

APPLIANCE & HVAC

REPORT

Reaching Design Engineers at the OEM Level

January 2023

www.appliancehvacreport.com

VOLUME 5 > NUMBER 1

#1 IN A SERIES

THE 6 HAZARDS OF PRODUCT SAFETY – **RISK OF SHOCK**

(See page 18)

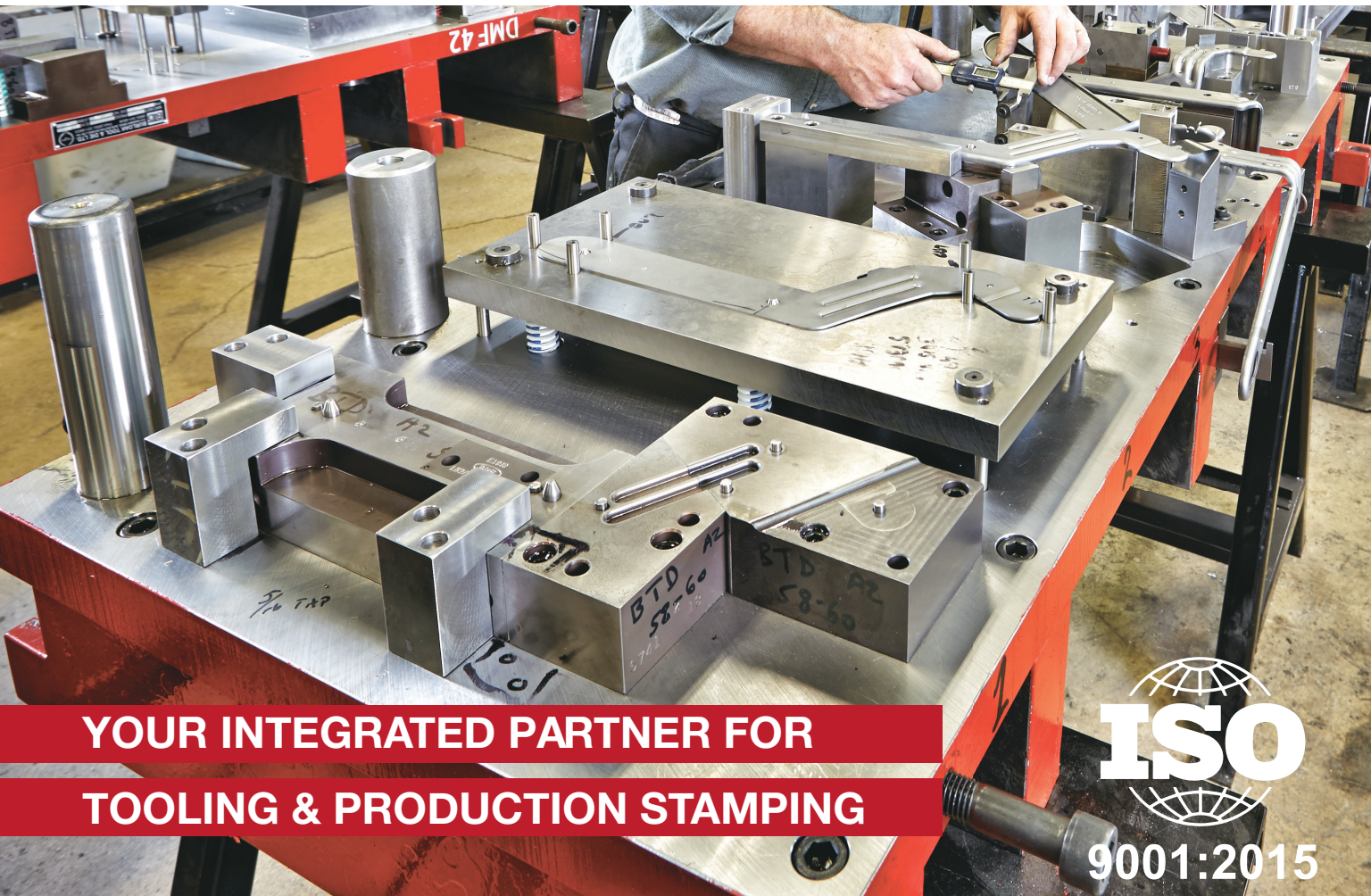
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**FEATURES
COVERING**

WATER HEATERS
SHOCK RISK
GLOBAL WARMING
THERMOSTATS
ADHESIVES
HOSES
AI & IoT

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Welcome to 2023. Our first issue of the New Year!



This begins our fourth full year of publishing *Appliance & HVAC Report*. Time flies...

This issue is special from two perspectives. First, we are exhibiting at the AHR show, as usual, and we will have hard copy distribution at our booth, B4474. So feel free to swing by, say hello and pick it up. Also, see pages 22-23 which lists the various award winners of their Innovation Awards. Congrats to one and all! Second, you will see this issue has Case Studies in it. It's our first foray publishing them and won't be our last. In time we hope to have a separate pub for case studies but for now we are including them here. This issue has two case studies, from Littelfuse and Peterson Manufacturing. Thanks to both organizations for being part of our maiden voyage.

Some new things happening with our brand in 2023, in addition to the publication of case studies as described above. We are starting an ENewsletter. It will be monthly, normally deployed mid-month, reaching our entire database of 24,000. Usually it will contain articles from previous issues along with news items that occurred subsequent to our most recent publication. Coming your way beginning in January.

Our Social Media sites are now more active than ever, so please follow us on LinkedIn and Twitter.

As you know we have the words Appliance and HVAC in our title. We have never surveyed our audience on who is working in one industry, and which one, and who is working in both. But we will be asking those questions with the deployment of this issue. So please respond. It helps us model our editorial calendar and answer our clients' questions.

Here are the names of companies whose editorial contributions appear in this issue: BrainBox, CertifiGroup, Hongfa America, Littelfuse, Masterbond, New Age industries, Peterson Manufacturing, and UL Solutions. While Littelfuse and New Age have contributed to us before, all the others are "newbies". So we are gratified to have them contribute for the first time.

By the way, if your company has a whitepaper or technical article that you think would benefit our readers (design engineers at the OEM level), please contact me. We are currently scheduling for 2023. There is no cost to this, no requirement to advertise and you do receive credit in the article's byline.

Have a great year, professionally and personally.

Brad

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REPORT Reaching Design Engineers at the OEM Level

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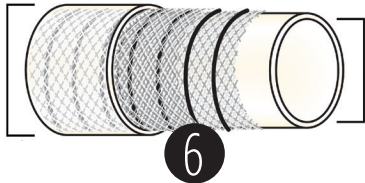
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January

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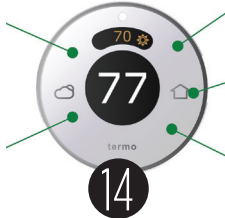


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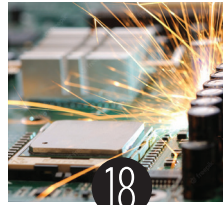


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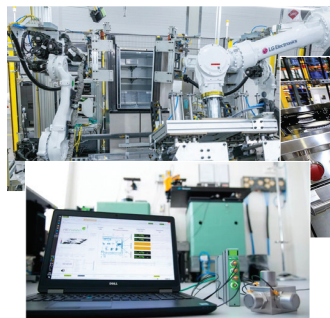
Fabricated Stainless Thermostat Probe Precision Deep Drawn Copper Thermal Bulb Precision Deep Drawn Brass Terminal Pin

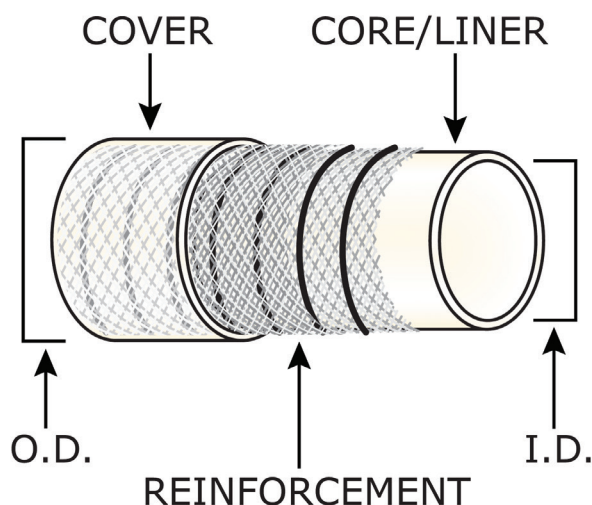
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Parts of a Hose

BY NEWAGE INDUSTRIES

What's the difference between hose and tubing, and what are the elements that comprise a hose?

To many people, hose and tubing mean the same thing. To others, a hose is a hollow, flexible transfer line, no matter the composition or material, and tubing is made of metal like copper or aluminum.

At NewAge Industries, we use the word tubing to refer to any unreinforced flexible tube and hose for any tube that includes reinforcement such as braiding, multiple layers, or wire. Note that NewAge's descriptions are not universal.

Either product may be used to transfer liquids or gases. Other

common applications include jacketing and protective sleeves, where tubing or hose is used to bundle multiple tubes together or to offer protection from heat, chemicals, abrasion, or rough and jagged surfaces.

Typical Hose Elements and Their Definitions/Purposes

Core – The inside part of a hose with which the product being conveyed comes in contact; see Liner below

Cover – The outer part of a hose that protects the interior and is engineered to withstand the environment the hose will be used in; the cover may be the same material used for the core

Cuff – A smooth end on an irregularly surfaced tube or hose (such as one that is corrugated or convoluted) used to secure a connector or fitting

Flare – The enlargement of the end of a tube or hose; typically used for fitting attachment

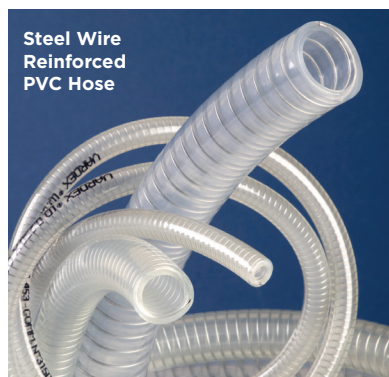
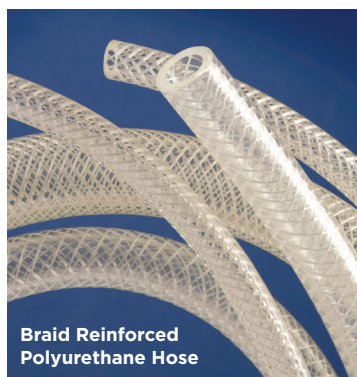
I.D. – The inner or interior diameter

Liner – The inner-most layer of a multi-layered product and that with which the product being conveyed typically comes in contact. This may be the same material as the outer layers of the tube or hose or a different material that is adhered to the outer part. The liner also protects other parts of the hose (the reinforcement and cover) from the substance being transferred within. A liner is sometimes referred to as a core.

