 3D printing that have these protections such as, PP, PC, fire retardant ABS, and PVC. New materials are constantly being developed, and for example, metal 3D printing is a real possibility with automated 3D printers as well. Metal prints will require a secondary manual sintering step.

## Case-Study: Break-Even Cost for a Washing Machine Part

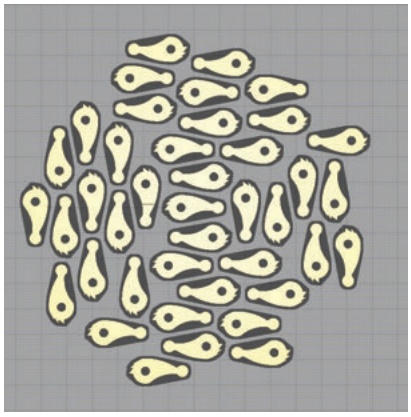
It's hard to fully realize the power of 3D printing automation without analysing the cost per-part. This simple example should demonstrate that part quantities up to 300,000 (!) are viable by automated 3D printing compared to injection molding.



For this example, we'll look at an agitator dog found inside many washing machines (Whirlpool part# 80040). This small component is part of a ratcheting mechanism which spins the agitator. This part is made entirely of plastic, and slowly wears out over years of use. They are commonly sold in sets of 4, so we will print them in sets of 4.



**Optimal batch layout**



**Unreliable batch layout**

## PRINTER COSTS

Since 3D printers can print any part at all, it isn't a sunk cost like an injection mold, it is more of an investment. As more parts can be 3D printed, the printer itself becomes more valuable. Let's assume a small print lab costs $50,000. If there are 100 different parts that can be 3D printed, then this cost could be distributed among those 100 parts. In this way, we can consider the "tooling cost" for each different part to be only $500. Considering high-volume injection molds typically cost a minimum of $10,000, then this is a significant improvement.

## MATERIAL COSTS

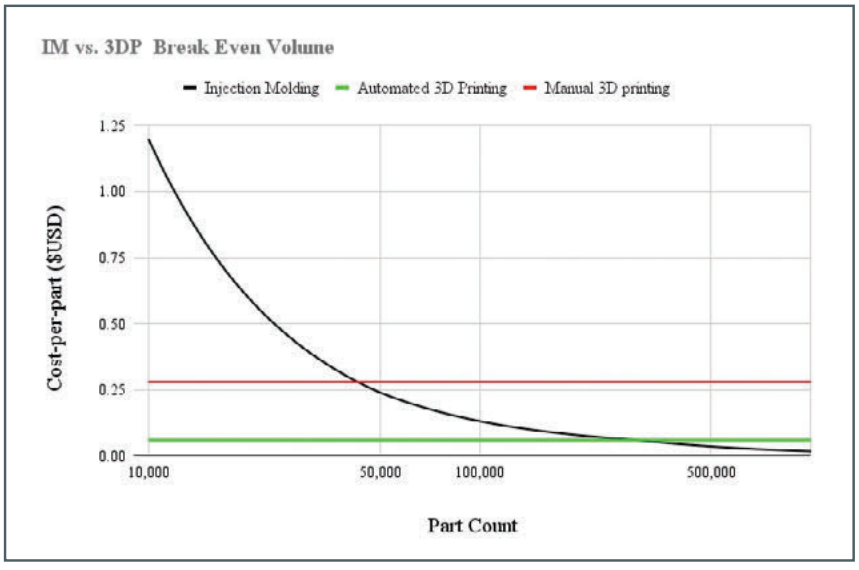
Each part needs 1 gram of material, and 10 minutes of print time. Since this part is a functional internal component, we printed it in nylon for durability and wear resistance. A set of 4 will take 40 minutes to print and use 4 grams of material. Even when 3D printed, the surface finish looks very nice and will work just as well as the original injection molded part. Considering material cost is $0.04/part and 3DQue automation costs an average of $0.02/hour for standard FFF 3D printers, it costs about $0.06 per-part to manufacture them this way.

## LABOR COSTS

Manually 3D printing thousands of parts is infeasible since someone would need to come to the printer every cycle to restart the print. If it takes a human 3 minutes to restart a print, then the cost per-part increases almost 5x becoming $0.28/part, assuming you're paying the operator $18/hr. With an automated 3D printing system, this labor cost is almost entirely eliminated.

The only labor cost with automated 3D printing is reloading the 3D printing material when it runs out. Assuming 5kg spools of filament, and 5 minutes to reload material, this results in a negligible $1.50 per 5000 parts.

With manually operated 3D printers, one way to reduce labor costs would be to print huge batches of parts at the same time, however this method is prone to failure. If one part fails, then the rest fail too. In practice, batching like this ends up being unreliable.



## DOWNTIME CONSIDERATIONS

With automated 3D printing, orders can be received in the middle of the night, and parts begin printing automatically. Production can continue through the weekends too. With a manual 3D printer, machines might sit idle overnight, with a backlog of orders waiting for the operator in the morning, causing delays.

## POST-PROCESSING

3D printed and injection molded parts may require some amount of post-processing, however for optimized 3D prints, no post-processing at all is required. Since it is hard to quantify the cost of post-processing for injection molded parts, we will neglect it.

## INJECTION MOLDING

We're not experts in injection molding, so we will use conservative estimates for the costs involved. In fact, the only cost we will consider is the cost of the mold itself. Material costs for injection molding are neglected in this analysis, so we're being generous here. Let's assume that we can get 50,000 parts manufactured for $12k in mold costs, and 300,000 manufactured for $18k.

### Results

From this initial analysis, and using conservative estimates, automated 3D printing can be competitive with injection molding with part quantities of up to 300,000. This is likely a rough upper bound since the parts in question are quite small, however this proves the effectiveness of 3D printing as a solution for spare parts.