O.D. – The outer or outside diameter

Parting Line – A line formed by the mating surfaces of molded parts; there is no parting line on extruded products like plastic or rubber tubing, but other types of hose construction may include a mold parting line

Reinforcement – A material, typically applied in a pattern, used to add durability, strength, dimensional stability, pressure carrying capability and/or vacuum capability to hose. Reinforcement materials include wire, thread, fabric, polymer and even the same material as the hose. Patterns include braid, linear, spiral and helical. ●





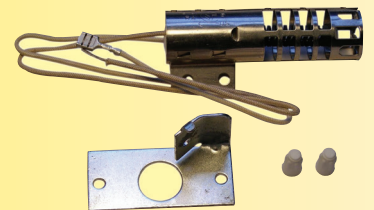
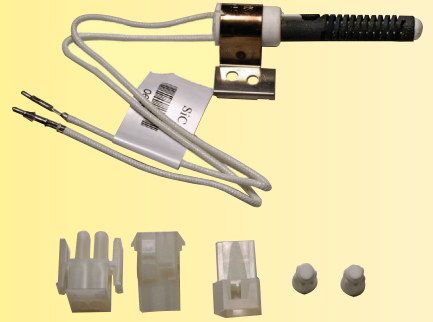
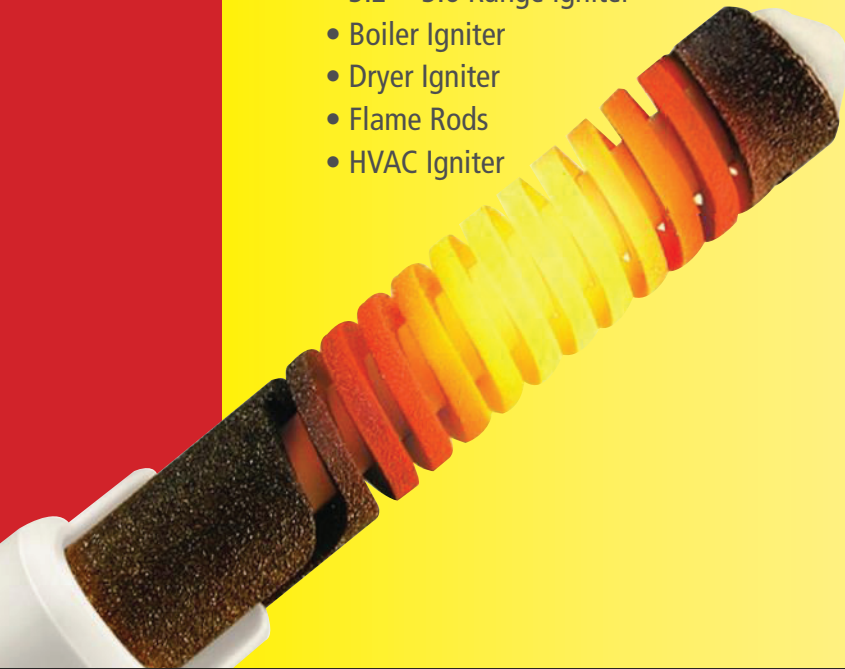
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The Impact of AI and IoT on HVAC Efficiency

BY BLAKE STANDEN

Although artificial intelligence (AI) and Internet of Things (IoT) technology are evolving, the built environment has been slow to keep up. This is because the commercial real estate design model remains segmented and focused on unique structures that are difficult to utilize efficiently. Additionally, energy efficiency technology opportunities are often value engineered out during a building's design phase due to budget constraints. Yet investors and owners alike are beginning to realize that the decision to save on tech often results in higher energy costs, greater CO₂ emissions, and reduced occupant comfort.

HVAC Efficiency & IoT

Perhaps the clearest examples of technology that address these issues are those that work to improve the efficiency of HVAC (heating, ventilation, and air conditioning) systems, which account for approximately half of a building's total energy consumption. What's more, a staggering 35% of this energy is generally wasted, an inefficiency due in large part to the fact that traditional HVAC systems are typically programmed to operate in a static environment even though weather, seasons, and tenant behaviors are fluid and dynamic.

The effects of these inefficient, poorly managed HVAC systems don't just extend to higher energy costs, they also play a major role in occupant discomfort and contribute significantly to rising concentrations of greenhouse gases. Yet there is no sign of slowing growth in the HVAC industry. Instead, the American HVAC market is set to reach over 37 billion USD by 2025 (a compound annual growth rate of over 4% from 2019-2025).

Growing in symbiosis with the HVAC industry is the commercialization of IoT technology for HVAC systems. Innovative solutions such as connected devices, AFDDs, and supervisory controls driven by artificial intelligence are rapidly gaining popularity as a means of continuously monitoring, assessing, and adjusting HVAC systems. The impact of these technologies on big buildings includes dramatic reductions in total energy costs, lowered HVAC equipment maintenance and life cycle expenses (due to the decreased unit runtime needed to maintain consistent temperatures), improved occupant comfort, and a reduced carbon footprint.

HVAC Systems & Climate Change

The drive to reduce carbon emissions is a key factor fuelling the recent surge in the adoption of technology for commercial real estate. Thanks in large part to the aggressive climate objectives set forth by global government bodies following the 2021 United Nations COP26 conference, an increasing number of real estate organizations have begun to implement AI-driven supervisory technologies that focus on lowering energy consumption without forgoing occupant comfort.

BrainBox AI is an example of a firm that is doing just that. The company's

technology makes micro-adjustments to a building's existing HVAC system, continuously monitoring a multitude of existing internal and external data points before deciding how best to optimize the HVAC system in real time. The solution easily adapts to hourly fluctuations in air quality and temperature changes while accounting for energy spend and maintaining desired thermal setpoints, resulting in up to a 60% increase in occupant comfort, a 25% reduction in total energy costs, a 40% reduction in carbon footprint, and a 50% increase in HVAC equipment life.

Figures like this matter even more

today as the price of energy soars, the climate emergency intensifies, and occupants (particularly in Europe) brace for a costly, cold winter. As these factors become more pressing, we are seeing increasing numbers of commercial building owners and facilities managers turning toward HVAC management technologies that optimize energy, cut costs, maintain comfort levels, and reduce CO2 emissions. This, in turn, is resulting in a rapid propulsion toward the adoption of AI and IoT technology in the typically slow to adapt commercial real estate industry. ●

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1: <https://www.prnewswire.com/news-releases/us-hvac-market-size-to-reach-revenues-of-around-usd-37-billion-by-2025-arizton-301169727.html#:~:text=U.S.%20HVAC%20Market%20Size%20to,37%20Billion%20by%202025%20%2D%20Arizton>



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Making Water Heating Safer: Demystifying Regulatory Changes

BY KENT NELSON

There are some overarching trends in the appliance industry, directed specifically at HVAC equipment manufacturers — especially for water heating appliances. Regulations are constantly being updated to require enhanced connectivity and interoperability, to reduce environmental impacts and to be more sustainable. Appliance manufacturers must meet the continuous changes of the regulatory landscape. Certification requirements are constantly evolving to meet this need, as well.

The Open Automated Demand Response (OpenADR) Alliance was founded in 2010 [1] to create a consistent language for “smart” energy meters, which communicate usage data to the utility to assess whether to shed or shift loads to level out demand and prevent supply shortages at peak times. Since then, regulatory bodies have been accelerating their pace of implementing regulations to evaluate and require these practices by law. For example, CTA-2045 interfaces are required per the 2021 Washington State Energy Code according to

Washington House Bill 1444 since Jan. 1, 2022 [2]. Chicago has recently adopted a new energy code, which is based on — and exceeds — the 2021 International Energy Conservation Code published by the International Code Council. It has been effective for new building permits since Nov. 1, 2022 [3] to incentivize the use of smart heating, cooling and hot water equipment integrated with the electric grid to reduce demand during peak usage. However, the details of these requirements and how to apply them are inconsistent, causing confusion

because individual states and municipalities pass their own laws that may conflict with one another. Perhaps most importantly, this does not address the potential safety concerns which can manifest based on how an appliance might respond to supply variations or other data, such as pricing information received from a utility.

For example, when a utility sends a signal to an appliance to indicate that energy is expensive and to prevent heating appliances from consuming energy, this may cause a homeowner to attempt to increase the setpoint on the local device to compensate for the automated system decreasing the temperature in the tank to reduce demand.

In theory, the length of time that such events occur should be generally transparent to the homeowner, but it is not necessarily so. In the reverse situation, demand could be low, and the supply system could request heating the temperature of the water above the setpoint. This, however, would be prohibited per the current requirements.

UL Standards already include specific language that only allows for demand response control to decrease the setpoint (e.g., to shift usage to later periods, not to shed energy when the demand is low, but the demand is already satisfied locally).

For example, UL 174, the Standard for Household Electric Storage Tank Water Heaters, 11th Edition, issued April 29, 2004, revised Dec. 16, 2021, states in Section SB3 that the demand response control shall not automatically override the water temperature setpoint above the value selected by the consumer. There is a proposal for adding new requirements for permitting demand response in electric boilers, which is currently being developed for public review for consideration in the next edition of UL 834, the Standard for



Heating, Water Supply, and Power Boilers - Electric, which would contain the same requirement.

An alternative method for allowing internal water storage to be at a higher temperature than that which is delivered to the point of use is with integral mixing valves. UL 174 was updated to include Clause 23.4, which references ASSE 1017, Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems.

Generally, the requirements are structured to indicate that the safety of the appliance must be ensured locally. However, there is an increasing need for both remote reset and safety software update functionality which relies on connectivity to the cloud to permit safe access to restart appliances and to implement bug fixes and feature enhancements in the internal firmware.

Up until now, the standards for evaluating safety software used in electronic protective controls did not include networked software in scope. For example, UL 1998, the Standard for Software in Programmable Components, 3rd Edition, issued Dec. 18, 2013, revised Sept. 24, 2018, said in the very first Clause 1.1 that, "These requirements apply to non-networked embedded software residing in programmable components performing safety-related functions whose failure is capable of resulting in a risk of fire,

electric shock, or injury to persons."

However, now there are several different requirements published which could be used, such as UL 5500, the Standard for Remote Software Updates, 1st Edition, dated Sept. 9, 2018, which would allow such networked systems to be used to update this software.

The same has also been true for controls investigated to globally-harmonized standards such as in the latest (6th Edition) of IEC 60335-1, Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, where Annex U offers a solution for these electrical appliances as the specific Part 2 requirements are updated, such as the next edition of IEC 60335-2-21, Household and similar electrical appliances - Safety - Part 2-21: Particular requirements for storage water heaters, which will offer a solution for the global market.

Here in the United States and Canada, there have already been standards that have adopted similar requirements, such as UL 60730-1, Standard for Safety for Automatic Electrical Controls - Part 1: General Requirements, and CSA E60730-1, which are based on IEC 60730-1 with the same title. That changed with the publication of the 5th Edition, first Issued Aug. 3, 2016 (and recently updated on Oct. 18, 2021 for incorporating the latest updates in the 2nd Amendment of the IEC document), when requirements for

remotely actuated control functions were added in Clause H.11.12.4, with software download and installation added in Clause H.11.12.4.4. These requirements can only be utilized when the product or application standard directly references them.

In addition to directly altering the demand, there is a push for more sustainable methods of heating the water, such as heat pump hot water heating. This method uses the vapor-compression cycle of a refrigerant to efficiently heat the water, which also provides comfort cooling to the space where the water heater is installed by transferring this heat into the water directly.

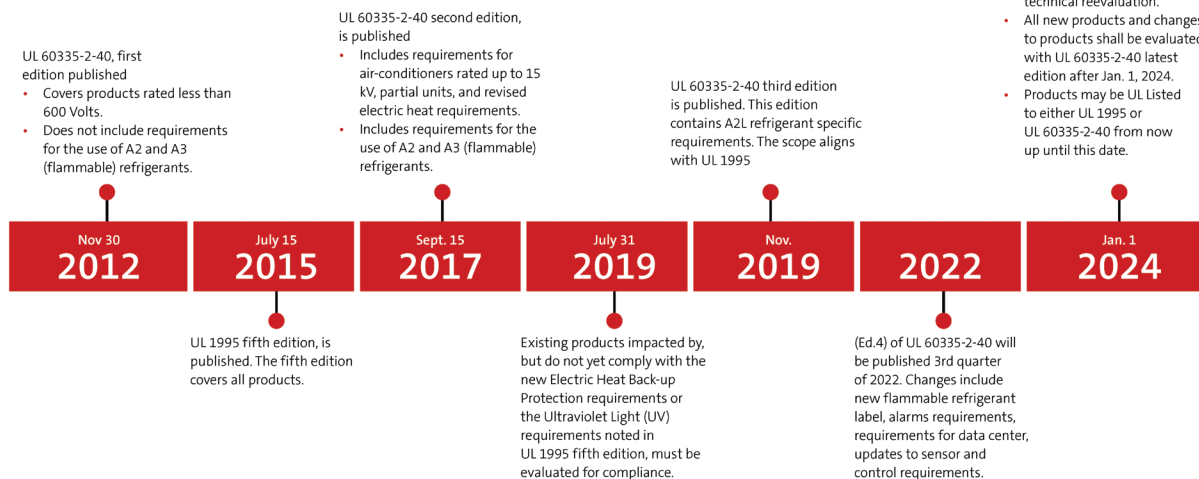
Until now, UL 1995, the Standard for Heating and Cooling Equipment, was used for evaluating the heat pump sections of these appliances. However,

this document only addresses the use of non-flammable refrigerants, which does not include the lower global warming potential flammable refrigerants, which will soon be required in the marketplace. ANSI/ASHRAE 34, Designation and Safety Classification of Refrigerants, issued in 2019, defines these classifications by a two- to three-character "safety group" code, where the first character is a letter indicating toxicity, and the second (and sometimes third) character indicates flammability. An "A" refrigerant is deemed to be lower toxicity, whereas a "B" refrigerant has higher toxicity. Flammability is indicated either by a "1" for no flame propagation, a "2L" for lower flammability, a "2" for flammability, and a "3" for higher flammability. As common examples, typical R-134a (1,1,1,2-tetrafluoroethane) and R-410a

(50/50 zeotropic blend of R-32 and R-125) are "A1" refrigerants, whereas R-32 (difluoromethane or methylene fluoride) and R-454B (68.9/31.1 zeotropic blend of R-32 and R-1234yf) are classified as "A2L" refrigerants, and R-290 (propane) and R-600a (isobutane) are classified as "A3" refrigerants.

Any heat pump product using flammable refrigerant is required to use UL 60335-2-40, the Standard for Household and Similar Electrical Appliances – Safety – Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers, 4th Edition dated Dec. 15, 2022. The International Mechanical Code has adopted the 4th edition, and it shall be used for market access. In addition, for any changes to such products which require recertification, even for units containing A1 refrigerants only, after

UL 1995 Transition to UL 60335-2-40



Currently, manufacturers may have UL 1995 Certified products evaluated to UL 60335-2-40. UL 1995 will remain a valid certification standard through January 1, 2024. At that time, UL 1995 will no longer be used to certify new products.



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CS416302(0722)



Jan. 1, 2024, all these products must be certified to the latest edition of UL 60335-2-40.

In both documents, there is a refrigerant charge limit specified in Annex GG such that any non-portable fixed-wired appliance which contains more than six times the Lower Flammable Limit of charge shall either be provided with continuous ventilation or a Refrigerant Detection System in accordance with Annex LL which initiates mitigation ventilation. For example, for R-32 this means any refrigeration system containing more than 1.8 kg (4.1 lbs) of refrigerant would be required to have such mitigation. The properties of refrigerant, including the Lower Flammability Limit, are directly included in Annex BB of UL 60335-2-40, or in ASHRAE 34.

The landscape of requirements for water heaters is ever-changing, now with not only the need to integrate refrigeration systems, but with even those requirements having their own challenges with respect to the nature of the refrigerants used. Keeping pace with the requirements requires vigilance, but following the details is always possible due to the openness of the standard development processes.

As part of the standards development process, the requirements are sent for free, public review when updated proposals are made. For any of the UL Standards, a complimentary account can be made on <https://csds.ul.com/>, where users can search for specific standards of interest to find proposed

and upcoming changes. It is not required to be a member to submit proposals. Any proposal submitted requesting explicit additions, modifications or deletions to the document's text and which is accompanied by a technical rationale must be heard by the committee. The best way to be in sync with the requirements is to help drive them — otherwise, the risk is being left behind. ●

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2: <https://app.leg.wa.gov/billssummary?BillNumber=1444&Year=2019>, retrieved 2022-10-18

3: https://www.chicago.gov/city/en/depts/bldgs/provdrs/bldg_code/news/2022/september/energycode.html, retrieved 2022-10-18



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How to Improve Smart Thermostats for Reliably Efficient Environmental Control

BY RYAN SHEAHEN

Intelligent or smart thermostats have become a popular method of energy conservation for homes, office buildings, and retail facilities. Since 2018, the market for smart thermostats has been growing at a high CAGR of 22%. With such high growth, manufacturers can easily justify continuing innovation in new models. Future smart thermostats will provide a wide range of information, including energy usage audits and comparative data on energy consumption before and after an HVAC system upgrade.

Today, smart thermostats employ more technology, such as a wide range of IoT interfaces for control and data communication. Additionally, these devices operate from AC line power and have battery backup power to remain operational during a power outage.

To ensure highly reliable smart thermostats, design engineers should incorporate robust components that protect the thermostat from potentially damaging external threats, including power line current overloads, voltage transients, and electrostatic discharge

(ESD) strikes. In this article, designers will learn how to protect their sensitive electronic circuits from these hazards. With this information, designers will confidently be able to develop smart thermostats that can withstand hazardous transients and be highly robust and reliable.

Smart Thermostats: Operation Overview

Smart thermostats perform a wide range of functions. First and foremost, the thermostat's primary function is to monitor the surrounding environment's temperature and activate the HVAC system, when necessary, to maintain the thermostat setpoint temperature.