The break-even volume isn't the end of the story. Benefits of a digital inventory go further than the cost-per-part. Keeping a lean inventory by printing on-demand will show significant logistical benefits, and the flexibility granted by 3D printing is highly valuable as well. The ability to print low volumes at low cost is now possible due to 3DQue's 3D printing automation. This is just the beginning of the next phase of the industrial revolution.

**3D PRINTING/INJECTION MOLDING**
Cost Comparisons

| PRODUCTION METHOD | COST/PART ($USD) |
|---|---|
| Manual 3D printing (Qty. Any) | $0.28 |
| Injection molding (Qty. 50k, Mold $12k) | $0.24 |
| injection molding (Qty. 300k, Mold $18k) | $0.06 |
| Automated 3D printing (Qty. Any) | $0.06 |
| Retail price (4 pack) | $1.25-$5.25 depending on vendor |



***Steven McCulloch*** *is the Product Lead at 3DQue. He guides the product design and marketing direction of 3DQue's flagship product. Looking forward, he is working to establish automation as the next step in 3D printing technology. Steven has a background in mechatronics engineering and has been 3D printing for over 7 years.*



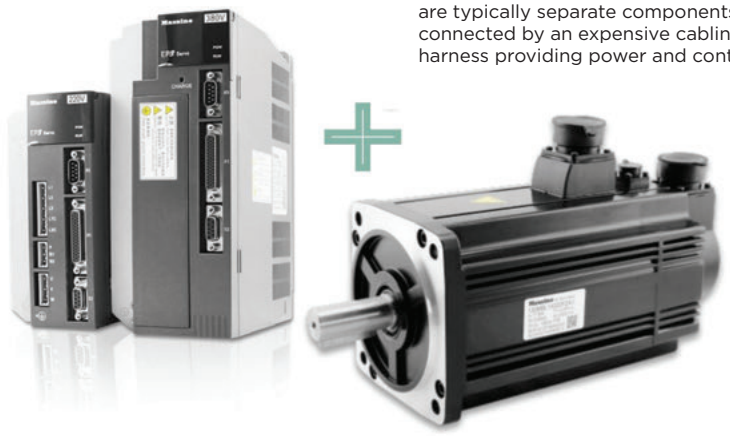


**Figure 1:** Servo motors and drives are typically separate components connected by an expensive cabling harness providing power and control.

# The Perfect Solution For Servo Drives

**BY INFINEON TECHNOLOGIES AG**

## Industrial Servo Drives

When it comes to attaining accuracy and speed in automation applications, servo drives are a key component. Ranging in power from a few hundred watts to kilowatts, they established themselves during the 1970s as the performance of the electronic solutions required to control them accurately improved. The DC servo motors of the time were cleaner than the hydraulic servos on the market that often suffered from oil leakage. But one remaining challenge was related to maintenance due to the need to replace motor brushes, and deal with the dust generated.

Commercially available AC servo motors were developed in the 1980s and, being brushless, offered a low-maintenance alternative to their DC counterparts [1]. However, it took some time before the required microcontroller-based control technology matched, then exceeded, the performance of DC motor servos.

The servo motors and drive systems on offer today would be the envy of the automation engineers of yesteryear (Figure 1). But this does not mean that the quest to deliver further improvements is over – far from it. Increasingly, servos are integrated into compact spaces where volumetric limitations place constraints on the location of the motor, drive, and connecting cable.

But perhaps the most frustration results from the cabling. Servo motor cables are notoriously expensive, having to handle both control signals and high currents passing from the drive to the motor. Furthermore, they can be the source of significant electromagnetic radiation, resulting in issues fulfilling the electromagnetic compatibility (EMC) testing. Finally, traveling wave reflections caused by an impedance mismatch between the cable and the motor are often a source of trouble [2] [3]. The fast-rising edges caused by the pulse-width modulated (PWM) drive inverter can result in damaging stress on the insulation of the motor windings.

## Relocating The Motor Drive

One obvious answer to this dilemma is to combine the motor and drive into a single unit. While this is easily said, the challenge lies with the precise implementation [4] [5].

Drive inverters use silicon IGBTs in their power stages. These are chosen for their excellent performance at high voltages. Today's most advanced solutions have been continuously refined to offer very low on-state losses, enhanced free-wheeling diodes with lower forward voltage drop, and improved reverse-recovery softness. This, coupled with packaging technology advances to simplify heat dissipation, has allowed servo drives to shrink considerably. However, the advancements achieved still do not provide enough improvement to consider mounting the drive directly to the servo motor.

The conditions under which servo drives are used are a significant contributing factor to the challenges designers face. As robotic arms move quickly from one position to another, high levels of acceleration result in levels of overload unmatched by other motor applications. A high level of overload is considered to be pushing to 200% of rated current for three seconds in a ten-second period. Very high overload lies at around 300% of rated current for one-quarter of a second in a four-second period. This leaves little time for the power devices to recover from the resultant rise in die temperature.

With increasing temperature, silicon IGBTs display a rise in the tail current at turn-off and higher reverse-recovery charge losses (Qrr) at turn-on (Figure 2). This is one reason why a passively-cooled, IGBT-based, motor-mounted servo drive is not attainable.

## Enhanced Power Switches

The semiconductor industry has been working hard to develop new substrates as an alternative to silicon. One of these, silicon carbide or SiC, is a highly suitable replacement for silicon IGBTs for applications looking to resolve

the issues discussed, belonging to the family of wide bandgap technologies (WBG). Compared to traditional silicon switches, they offer higher temperature endurance and operation, enable higher frequency switching through lower switching losses, and higher drain-source voltages.

A direct comparison of silicon IGBTs with SiC MOSFETs in the context of servo drives helps to understand the differences further and from where the advantages emanate. Silicon IGBTs use a PNPN, four-layer structure that results in a further junction voltage at the additional collector-side PN junction. It leads to a knee voltage drop in addition to the one caused by the freewheeling diode. By comparison, under servo-drive operating conditions, SiC MOSFETs offer a much lower forward voltage over the relevant load current region (Figure 3).