The features that make the thermostat smart include:

- communicating HVAC system status,
- processing control information from remote devices (e.g., smartphones, tablets, etc.), and
- alerting the homeowner

Figure 1. Smart thermostat example

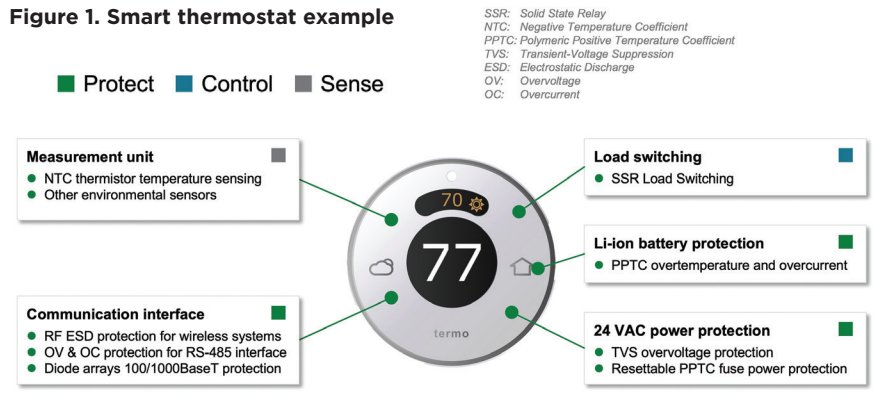
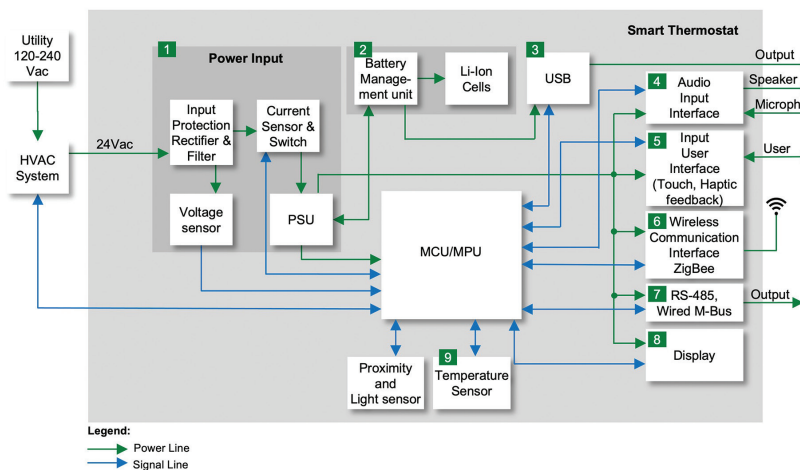


Figure 2. Smart thermostat block diagram



	Technology	Series
1	Chip Fuse (24V AC)	437, 468
	PPTC	2920L, SMD
	TVS Diode	SACB, SMAJ, SMF3.3
2	Latching Relay Driver	CPC1600
	TVS Diode, MLV	MLA, SMF
	PPTC	femtoSMD, nanoSMD, picoSMD
3	Strap PPTC	MXP, SL
	TVS Array	SESD, SPXX
	PPTC	0402L, femtoSMD
4	TVS Array	SACB, SMAJ, SMBJ
	TVS Array	PESD, SP3213-01UTG
	TVS Array	SP3213-01UTG
5	Polymer ESD	PESD
	TVS Array	SM712
	TVS diode, MLV	MLA, PLED, SMF
9	NTC	SM Series, RB, DO-35

or facilities manager if an action is required.

Many smart thermostats have a battery pack for backup power if AC line power is interrupted. Figure 1 illustrates an example smart thermostat. The boxes around the image describe its functions and list recommended technologies for the protection, control, and sensing that will help improve the smart thermostat's reliability and efficiency.

Figure 2 shows a detailed smart thermostat block diagram. The table provided lists recommended components that protect the circuit blocks and enable efficient control and sensing. The following paragraphs describe the hazards that can damage the circuitry and the recommended protection, control, and sensing components needed for high reliability and efficiency.

Protecting the SmartThermostat From Overloads, Transients, and Electrostatic discharge

The Power Input block converts the 24 VAC input from the HVAC system into the DC voltage that powers all other circuit blocks. Although the HVAC system reduces the power line AC voltage for the thermostat to 24 VAC, the 24 VAC line is still susceptible to power line overload currents and voltage transients that can pass through the HVAC system.

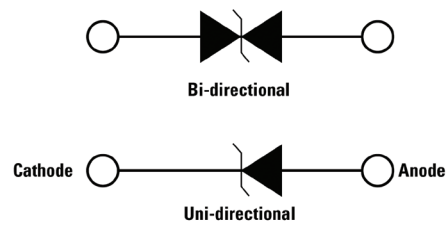
To protect the Power Input from sustained current overloads, use a time delay fuse to enable the fuse to withstand inrush currents caused by motors turning on and turning off. A time delay fuse will avoid nuisance shutdowns resulting from inrush currents. Miniature axial lead and surface mount fuses are available for low voltage circuits to save on precious pc board space.

A Polymeric Positive Temperature Coefficient (PPTC) resettable fuse is an alternative to a standard, one-time

overload fuse. The fuse opens due to heat from an overload current; however, it resets when its temperature falls below a threshold level and does not need replacement after it has opened.

Lightning strikes on the power line and large motors inducing back EMF voltages on the power line can result

Figure 3. Bi-directional TVS diodes connected cathode-cathode and a uni-directional TVS diode



in damaging transient overloads. These voltages can reach kV levels. While the HVAC system can have



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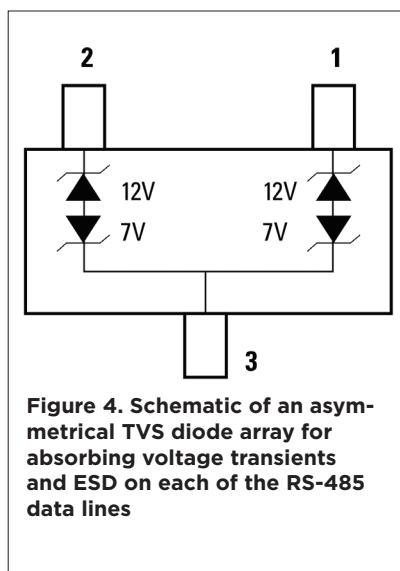


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protection from these overloads, some of the energy can pass through the HVAC circuit to the Power Input block. Use a transient voltage suppressor (TVS) diode to clamp and absorb the residual transient voltage and its energy. TVS diodes offer:

- Ultra-fast response time of under 1 ps
- Low clamping voltages to protect sensitive semiconductors
- Ability to safely absorb peak pulse power of 400 W
- Bi-directional and uni-directional configurations
- Versions with surface mount form factors.

Figure 3 illustrates the symbols for the bi-directional and the uni-directional TVS diodes. The two diodes, shown in the bi-directional configuration, use cathode-cathode connected diodes.

The Battery Management unit ensures that all battery cells equally power the load and monitors the state-of-charge of the cells. Protect the semiconductor control circuitry from voltage transients and ESD with a TVS diode. Consider a TVS diode or a multilayer varistor (MLV). Either device can provide very low clamping voltages to protect low voltage semiconductors and provide ESD protection compliant to IEC 61000-4-2, the electromagnetic compatibility standard.

Designers should prevent battery overcharging and battery overtemperature conditions by using PPTC resettable fuses. Versions of PPTC fuses can be either surface-mount PC board components or directly mountable on the battery pack to quickly detect an overtemperature condition.

Input/Output Interfaces. A smart thermostat can have several wired and wireless interfaces. The interfaces are subject to hazards from the external environment, which is

typically ESD strikes.

For the USB interface, use TVS diodes for ESD protection. Look for:

- A minimum safe absorption of a ± 20 kV ESD either through the air or via direct human contact
- A maximum of 1 pF of capacitance for minimum distortion of transmitted and received signals
- A low clamping voltage of no more than 10 V
- A uni-directional or bi-directional diode
- Leakage current under 100 nA.

Consider a PPTC resettable fuse to protect the USB interface from current overloads. Look for a small model to save PC board space.

The Audio Input Interface outputs alarms and has voice-activated input. Protect this interface's I/O lines with a TVS diode. Consider either a uni-directional or bi-directional diode for each line.

The Input User Interface provides a data entry panel. The Zigbee Wireless Communication Interface transmits data and receives control information from devices such as a smartphone or a tablet PC. Both interfaces require protection from an ESD strike. A TVS diode array that provides at least 10 kV of bi-directional energy absorption will protect these two interfaces safely. An alternative to the TVS diode for the Wireless Communication Interface is a polymer ESD suppressor. A polymer ESD suppressor has very low capacitance, typically around 0.25 pF, to minimize its impact on the RF signals, under 1 ns response time, and a typical leakage current of under 10 nA.

The RS-485 Wired M-Bus in a commercial smart thermostat provides data to an external system. Use an asymmetrical TVS diode array to protect the -7 V and +12 V working voltages on the RS-485's data lines. Also, look for high ESD absorption above 20 kV. One component, as shown

Table 1. Safety standards for smart thermostats

Standard	Title
UL 873	Temperature-Indicating and Regulating Equipment
ANSI/UL 60730-1	Automatic Electrical Controls – Part 2-9: Particular Requirements for Temperature Sensing Controls
UL 60730-2-1A	Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Energy Regulator
UL 1449	Standard for Surge Protection Devices
UL 1434	Standard for Thermistor-Type Devices
UL 4248-9	Standard for Fuseholders
IEC 60334-2-30 Ed. 5.1b: 2016	Household and Similar Electric Appliances – Safety – Part 2-30: Particular requirements for room heaters
UL 1642	Lithium Batteries
UL 2054	Household and Commercial Batteries
IEC 62281	Safety of Primary and Secondary Lithium Cells and Batteries during transport

in Figure 4, protects both data lines.

The last interface is the Display which, at a minimum, shows the temperature setting and actual room temperature. A TVS diode such as the one recommended for the Battery Management Unit or a multilayer varistor can protect the display circuitry.

Efficient Control and Sensing

Consider a latching relay driver to control power to the smart thermostat's circuit blocks. To avoid generating electromagnetic interference (EMI) during switching, look for a driver that switches when the AC line voltage passes through 0 V. Also, latching relays save on power consumption since they do not draw power in the closed-contact state.

The most critical element of the smart thermostat is the temperature sensor. Consider using a thermistor, a negative temperature coefficient (NTC) element. Thermistors offer better accuracy than other temperature sensor types and detect a wide temperature range, -55 to +220° C. Use a hermetically sealed thermistor to obtain long-term reliability and stability. Small, surface-mount versions save PC board space and allow automated insertion.

Applicable Safety Standards For SmartThermostats

Designers need to be aware of the standards that apply to smart thermostats, and Table 1 lists these safety standards. Failure to comply with the appropriate standards can result in failure to pass compliance certification testing, additional development costs, and delayed introduction to the market.

Designing in Protection and Long-Life Components Achieves High Reliability

Designers need only a small number of components to protect a smart thermostat and enhance its reliability thoroughly. It is challenging to be an expert in all aspects of electronic design, so designers can take advantage of the expertise of a manufacturer's application engineers on circuit protection and efficient control. They can help with:

- Cost-effective component selection
- Guidance on complying with the applicable safety standards
- Pre-compliance testing to help identify problems before compliance testing (service provided by some manufacturers).

Using the recommended protection, control, and sensing components will ensure a reliable smart thermostat with robust protection from external hazards while providing efficient operation. ●

Sources

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Ryan Sheahen is the Global Strategic Marketing Manager for the Electronics Business Unit. Ryan joined Littelfuse in 2011 as an inside sales specialist.

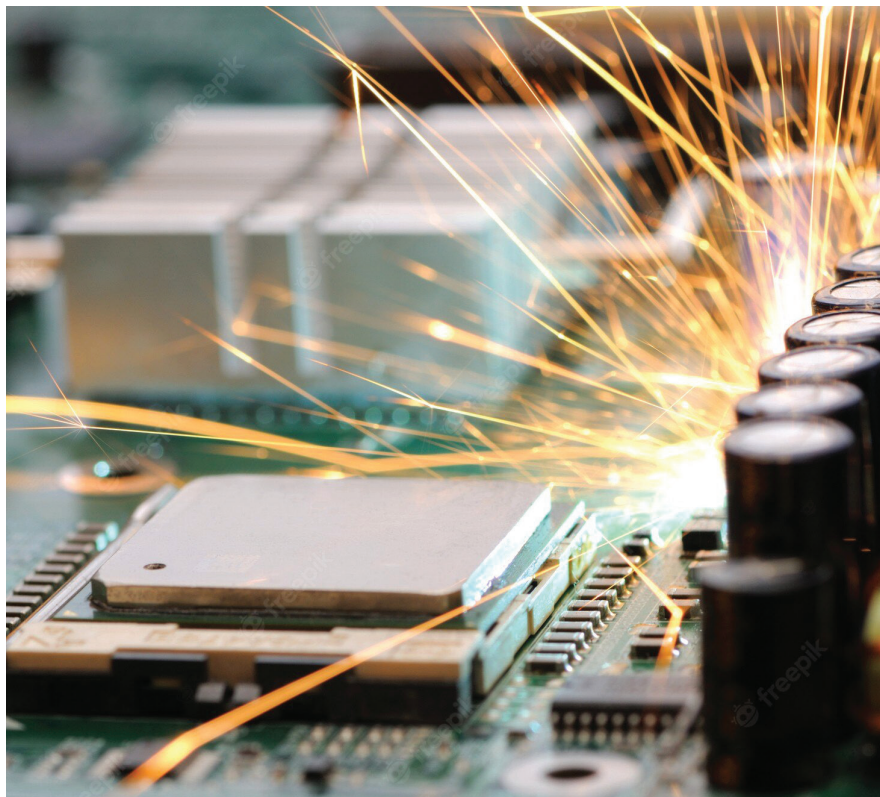
He was previously the Global Product Manager for the magnetic sensing product portfolio. His current responsibilities include developing marketing collateral, managing marketing activities for new product launches, and performing marketing studies and feasibility analysis for new product ideas. Ryan earned his BS in Mechanical Engineering Technology from Purdue University.



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The 6 Hazards of Product Safety – Risk of Shock

BY BILL BISENIUS

Designing for Compliance is critical to getting your product certified on the first try. Designing for Compliance requires owning, knowing, and applying the standard(s) while designing your product. However, in order to successfully read and understand the standard, you have to know the intent of the requirements. Our “Designing for Compliance” series of whitepapers will educate you on “The 6 Hazards of Product Safety”. The intent of the requirements in all UL/CSA/EN/IEC safety standards is to protect the user from the “6 Hazards of Product Safety”. This whitepaper covers Hazard #1 – Risk of Shock.

Risk of Shock Definition:

A “Risk of Shock” is considered to exist within a product if the user can access a hazardous voltage circuit (typically >30VAC). Due to the potential for severe injury or death from an electrical shock, two levels of protection are required from circuits presenting a shock hazard. Two levels of protection means that even when one protection method goes bad (referred to as a single fault condition) the user still cannot be shocked.

Risk of Shock – Level of Importance: The most important requirement in the product safety standards is to protect the user from receiving an electric shock. And,

because the outcome from an electric shock can be so severe (potential for death), the product safety standards require that you provide “2 Levels” of protection from a potential shock hazard. And it’s that “2nd level” that results in much of the difficulty in understanding how to design for shock hazard compliance. It is also part of the reason that Risk of Shock protection accounts for more than 50% of the requirements and tests in most UL standards. So, if you learn Risk of Shock, you have learned a large part of the standard.

Risk of Shock –

Accessibility: The first element of learning Risk of Shock protection is to understand the term “accessibility”. In order for the user to get “shocked”, the user must touch an electrical circuit. Ability to touch an electrical circuit is typically referred to as “accessibility”. This is critical to understanding Risk of Shock and it provides us with the first set of important compliance design questions:

1) Can the user access the circuit?

And,

2) Do you need the user to access the circuit?

To answer these questions, we need the product safety standards. Product safety is not intended to be a subjective process. Determining whether the user can access the circuit should not be dependent on whose finger is used. Rather, the product safety standards specify “accessibility probes” that are used to determine what circuits are considered to be user accessible. There are different accessibility probes in different standards.

Many compliance professionals are familiar with the “International Finger” which is based on an adult male hand size. There is also a “UL Finger” that is much smaller as it is based on the

hand size of a woman and, a set of "Child Finger Probes" representing two different age groups of children, with the probe including a child's arm. In addition, some standards include probes that represent a basic tool that is typically found in the product's user environment (paper clip, screwdriver, etc.). There is even a test chain that simulates a user's jewelry drooping into a product vent to see if it can "access" a hazardous circuit. Be sure to check your product safety standards to identify what accessibility probes and conditions of use apply to your products (i.e. force limitations, limited use guidelines, etc.).

It should be noted that most safety standards require opening and removing all parts that can be removed or opened without tools before applying the accessibility probes. This can include using a Finger Nail probe to try and pry open snapped together parts. And for products with electrical connectors for communication or accessories (USB, headphones, etc.), these connectors are assumed to be accessible regardless of the type of connector. This is very important – all circuits connected to external connectors are usually considered user accessible (other than certified power receptacles).

Risk of Shock – Shock Hazard Levels: Once you identify all circuits that can be "accessed" by the probes, the next step is for you to answer the question "do you need for the user to access the circuit"? If the answer is no, you should design means into the product to prevent the accessibility probes from accessing the circuit (locking door, screw down a panel, replace thumbscrews, change a vent size or location, etc.). However, you may need the user to be able to access the circuit (usb port, headphone

jack, change battery, plug-in options, etc.). Circuits which are accessible must not be a "Shock Hazard". For an accessible circuit, the first step in verifying compliance is to determine if the accessible circuit is at a "Shock Hazard Level".

Each product safety standard defines a Shock Hazard level circuit. This definition always begins with a definition for "hazardous voltage level". In many standards, voltages above 30 Vrms are considered a shock hazard. Some standards expand that definition to 30Vrms, 42.4 Vpk or 60VDC. These numbers can vary by standard, so be sure of the limits in your standard. Also be aware that for some standards such as the standard for electrical medical products, the accessible voltage limit is lower (25 Vrms).

Risk of Shock – 2 Levels of Protection: Once you know which circuits are user accessible, and you have verified they are not at shock hazard voltage level, you must verify that the accessible circuit is properly protected during fault conditions. The product safety standards require that you must protect the user from all potential shock hazards with 2 levels of protection ("2 levels", not "2 layers"). Two levels of protection means that if the user is touching the circuit, and a fault occurs, the user still will not be shocked (the voltage in the accessible circuit will not increase above the hazardous voltage limits). The standards accomplish this by requiring "Double" or "Reinforced Insulation" between accessible circuits and all hazardous voltage circuits. For double and reinforced insulation, a single fault will not eliminate the insulation.

Double or reinforced insulation can only be achieved through the use of an isolation device = meaning that you must have an isolation transformer or

opto-isolator between the accessible circuit and all mains/hazardous voltage circuits. This can be a very complex process, ensuring that each isolation device has 2 "levels" of insulation, and that each of the 2 levels protects in the event that 1 fails. Which is the reason Risk of Shock is such a large part of the product safety standards.

Risk of Shock – Summary:

In summary, "accessible circuits" are those circuits that can be contacted by the accessibility probes. Users must be protected from a Risk of Shock. To do this, all accessible circuits must be verified to have 2 levels of protection from shock hazards. Shock hazard circuits include all interconnected circuits that contain a hazardous voltage (30Vrms, 42.4Vpk, 60VDC). Accessible circuits must be "isolated" from all hazardous voltage circuits by 2 levels of protection = double or reinforced insulation. Primarily, shock hazard protection involves verifying the product has 2 levels of protection between all accessible parts/circuits and all hazardous voltage circuits, and that each level of protection meets the requirements within the standard. ●



William Bisenius is President and co-founder of CertifiGroup Inc. "Bill" has worked in the regulatory compliance field for over 35 years and is considered to be an international expert in the field of Product Safety. Mr. Bisenius has written and presented many training seminars in his fields of expertise. Throughout his compliance career, Bill has worked closely with some of the top names in the industry including NASA, IBM, Dell, Phillips, and Siemens.

Bill is a NARTE certified NCE and NCT and a Trial Experienced Expert Witness. He has authored over 100 whitepapers on Product Safety & Regulatory Compliance and published numerous articles in IEEE journals and other industry trade publications.



The supervisory board of **Ziehl-Abegg** appointed **Dr. Marc Wucherer** as the new Managing Director. He assumed his new position in December 2022.

The Doctor of Engineering with a degree in Business Administration began his career at Siemens AG. During a number of managerial roles, he was responsible for several business units both in Germany and abroad, and was president of the Industry segment in Northeast Asia.

Dr. Marc Wucherer has been on the board of directors of Bosch Rexroth AG since 2017, with global responsibility for sales and marketing and, later, also for the factory automation segment. Dr. Wucherer is a first-class manager with tremendous experience in multiple business areas. In addition to his wealth of experience and reliability, his international experience is perfect for actively shaping Ziehl-Abegg's continued global growth.



H.B. Fuller Co. announced Celeste Mastin, executive vice president and chief operating officer, succeeded Jim Owens as president and chief executive officer, effective December 4, 2022. Upon assuming the role, Mastin joined the company's board of directors, replacing Owens, who retired.

"It has been a privilege to serve as CEO of H.B. Fuller, and I am very proud of all that we have accomplished as a team over the last 12 years," said Owens. "With a proven value-creation strategy, an experienced leadership team in place, and positive momentum, this is the opportune time to transition the company's leadership."