Like their silicon counterparts, SiC MOSFETs also integrate a body diode but, due to its WBG characteristics, the forward voltage is higher than that of the diodes selected to partner a silicon IGBT device. Reverse current during freewheeling inevitably leads to passive conduction, but it is not recommended to rely on this effect

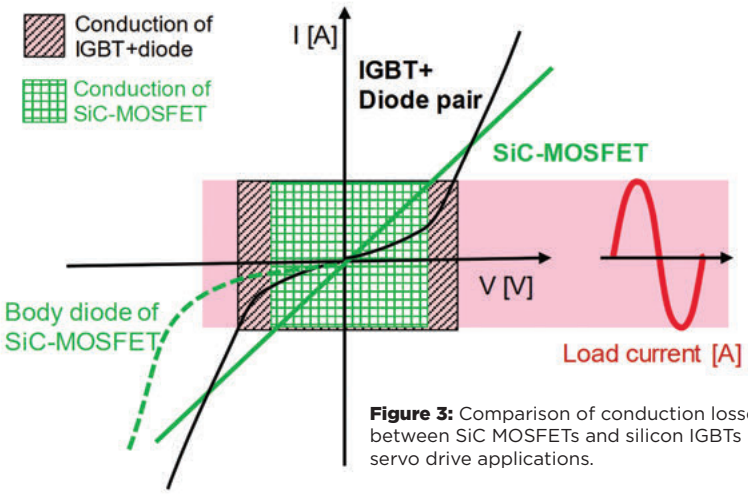



**Figure 3:** Comparison of conduction losses between SiC MOSFETs and silicon IGBTs in servo drive applications.

for the entire cycle. Instead, since SiC MOSFETs can conduct from source to drain through the channel at very low resistance, synchronous rectification (also known as 3rd quadrant operation) can be used. All this contributes to the significant energy-saving improvements of SiC MOSFETs over silicon IGBTs.

## Comparison of SiC and IGBT in The Lab and Simulation

Lab experimentation using double-pulse testing quantifies the improvement. Here a DC link voltage of 800 V, together with a load current of 40 A, was used. For the MOSFET, a CoolSiC™ 1200 V, 45 mΩ device from Infineon was selected (-5 V/+15 V gate voltage), while the silicon IGBT used was a 1200 V/40 A device (-5 V/+15 V gate voltage). The power devices were placed in the low side of a half-bridge for the tests, together with a 20 A SiC Schottky diode in the high side for freewheeling.

At room temperature, the CoolSiC™ MOSFET displays only half the turn-on losses of a silicon IGBT and one-fifth of the losses at turn-off. More importantly, the results highlight the exceptional stability over temperature of CoolSiC™ with almost no difference in losses at 175°C compared to room

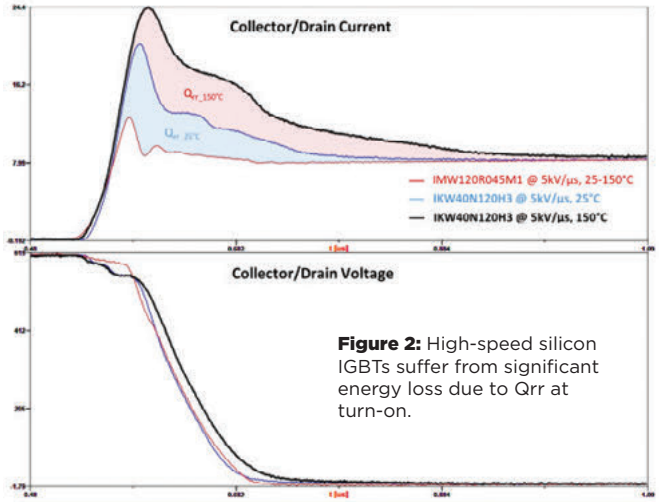



**Figure 2:** High-speed silicon IGBTs suffer from significant energy loss due to Qrr at turn-on.

Turn-on switching behavior of Si IGBT vs CoolSiC™ MOSFET at 5 kV/µs

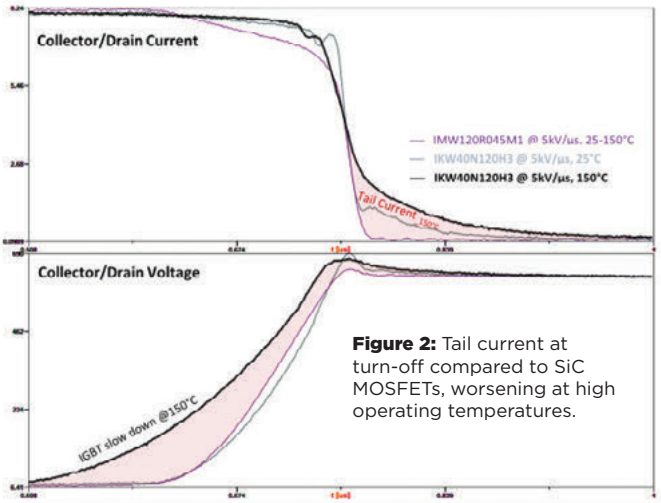
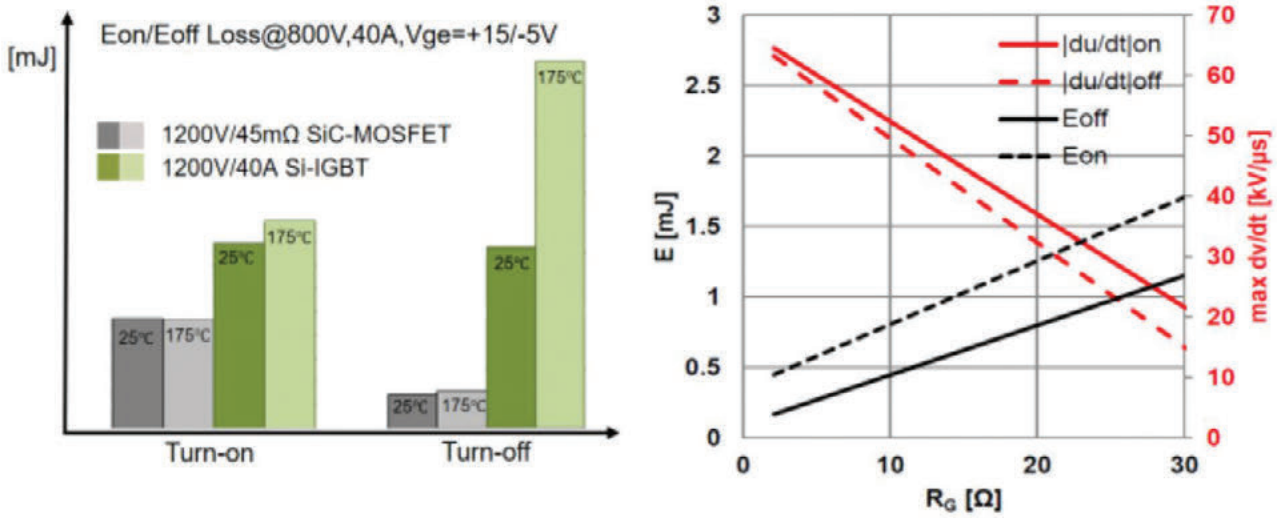