Owens added, "Celeste is an outstanding leader and ideal fit with H.B. Fuller's entrepreneurial, customer-focused, global culture. She brings strategic insights, continuity of leadership, and a strong record of delivering exceptional results. I am confident the company will excel and reach new levels of financial and operational performance under her leadership."

Prince International Corporation, a portfolio company of American Securities

LLC, announced that it has completed its acquisition of **Ferro Corporation**, which was previously announced on May 11, 2021. Prince paid \$22.00 per share in an all-cash transaction valued at approximately \$2.1 billion.

In conjunction with the closing of the transaction, the company will also combine with **Chromaflo Technologies**, a premier global provider of colorant technology solutions and also an American Securities portfolio company. The new company, renamed **Vibrantz Technologies Inc.**, will be headquartered in Houston, Texas, and will be a leading global, diversified technology leader in advanced materials, color solutions and performance coatings with sales of approximately \$2 billion. The newly combined company employs approximately 5,500 people and operates 64 manufacturing sites across six continents.



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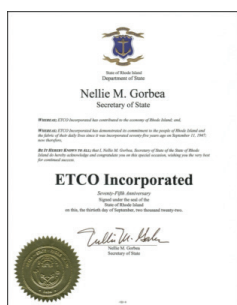




The Marcone Group, the largest authorized appliance parts distributor in the world, is pleased to announce a partnership with **Bruviti**, the leading provider of AI-driven predictive and triage service technology.

Marcone has been operating for nearly 90 years and has a track record of delivering exceptional service and parts availability. In the last year, Marcone has expanded from its roots to become the preferred hub of parts for specialists servicing the home, leveraging leading-edge technology to do what the company does best: serve customers in the home appliance, HVAC, plumbing, commercial kitchen and pool industries efficiently and effectively via a best-in-class user experience.

The partnership combines Bruviti's natural language processing algorithms and parts prediction models with Marcone's best-in-class proprietary technology and nationwide distribution network.



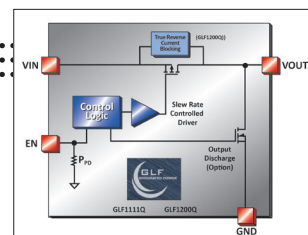
Rhode Island Secretary of State **Nellie M. Gorbea** on September 30, 2022 recognized **ETCO Incorporated's 75th anniversary**. Secretary Gorbea cited ETCO's long term commitment to the economy and people of Rhode Island.

Founded in 1947, ETCO is a privately owned company. The Company manufactures precision stampings and rubber and plastic molded products used principally by major automotive and appliance manufacturers. ETCO also has major customers in a variety of other industries in the USA and over 30 countries throughout the world.

Dow introduced **DOWSIL™ Immersion Cooling Technology**, a next-generation solution for cooling hyperscale cloud and enterprise data centers with optimized efficiency and sustainability. Award-winning DOWSIL™ Immersion Cooling Technology offers a revolutionary approach to thermal management and sustainability for fast-growing data centers in a new era of high-speed, high-volume data communications.



Hottinger Brüel & Kjær launches its latest version of its **Tescia software**, which is ideal for targeting vibration, acoustics and observing applications. It helps reduce setup time, safeguard test items and improve data quality and test result validation. The Steady Data Analyzer and Interface Protocol enables engineers to gather and correlate steady and dynamic data so that parameters such as temperature, wind and humidity can be mapped and analyzed. A new Acoustic Post Correction license helps optimize test time by automating calibration processes, calculating and applying frequency response corrections for microphones and other accessories.



GLF Integrated Power, manufacturer of innovative ultra-low-power load switches, is pleased to introduce two new Automotive grade **AEC-Q100 IQSmart™ load switch ICs**. The AEC-Q100 qualified GLF1111Q and GLF1200Q are rated for a wide temperature range (Grade 1 -40°C to +125°C). The GLF1200Q features a true reverse-current blocking, which prevents a backup power source from being discharged when an input node is shorted. The GLF1200Q works all of the time regardless of on or off state.

Applications for the GLF1111Q and GLF1200Q include infotainment and cluster display systems, diagnostic systems, passive entry/start systems (PEPS), customer premise equipment (CPE), face recognition systems and intelligent cockpit and autonomous driving applications.

Both the GLF1111Q and GLF1200Q IQSmart™ devices, packaged in a SOT-23-5L, offer easy visual inspection of solder joints. Both feature integrated slow-rate control that limit inrush upon turn on, therefore minimizing the effects of voltage droop.



Grundfos, the world's largest pump manufacturer, announced the next generation of small circulators for the residential heating market with the introduction of the Grundfos Digital NEXT range — starting with the **UPSe 15-58** in late 2022, followed by the release of the new, digital **ALPHA 15-58** in early 2023. Both circulators have been rated with the highest Energy Rating in the market at 193, revolutionizing the market by delivering enhanced efficiency and performance and offering the highest wire-to-water efficiency available today.

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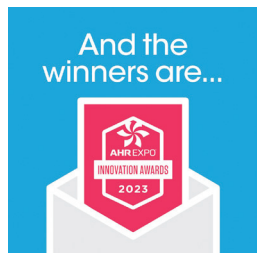
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The AHR Expo (International Air-Conditioning, Heating, Refrigerating Exposition) announced the winners of the 2023 AHR Expo Innovation Awards. Each year, winners are chosen in ten industry categories to represent the most innovative products and technologies set to hit the market in the year ahead.

“The awards program experiences growth year on year,” said Show Manager, Mark Stevens. “This is a direct correlation to just how fast our industry is growing through innovation. The awards are a key indicator of how HVACR is being called upon to solve worldwide issues at a rapid pace. We aim to highlight this innovation trajectory and honor those that are pushing the bar to create real solutions to difficult problems.”

The Innovation Awards draw hundreds of manufacturers who are designing new and never before seen solutions or improvements upon existing products and technologies launching into the marketplace in the coming year. They encourage exhibitors to submit new products and technologies for recognition via review and selection by a panel of third-party judges comprised of distinguished ASHRAE members. Entrants are evaluated based on overall innovative design, creativity of the product or service offered, product or technology real-world application, as well as overall potential market impact.

“We are thrilled to celebrate this year’s winners as well as to continue to champion innovation among our industry professionals,” continued Stevens. “In the last few years, HVACR has taken on a wider audience outside of our direct industry stakeholders. It is refreshing to welcome an understanding of the value HVACR brings to the world in essentially every factor of daily life.

Manufacturers on the AHR Expo show floor are challenged to continuously innovate and adapt as the built environment around us changes, and you’ll see them meeting this charge head-on in Atlanta.”

The Innovation Awards program serves as an annual metric for year-to-year industry development and growth, as well as a forecast of the marketplace in the upcoming year. While the Awards officially recognize only a select few, the show floor is a robust example of how manufacturers are growing the industry in exciting ways.



BUILDING AUTOMATION

Cielo Breez Max (Max) is the industry’s first true smart thermostat for mini-split, window and portable air conditioners. It is loaded with an AI-based engine to auto-detect AC type and model number. Backed with AWS cloud, Max is universally compatible with any brand or type of ductless air conditioner. It works with a 5V adapter or can be hard-wired through 12/18/24 volts AC. It can also be powered with 12/18/24 Volt DC. All Cielo Breez Max are secured with TLS1.2 to authenticate and encrypt data securely when transferred over a network. Max is compatible with Amazon Alexa, Google Home, SmartThings, IFTTT and Siri shortcuts.

Finalists in this category include **Falkonair Inc.** and **Automated Logic Corporation.**



COOLING

Opteon™ XL41 is a non-ozone depleting, low global warming potential refrigerant replacement for R-410A in residential and light commercial air conditioning, and scroll chiller applications. This innovative product maximizes the benefits of the transition to HFO refrigerants while minimizing the impact of the transition. Opteon™ XL41 provides a 78% reduction in GWP from R-410A, while remaining compatible with all R-410A residential and commercial applications and lubricants. This greatly reduces the re-design effort for OEMs, and reduces the learning curve for the technicians in the field.

Finalists in this category include **Copeland Compressors** and **Condensing Units/Emerson**, and **Fujitsu General American, Inc.**

HEATING

Built on the award-winning ZPSK6 platform, **Emerson’s ZPSK7 scroll compressor** is the most efficient two-stage compressor developed in the 100-year history of the **Copeland™ brand**. The Copeland™ ZPSK7 scroll compressor is a product line of 1.5 – 5-ton two-stage compressors ideally suited for residential and light commercial HVAC applications. These compressors can operate at 100% capacity or as low as 65% capacity based on heating/cooling demand. When a partial load is needed, bypass ports inside the compression chamber open which partially unload the compressor. This allows the compressor to achieve 65% capacity, thereby consuming less energy at light loads and avoiding costly stops and starts which use more energy. When demand increases, the modulation control valve is activated, sealing the bypass, and shifting capacity to 100%.

Finalists in this category include **Dorin USA** and **Mikrofill by Stuart Turner global growth.**



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Finalists in this category include **AirGreen**, and **Particles Plus, Inc.**



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The only direct-acting pressure regulating valve in North America with true piston operation, the PresCal™ HP family ensures stable, high-precision water pressure control while withstanding severe inlet pressure or punishing downstream water hammer. It's perfect for staged pressure control or demanding applications that are fraught with extreme pressure fluctuations. Being the bridge between a building's water main and its distribution piping, a PRV experiences pressure fluctuations on both downstream and upstream sides. These fluctuations can be of sufficient magnitude to cause premature fatiguing and failure of a rubber diaphragm design, the industry standard (including Caleffi). The higher the incoming pressure, the more severe the fluctuations and their effects frequently are. This is because higher-pressure applications often involve commercial buildings containing quick-acting devices. They are also interconnected with other similar buildings.

Finalists in this category include **EasyFit Isolator** and **Viega LLC**.