**Figure 2:** Tail current at turn-off compared to SiC MOSFETs, worsening at high operating temperatures.

Turn-off switching behavior IGBT vs CoolSiC™ MOSFET at 5 kV/µs

**Figure 4:** The CoolSiC™ MOSFET, compared to silicon IGBT technology, shows little change in losses at high temperatures and offers a linear dv/dt control through RG.



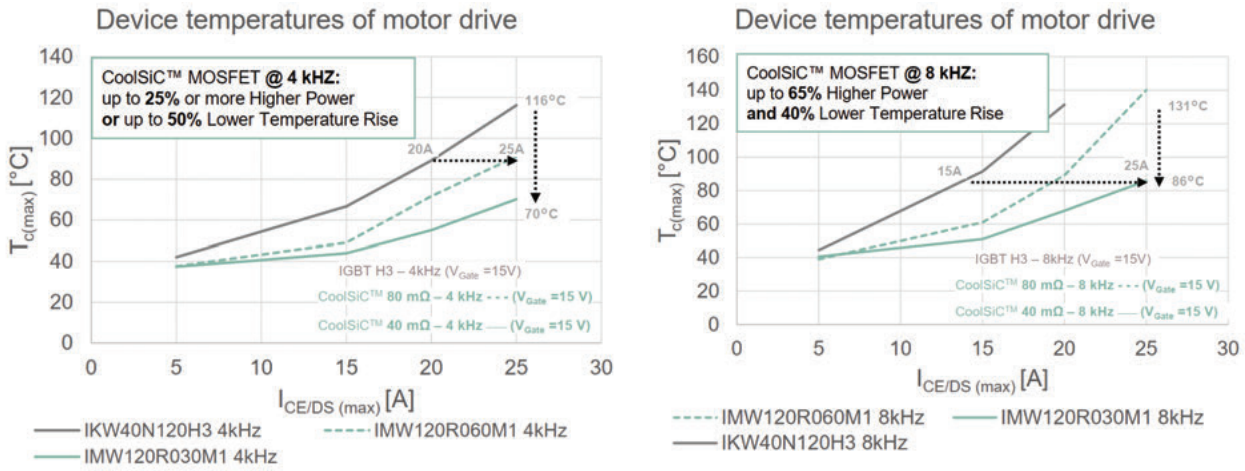

temperature (Figure 4).

The dv/dt of the CoolSiC™ MOSFET also shows itself to be highly controllable, along with switching losses, displaying a linear relationship between the gate resistor, RG, and these parameters [6]. Smaller values of RG lead to a higher di/dt on the body diode, leading to EMC challenges. Ultimately, the minimum RG value is determined by the motor windings. The important point to take from this testing is that CoolSiC™ MOSFETs enable a significant improvement in efficiency in hard-switching DC/AC inverter topologies and a resultant drop in heat dissipation challenges.

SiC also provides design engineers with the option to move to higher switching frequencies. This eases the design of compact designs, as the volume of magnetic components required can be reduced. Also, compared to a comparable silicon-IGBT design, and when moving from 4 kHz to 8 kHz, it offers the choice of lowering the operating temperature of the drive solution by up to 40% or providing up to 65% more power at a similar operating temperature (Figure 5). The higher switching frequency also delivers a faster servo response time to dynamic changes in load.

Further simulations undertaken also highlight the benefits of SiC MOSFETs in the extreme environment of servo drives and their ability to minimize temperature dissipation issues

**Figure 5:** The move to CoolSiC™ MOSFETs and changing from a 4 kHz (left) to 8 kHz (right) switching frequency provides manufacturers with options to reduce operating temperature and increase drive power.



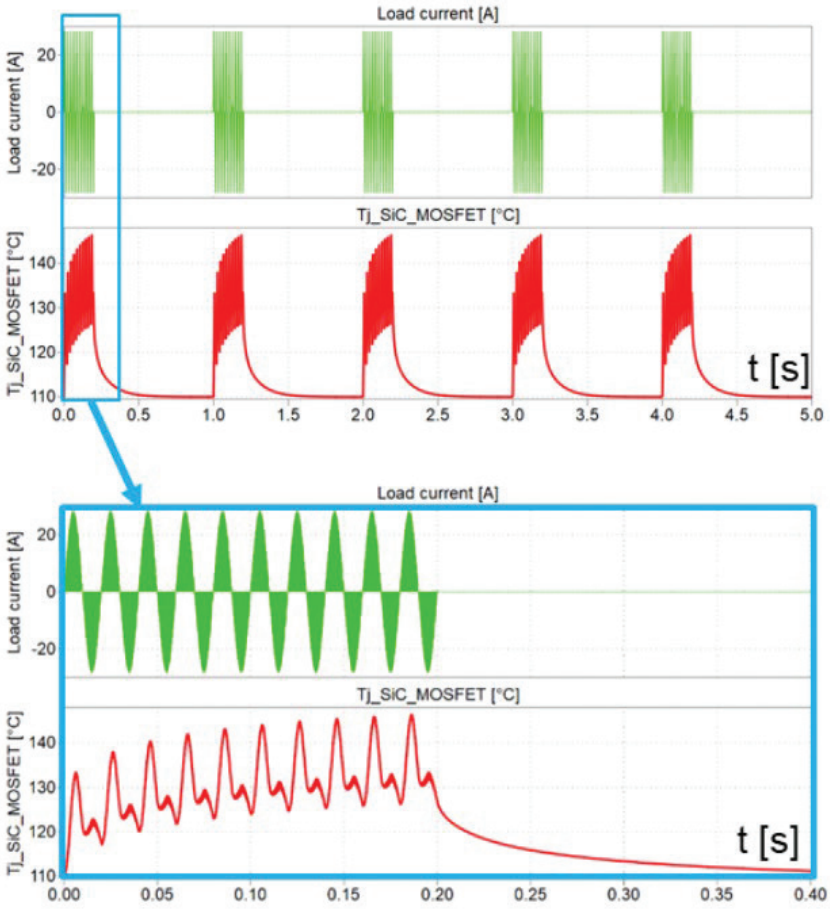



**Figure 6:** An IMBG120R030M1H CoolSiC™ MOSFET thermal simulation under 20% duty operational conditions (20 kHz switching).

compared to silicon IGBTs. Using an inverter operating from a 400 Vac (50 Hz) line voltage, with 800 Vdc link voltage and output current of 20 Arms and power factor cos. of 0.8, 20% duty (20 kHz switching) was analyzed.

With an Infineon IMBG120R030M1H (30 mΩ), it demonstrated a loss of just 22 W during operation with the maximum junction temperature rising from 110°C to 146°C during 200 ms of operation. After a further 200 ms, the temperature dropped to its initial value (Figure 6). This provides a safe margin for the junction of around 30°C.

While the SiC MOSFETs are the main contributor to heat generation, the effect of the current and voltage monitoring resistors and other components must also be considered. Thermal analysis of the power stage using a metal core printed circuit board (MCPCB) showed that under 20 A intermittent operation, total auxiliary power losses amounted to less than 3 W. For a self-cooling design, heat dissipation must occur via the back cover of the servo to which the MCPCB is attached using a high thermal conductivity epoxy resin. Calculations for the area of this back cover deliver a required surface area of 300 cm2, something that can be achieved by using a toothed design. Finite-element thermal simulation for an ambient temperature of 40°C showed that the top side of the MCPCB reaches around 113°C, while the surface of the back case lies in the range of 70°C to 80°C (Figure 7).

**Figure 7:** Finite-element thermal simulation of drive circuit implemented using an MCPCB using the servo housing as a heat sink.

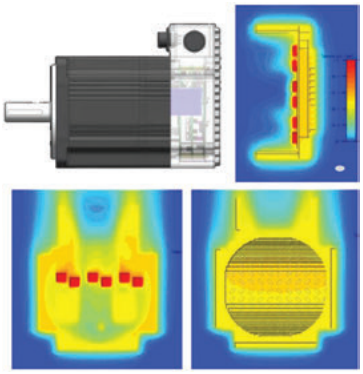


**Figure 8:** Integrated servo motor and drive (left) and compact driver board featuring CoolSiC™ MOSFET technology with XMC4800 microcontroller (right).



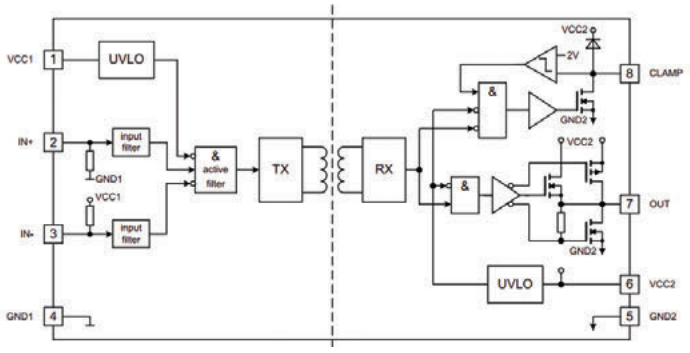
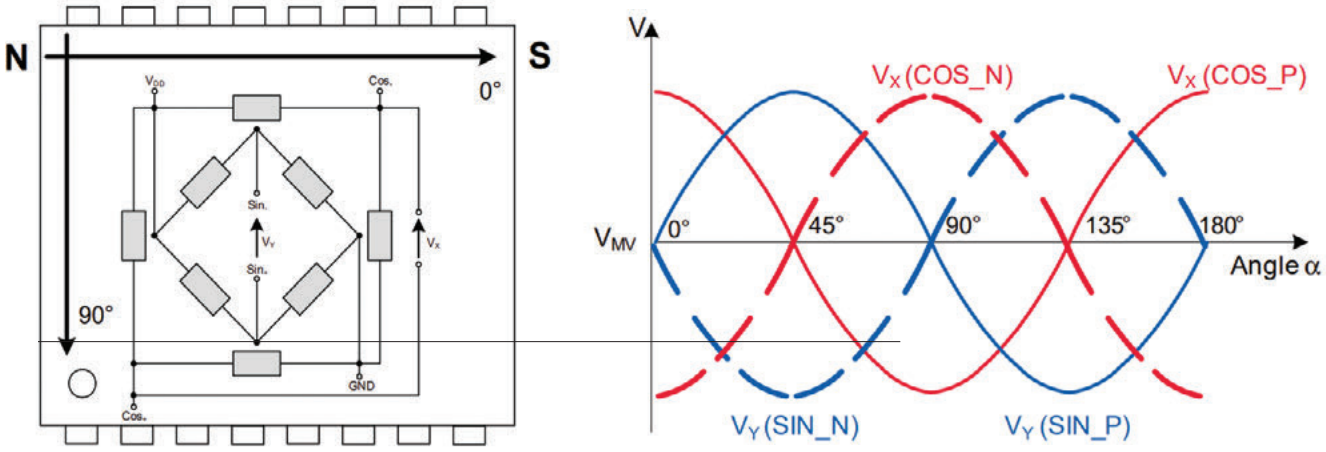