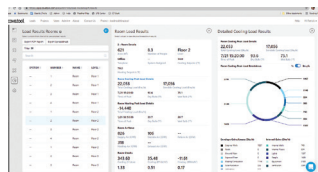
REFRIGERATION

The Copeland™ ZFW variable speed scroll solution includes brushless permanent magnet (BPM) motor-based scrolls and variable frequency drives (VFDs) targeted for low-temperature, stationary refrigeration applications. The variable speed scroll provides better efficiency, precision, flexibility and reliability, while Copeland variable frequency drives, EVM/EVH Series complement Emerson compressors and controls. It has double the capacity of a fixed-speed compressor of the same size while providing a 20–30% efficiency improvement. With vapor injection technology and a speed



range of 1,000–7,000 rpm, it offers unparalleled levels of control, while reducing cycling rates and greatly improving reliability. Optimized for use with new Copeland EVM variable frequency drives, the combination offers cutting-edge levels of performance. While intended for compression, EVM drives are also universally applicable for fans, pumps and other electric motors. The Copeland EVM has been preconfigured for Emerson controls (iPro, E2, E3, Site Supervisor) and can be integrated universally with any controller. Available today with A1 refrigerants and moving toward A2L approval by 2024, the platform offers a robust design option for complying with current and future commercial refrigeration regulations.

Finalists in this category include **Danfoss**, and **MATELEX**.



SOFTWARE

Built for mechanical engineers, the **loadmodeling.tool** quickly and automatically establishes peak cooling and heating loads to design and right-size the mechanical system using the EnergyPlus engine. This web-based tool supports **cove.tool**'s goal of providing the solutions needed for the AEC industry to unlock productivity and solve the climate crisis. One of the most revolutionary aspects of the loadmodeling.tool is that it is web-based, which presents a new opportunity for mechanical engineers as the majority of their tools are only available via desktop platforms that haven't evolved much in the last few decades. As it is web-based, mechanical engineers can access the tool anywhere, including results, which means large files aren't having to be transferred or shared manually. Multiple people can log into the project and work on various tasks at the same time.

Finalists in this category include **HVACSolution, Inc.** and **Rep Order Management (AccuQuote)**.

SUSTAINABLE SOLUTIONS

The ultra-efficient **System M** consists of a sleek, whisper-quiet, inverter-driven outdoor heat pump that can be up to 4 times more efficient than a gas furnace. The outdoor heat pump seamlessly integrates with **Taco's** exclusive indoor HydroBox to provide a complete system with just 6 pipe connections needed. System M is a radically innovative air-to-water heat pump system that provides comfortable, efficient heating, cooling, and plenty of domestic hot water. A true plug-n-play appliance, its packaged design makes



installation less intrusive; no refrigerant or gas lines are needed. System M seamlessly integrates with almost any high-efficiency heating and cooling system and is perfect for both new construction and existing HVAC systems. The installation time is half of a typical air-to-water heat pump by eliminating the work to design, procurement, and installation of all the required hydronic components. Just 6 connections needed; 2 connections to the heat pump, 2 connections to the domestic hot water tank (DHW) and 2 connections to the heat and cooling system.

Finalists in this category include **Mitsubishi Electric Trane HVAC US** and **Trane**.



TOOLS & INSTRUMENTS

NAVAC NEF6LM BreakFree® Power

Flaring Tool yields accurate, hassle-free tubing flares in a fraction of time compared to traditional flaring methods. Designed to perform reliably in harsh environments, NEF6LM also allows one-button, one-hand operation. The tool is equipped with a high-performance rechargeable battery that makes over 100 flares per charge. Manual flaring is rough and inconsistent, very much depending on the operator's experience level. As a result, distorted flares are made all the time, which causes leaks in connections. Refrigerant leak is a major service issue, especially for ductless VRF systems with many flared connections. NAVAC BreakFree® Power Flaring Tool NEF6LM delivers a fully automatic flaring operation and provides the ultimate quality of flares that an excellent experienced technician could achieve in years to be delivered simply by pressing a button.

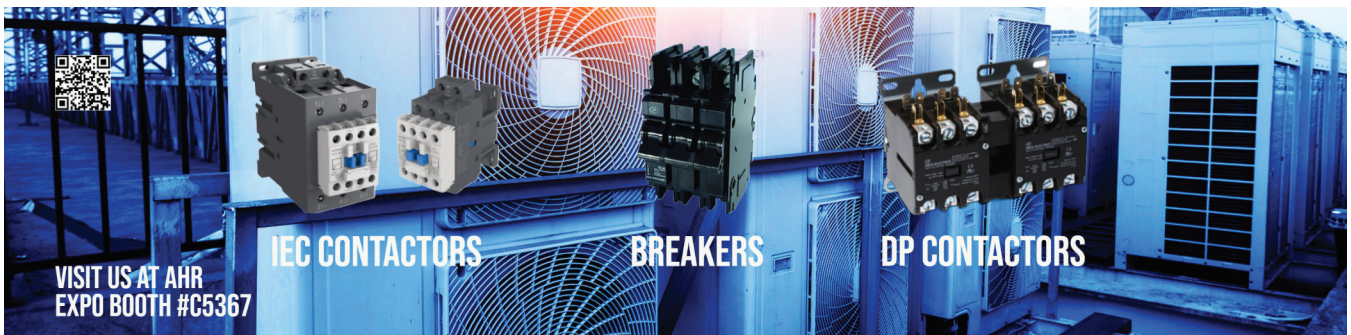
Finalists in this category include **Airthings** and **Onset - HOBO Data Loggers**.



VENTILATION

SmartD's Clean Power Variable Frequency

Drive changes the motor control landscape. By delivering a clean, sinusoidal signal it reduces motor system losses by up to 40% and extends motor lifetime in a compact footprint that can be deployed without ancillary filters. The SmartD VFD integrates wide-bandgap (WBG) semiconductors into its multi-level inverter architecture and combines them with patented modulation algorithms to produce a pure-sine wave electrical signal without the need for external filters. WBG semiconductors have intrinsic characteristics that make them more efficient: on-state losses are 10–80% lower and switching losses are 9 to 30 times lower than standard IGBTs. While the benefits of WBG are clear, they are but a piece of the SmartD innovation equation. By combining a single-carrier harmonics-canceling modulation, with a multi-level architecture and the high frequency switching of the WBG transistors, SmartD is able to integrate filters 400 (four hundred!) times smaller than auxiliary filters normally required to achieve a comparable signal quality. Finalists in this category include **ECM PCB Stator Technology** and **Lennox International, Inc.**



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IEC CONTACTORS

BREAKERS

DP CONTACTORS



Cornell Dubilier Electronics

(CDE) has expanded its standard-product offerings and brought to light its advanced custom capacitor capabilities. While the inverter circuitry at the heart of EV charging stations may seem familiar to design engineers, there are operational, environmental, and mechanical demands that make Level 3 EV charging stations unique. The latest designs are pushing voltages and current handling to higher levels to shorten recharge times.

According to Bob Kropiewnicki, Director of Applications Engineering of CDE, "We've found that design engineers engaged in Level 3 charger projects are faced with a balancing act to mitigate significant circuit harmonics that cause heating problems. Adequate input and output filtering, strategic current paths, and reducing inductance and ESR are all concerns. The DC link capacitor is often an afterthought which forces those problems to be dealt with in ways that are more complex than necessary. A better solution is to focus on the requirements of the DC link as early as possible. We are able to predict performance by using our advanced capacitor modeling based on project application conditions."



Schneider Electric's EcoStruxure Energy Hub

is a scalable, self-service IoT software-as-a-service solution, which simplifies the management of digitalized electrical and energy systems. Commercial, industrial and institutional building owners and operators can easily comply with emerging energy codes and standards, more effectively manage essential energy systems and ensure they're on track to meet larger sustainability goals. As a web-based application, it provides energy analysis and benchmarking features to identify the factors contributing to energy usage, analyzing energy usage patterns, and implement energy conservation measures. The software categorizes energy usage by load types such as HVAC, lighting, and plug loads to identify where to focus energy conservation initiatives.



Hottinger Brüel & Kjær launches a new

torque sensor, type T210, designed to help engineers carry out industrial application tests more efficiently. It is a shaft-style transducer measuring torque, rotational speed and the angle of rotation; it can be connected easily to devices under test or integrated in test benches, as well as other applications. The compact, strain-gauge-based torque transducer features a precise measuring system, with noncontacting voltage and frequency output. Available in nine capacities, from 0.5 N-m to 200 N-m. Accessories such as cables and bellows couplings are also available.



Multi-Wing America introduces its **OPTIMISER 11** fan specification app, an easy-to-use resource for original equipment engineers to specify the most efficient fan for their application. It is ideal for specifying fans in HVACR and features an intuitive interface that more efficiently accesses essential fan curve data, such as horsepower and sound information for select static pressure and cubic feet per minute (cfm) data. Users have more flexibility to modify their dashboard, including data preferences and color selection for customized visual display of fan performance curves.



CSA, a global testing, inspection, and certification service celebrated the grand opening of its second facility in Independence, Ohio – a distributed energy resource lab. The facility is adjacent to the company's U.S. headquarters on East Pleasant Valley Road. Batteries, chargers, and generation system components - that fuel our lives -- will be tested at this new site to ensure consumer safety standards are met.