**Figure 9:** Block diagram for the single-channel, galvanically isolated 1EDI20I2MH gate driver.

**Figure 10:** The MR bridges implemented in the AMR sensor (left) together with the sine/cosine analog output signal (right).




## Integrated Servo Motor Drive Implementation

Based on the lab testing's success and the results seen from the simulation, a compact, servo motor-mounted evaluation design has been developed. It fits flush with the motor when integrated into its self-cooling housing. A three-board approach spreads the functionality across a controller board, a driver board, and a power board. This allows the SiC MOSFETs to be thermally bound to the housing (Figure 8).

The power stage of the power board is implemented using the IMBG120R030M1H, 1200 V/30 mΩ CoolSiC™ MOSFET that was analyzed and compared with the silicon IGBT in the double-pulse tests already mentioned. Thanks to the PG-TO263-7 package, its compact size is well suited to this type of application's volume constraints. The gate is provided on a single pin next to a Kelvin source sense pin. The source sense is imperative in such designs, as it can lead to a threefold reduction in EON losses compared to the same MOSFET without the sense pin. The remaining five pins are source-connected, while the drain is provided on the device's tab. Package creepage and clearance distance of greater than 6.1 mm is provided, while the device is qualified for industrial applications according to JEDEC 47/20/22.

Further contributing to the mitigating of the thermal challenges is the use of Infineon's .XT interconnection technology. This uses a diffusion soldering method to connect the CoolSiC™ chip to the copper package leadframe, essentially eliminating the solder joint. The result is an Rth(j-c) MOSFET/body diode thermal resistance of just 0.5 K/W, some 25% lower than that of a conventionally soldered implementation.

To ensure the proper control of the SiC MOSFETs, the design uses the Infineon 1EDI20I2MH EiceDRIVER™ for the driver board (Figure 9). These drivers offer a typical peak current of up to 6 A rail-to-rail output, and are ideal for use with the 1200 V capable IMBG120R030M1H. The single-channel drivers are galvanically isolated using a coreless transformer technology, and include an integrated Miller clamp circuit that protects against parasitic turn-on. To simplify their integration with a microcontroller, they also feature logic inputs, an undervoltage lockout (UVLO), and active shutdown. Their low internal voltage drop also contributes to limiting the power dissipated by the device. The PG-DSO-8-59 package provides a creepage distance of around 8 mm between the two isolated sides of the UL 1577-certified, 8-pin package.

While optimal power conversion is essential, servos also have exacting demands on positional accuracy. Rotor-position sensing is implemented by the TLE5109, a magnetic field sensor that uses magneto-resistive

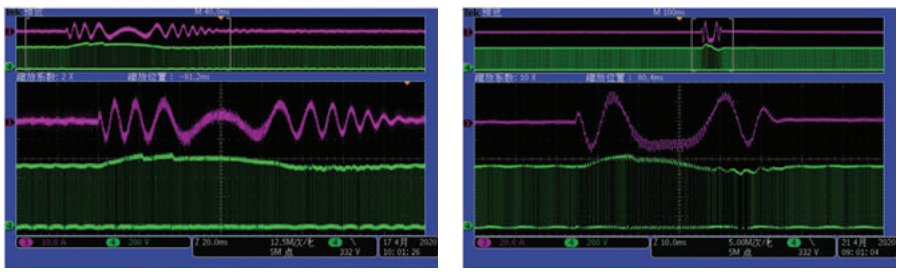


**Figure 11:** AC line current (magenta) and SiC MOSFET Vds (green) results for 150 ms (left) and 50 ms (right) acceleration/deceleration testing of the final drive design with servo motor.

(MR) elements (Figure 10). This anisotropic MR (AMR) sensor offers a high level of precision in a single package, providing analog sine and cosine outputs that describe the rotor's magnetic angle between 0 and 180°. MR sensors are implemented as a differential bridge that ensures the output is independent of the magnetic field strength, and provides a constant output voltage over a wide range of temperatures. Internal temperature compensation is also integrated for higher accuracy. Dual-die versions are available that offer a higher level of safety in safety-critical applications. The family also provides both 3.3 V and 5.0 V optimized solutions.

The control board houses the XMC4800, 144 MHz ARM® Cortex®-M4 industrial microcontroller that provides the servo's digital control and the required networking communication interface. Featuring up to 2048 Kbytes of flash memory and up to 352 Kbytes of SRAM, it is an ideal platform for an upgradeable,

powerful motor control solution. DSP and MAC instructions provide the necessary boost in computing performance for three-phase motor control algorithms and feedback loop implementations. Up to 12 channels of DMA help offload the demands on the CPU during the capture of sensor data and implementation of low-latency communications busses, such as an EtherCAT® slave. It also features a CAN interface together with a host of other established, embedded serial interfaces. A four-channel, 12-bit resolution analog-to-digital converter (ADC), offering four parallel samples and conversion and 26 analog input channels, is the perfect complement to the TLE5190 AMR sensor and current and voltage sensing circuitry.

## Real System Performance

A standard method used to verify the performance of servo motors is through acceleration and deceleration testing. The compact driver design described here, coupled with a servo motor, was tested using a conventional industrial servo controller and computer software, operating from a 600 V DC power supply, and connected to an inertia simulator. Under these conditions, the servo motor is accelerated between +1500 RPM and -1500 RPM over a slow cycle (150 ms) and a fast cycle (50 ms). Over a period of 150 ms, peak line currents reached around 11 A while, over a period of 50 ms, peak values of roughly 28 A were measured (Figure 11). The servo motor's successful operation under these conditions is considered to prove that the resultant drive design is reliable.

## Integrated, Fast, and Efficient Servo Drives

This CoolSiC™ MOSFET approach provides a short-circuit robustness (2-3 µs). However, the device can be protected by state of the art solution e.g. desat-Detection through gate drivers ICs or Itrip-protection. The lower switching losses highlighted, which are largely independent of temperature, deliver up to a 50% reduction in losses using CoolSiC™ MOSFET technology at a similar dv/dt to silicon IGBTs. The light-load conduction losses are also lower than comparable silicon IGBT designs.

Combined with advanced industrial microcontrollers, such as the 32-bit XMC™ family, galvanically isolated EiceDRIVER™, and advanced magnetic sensors, servo drive designers can confidently integrate servo drives into the servo itself. This delivers a compact servo solution that is self-cooling, and requires no more cabling than a power connection and digital connectivity (such as that combined in EtherCAT® P [7]). Since SiC MOSFETs can be switched at higher frequencies, they also provide improved dynamic control under changing motor load conditions. This applies equally to the integrated design shown here as well as to servo control implementations using external drives.

This evaluation design shows that drive circuitry can be mounted next to the servo motor, negating the need for the cable between it and the servo drive. The result is a highly compact servo solution that is easy to install and can be integrated into applications with severe space limitations.

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Achieving and maintaining full system closure ensures optimal performance and longevity for any residential or commercial HVAC system.

# How Full System Closure Impacts HVAC System Performance — and the Manufacturer's Reputation

**BY JOSE BARRIOS**

The goal of any HVAC installation or service is to ensure the system's efficiency for today and over the long-term. The performance of any system relies on the quality of the manufacturing of the system, the caliber of the products that support its installation and maintenance, and the ability and experience of the technicians performing the service.

Beyond these core elements, however, one of the most important aspects of overall HVAC performance is full system closure. Here, we'll examine what full system closure is, why it's important and how best to achieve it.

## The Impact of Full System Closure

Full system closure is achieved when an installed HVAC system shows absolutely no air leaks. It effectively prevents moisture, dirt, dust, bacteria, insects and other contaminants from entering the system and negatively affecting indoor air quality or compromising the system's integrity.

Beyond preserving indoor air quality, fully sealing an HVAC system also directly affects the system's overall performance. And, in turn, that impacts everything from whether the system will pass initial inspections to ongoing utility budgets for homeowners and businesses to the overall system lifespan.

To property owners and managers, leaky ducts may seem like an insignificant problem on the surface, but over time even small leaks can lead to air contaminants, higher utility bills and related mechanical problems — including full-on system failure. Negative experiences like these can reflect poorly on the original manufacturer brand and damage its reputation in the marketplace, even if the failures are beyond the manufacturer's control.

Therefore, it's critical for manufacturers to offer product education and technical support — and recommend suitable installation products from adjacent manufacturers — to help technicians and facility managers understand the systems and the best ways to install or service them.

## Best Practices: The Sum of All Parts

Achieving 100 percent (or near-100 percent) operational efficiency is broken down into sealing the individual elements in the system and the quality with which they're installed and maintained. Anywhere components meet presents the potential for leaks to easily occur, especially the air handler, main trunk, branch duct lines and connectors.

Identifying potential weak points is one piece of the equation. Determining the best HVAC tape solutions for sealing them is equally important. It's essential for HVAC system manufacturers to understand the characteristics of a reliable HVAC tape to offer support and recommendations to technicians for how best to install and maintain their products.

## Choosing the Best Tape for the Job

There are a broad range of pressure-sensitive foil, film and cloth tapes to suit a variety of HVAC surface materials — but not all are created equal. So how can the quality of one tape over another be determined?

At a bare minimum, tapes should be UL Listed to ensure their performance is verified. But no single measurement will reveal how well an HVAC tape will perform during installation or over the long haul. Assessing a combination of performance attributes is necessary



**Identifying the best solutions for sealing system weak points relies on a knowledge of tape products and their intended applications.**



**A range of foil, film and cloth tapes can suit a variety of system surface materials, and it's important for HVAC manufacturers to understand the differences among them when making recommendations in product installation and maintenance support.**

to ensure both the intended use and quality are right for a given system or application. Here are several tape qualities to consider:

***Permeability*** – The extent to which a tape can prevent air from leaking through it is an essential factor when striving for full system closure. Beyond bolstering a system's efficiency by fending off air leaks, non-permeable tapes are effective at maintaining air quality by keeping contaminants from coming in.

***Tack*** – Paying attention to a tape's tack reveals just how sticky its adhesive is – including the speed at which a bond will form. The faster the bond, the more immediate the seal.

***Adhesion*** – From insulation and sheet metal to flexible ductwork and fiberglass, it's critical to make sure a tape is capable of forming a permanent bond once it is applied. UL Listed HVAC tapes are rigorously tested for adhesion and resistance to thermal cycles and are a top choice for preventing tape failure.

***Conformability & Elongation*** – When working with irregular or non-smooth surfaces, tapes that are too rigid or taut will fail. Tapes that are capable of conforming to rough, irregular surfaces common in HVAC systems will minimize the threat of leaks and make installers' jobs easier.

***Shear*** – This is also known as a tape's "holding power" and demonstrates its adhesive strength (cohesiveness) over time. Again, UL Listed HVAC tapes avoid any cohesive failures and ensure that the tape will remain intact to facilitate full system closure for the duration of the system's lifespan.

***Temperature*** – While the climate of the HVAC system will often dictate the required temperature range for a tape, playing it safe with a tape that's rated for a wide application temperature range will always play to your benefit. For example, specialty cold temperature foil tapes are engineered to form airtight bonds on joints and seams even as temperature conditions fluctuate, with a temperature application range from subfreezing (-20 F) to extremely hot (260 F).



**The performance of any HVAC system is reliant not only on the quality of the original manufacturing, but also the caliber of tape products used in installing and servicing it.**

## Knowledge is Power — and Reputation

By familiarizing themselves with the products and tools that support installation and service of their systems, HVAC manufacturers can help ensure their products will perform over the long haul for homes and businesses. And that can ultimately lead to dependable products with a sound reputation and brand loyalty from customers. ●



*As a Product Manager for Shurtape Technologies, LLC,* ***Jose Barrios*** *is responsible for the product line management of all HVAC and electrical tapes. He has over 14 years of experience in managing categories and leading teams. Jose holds both a bachelor's degree and a master's degree in Business Administration from Florida International University and is Delta-Associates Black Belt Certified.*

# BBQ Grills and Microwave Ovens

**BY BRAD GLAZER**

The kitchen is the heart of our homes, and were especially so during the pandemic. Going out to eat was rare, and going to the fridge was not!. Yet no matter how often we use our culinary tools, most of us rarely stop to think about their origins. But the most common implements of food prep have been through many changes to find their present form, and some of their stories may surprise you. Here are just a few to ponder the next time you need a subject for dinner table conversation.



## Grills

Before the 20th century, outdoor meat cooking was done on massive grills, spits, or in barbecue pits lined with hot coals. Hot, heavy, and time-consuming, this was labor usually performed by groups of men, and in the South, enslaved men. But in 1897, the charcoal briquette was patented, cutting down on time and labor, and in the 1950s, the classic and compact ***Weber kettle grill*** was developed. Developed from a ***Lake Michigan buoy***, its lightweight design and stylish shape opened grilling to all.

When retailers began marketing home grills, they targeted men because there was a tradition of men cooking ***barbecue***, but also because men were usually the breadwinners. The thought was that women wouldn't be interested in buying another cooking appliance when they could just use their stoves. By targeting men, advertisers were finding a new market for cooking, and men were being motivated to feel that cooking outdoors over a fire was a very masculine thing to do. To this day, professional grill masters and pit masters are typically male.



## Microwave Ovens

Microwaves are electromagnetic waves capable of being bounced off distant objects for radar detection, and microwave ovens actually descended from radar technology developed during WWII. (The first microwave oven was developed after an engineer working on a radar apparatus ***accidentally melted*** a chocolate bar in his pocket.) When shot at food, microwave radiation makes water molecules inside the food vibrate, which creates the heat that cooks your dinner.

***According to food historian Andrew F. Smith***, the earliest microwave oven was bought by a Cleveland restaurant in 1947; the $3,000 price tag made the new tool more or less unattainable for home use. Smaller, more affordable units were developed by the 1960s, but these were found to leak harmful levels of radiation. By the 1970s, designs had improved and microwave ovens were deemed safe. But it took the partnership of the convenience food industry — who created microwave-safe packaging designs — and a slew of instructive newspaper articles, pamphlets, and cookbooks to teach the home cook how to use this new tool. As of 2001, ***over 90% of U.S. homes*** had a microwave.

# and Ice Makers, oh my!



**Ice Makers**

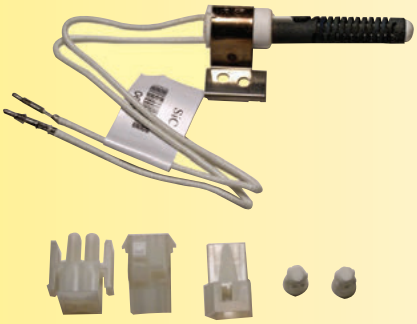
At the beginning of the 19th century, the ice industry was rapidly expanding. New England was the world's leader in ice production; ice cutters used new horse-drawn blades to cut ice off of frozen lakes. The ice was insulated in ice houses, and could stay frozen until the following October. According to food historian Jeri Quinzio in her book Of Sugar and Snow: A History of Ice Cream Making, by 1800 ice was being shipped to the West Indies, and in 1833, a Boston ice merchant began making regular shipments to Calcutta.

Ice became cheap and readily available by the mid-19th century, which spurred an abundance of iced drinks. The ice would have been brought into bars, soda fountains, or ice cream parlors in large blocks and skillfully chopped into different shapes by the resident bartender.

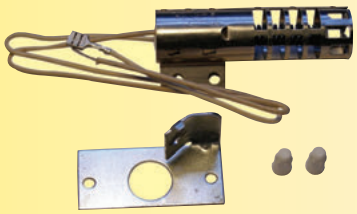
***The first mechanical ice-maker was patented in 1851***, and was designed "to convert water into ice artificially by absorbing its heat of liquefaction with expanding air." Initially, the machine was meant to ***help treat yellow fever patients***. Ice makers were first added to consumer refrigerators and freezers in 1953, and the fridge-door ice dispenser we're familiar with today was ***introduced in 1965 by Frigidaire***.

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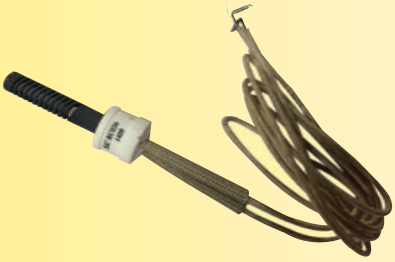


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