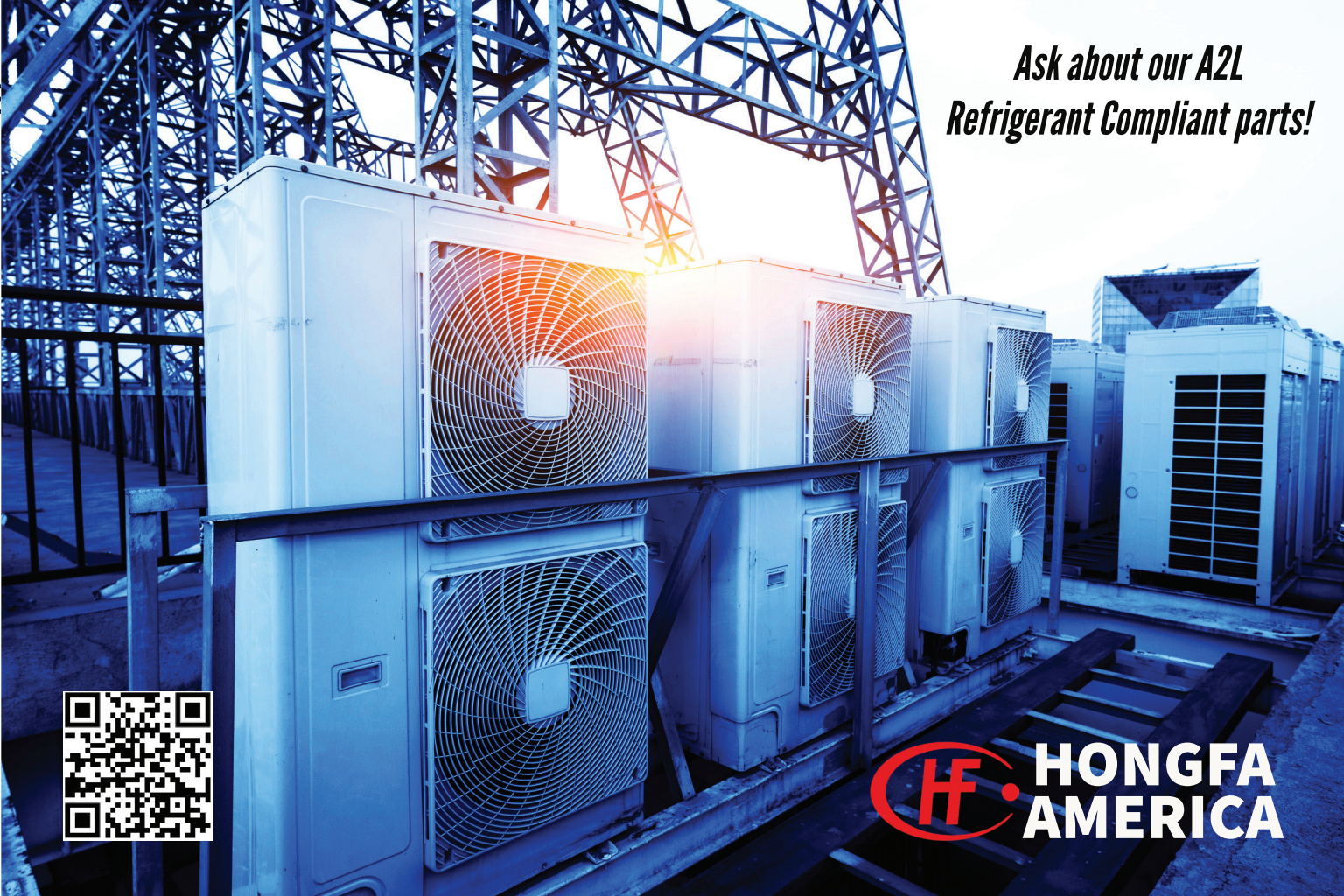
Mayor Gregory Kurtz said "CSA has also been one of the city's top 25 taxpayers for many years. Their contributions help the city provide a high quality of life for residents and a robust business climate."

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Churod Sensing is proud to announce its latest sensor for the HVAC industry. **The VRF (variable refrigerant flow) sensor** follows in the footsteps of the popular BPS (battery pressure sensor) by utilizing MEMS-based sensors to effectively reduce energy consumption. Sensors installed on the high- and low-pressure sides are needed to achieve complex system control. By calculating differential pressure between the high and low sides, the VRF can signal the compressor to cycle less frequently to maintain desired temperature in the application. Voila! Lower energy use. Todd La Londe, Director of Churod Americas, stated, "With all of the focus that VRF is receiving today, Churod Sensing is doing its part by contributing a high reliability sensor for use in systems designed to save energy."

Churod Sensing's secret lies in the virtual elimination of leaks via the sensor itself. There is no such thing as a perfect O-ring seal, so as system pressure increases, refrigerant will necessarily leak to a degree from sensors reliant upon this technology. Our welding process creates a hermetic seal that doesn't suffer from the same pressure range limitations as O-ring sealed sensors do. Pressure across a diaphragm results in tensile strength in the center and compressive strength at the edges. This compressive strength is measured by piezo resistors embedded in a silicon substrate in a full-bridge configuration. Proprietary signal conditioning amplifies the differential pressures resulting in a true pressure reading.

Low side pressure sensing ranges from 0-2MPa while high side sensing can range from 0.448-4.5MPa (pressure ranges can be programmed). The physical configuration of the VRF is highly customizable, and it can be used in a variety of refrigerant systems including R22, R32, and R410a). A wide temperature range enables outdoor and indoor use. Installation is simple, and long life is assured.



"Delta Breez ceiling fans continue to set the standard for ventilation technology. With an elegant design inspired by nature and quality components, these ceiling fans will serve as a beautiful centerpiece in your home," said Alex Lee, Vice President of **Channel Business, Delta Electronics Americas** Region. "It works best when used in conjunction with a Delta Breez Fresh Air Supply Fan and ventilation fan to create a perfectly balanced ventilation system and a healthier indoor environment."

The Rio Vista (8-blade) and Pleasanton Series (5-blade) are available in optional black or white, 60 or 72 inch diameter, and can be installed in numerous locations, including the living room, dining room, bedrooms, and outdoor locations such as a patio or lanai. Light commercial applications include restaurants, offices, hotels, and resorts.

Recognized as ENERGY STAR® Most Efficient, they provide smooth start-up, quiet operation, low vibration, and uniform multi-speed airflow for a great user experience.

Both, the Rio Vista and Pleasanton Series are up to 70% more energy efficient compared to similar AC motor products. The smooth start-up and quiet operation are enhanced by a brushless DC motor, which provides even airflow across the entire room. A hand-held remote allows you to easily adjust your preferred settings, and six fan speeds plus a reverse function are included, while a 20-watt LED light module provides up to 1500 lumens of bright light.

Benefits:

- Recognized as ENERGY STAR Most Efficient
- Brushless DC motor offers up to 70% more energy efficiency compared to similar AC motor products
- Handheld remote with 6 fan speeds and reverse function
- 20 Watt dimmable LED light module included (1500 Lumens)
- Easy remote control pairing
- Advanced aerodynamic profiled blade design
- Wet rated, for indoor/outdoor use
- Startup with no hesitation
- Threaded downrod ¾" Dia x 6" L, tighter stability

How to Make Surge Protective Devices More Robust for Building & Home Applications

BY LITTELFUSE

With intelligent devices propagating throughout homes and building, surge protection has become very important. Voltage surge sources can include lightning, induced power surges, industrial and switching surges, and electromagnetic pulses. A commercial or industrial facility

will have surge protection devices at the incoming AC line, at power distribution, and near critical electrically powered equipment. Type 1 and Type 2 Surge Protection Devices are growing at a CAGR* 5.5%. The 2020 National Electrical Code® requires all new homes in the U.S. to have Type 1 or Type 2 SPDs. Seventy

percent adoption of this code is expected by 2020 NEC®. NEC claims that \$15,000 of electrical equipment can be damaged in the home.

How do Surge Protection Devices work?

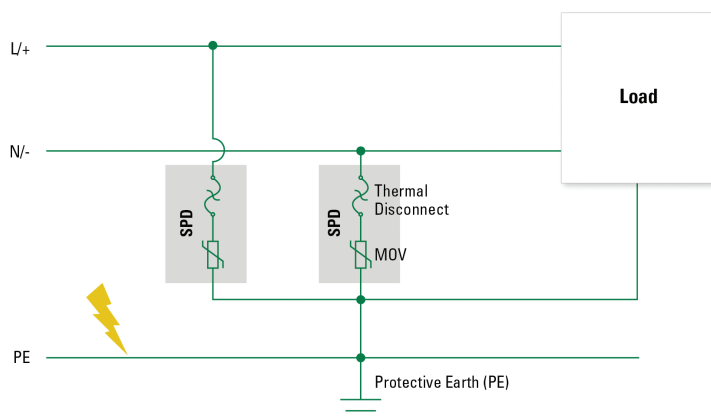
The basic function of SPDs is to limit the surge voltage amplitude to a defined level so dielectric strength of equipment is not exceeded. During voltage surge the LST/MOV inside SPD will quickly become a low impedance path to divert surge away from the load. This lasts for the duration of the surge voltage which is typically a few microseconds. The equipment is safeguarded and continues to operate.

An example of a circuit with common mode protection is shown in Figure 1.

Recommended Product Technologies for Protecting SPDs

A varistor is required for voltage surge protection along with thermal disconnect. The Littelfuse new varistor LST Series is designed for Type 1

Figure 1. Surge Protection Device activated by voltage surge



Source: *CAGR from Market & Markets & Grandview Research average

¹ Common mode shown in the example protects between active lines and protective conductor. SPDs could also be placed between active lines for normal (differential) mode voltage protection.

Figure 2. Littelfuse Components are Core to Type 1 and Type 2 SPDs

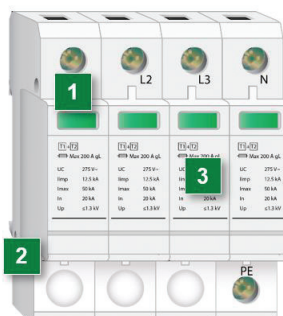
Key protection components inside Surge Protection Devices

1 Overcurrent protection

- Fuse

2 Overvoltage protection

- GDT



3 Overvoltage protection

- MOV
- TMOV

SURGE PROTECTION

Figure 3. Single-Phase load protection (Circuit Diagram)

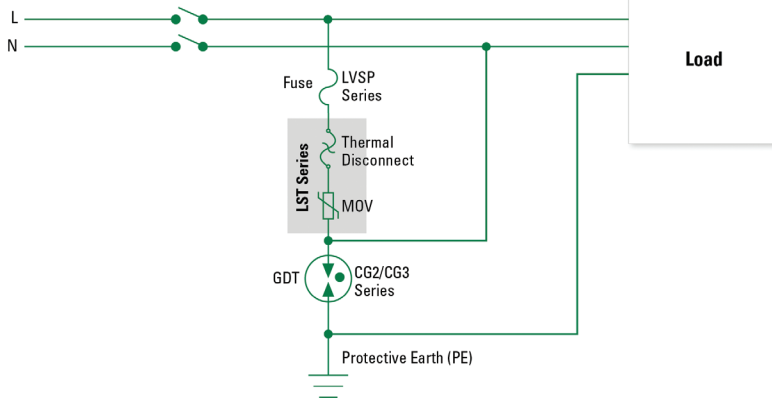
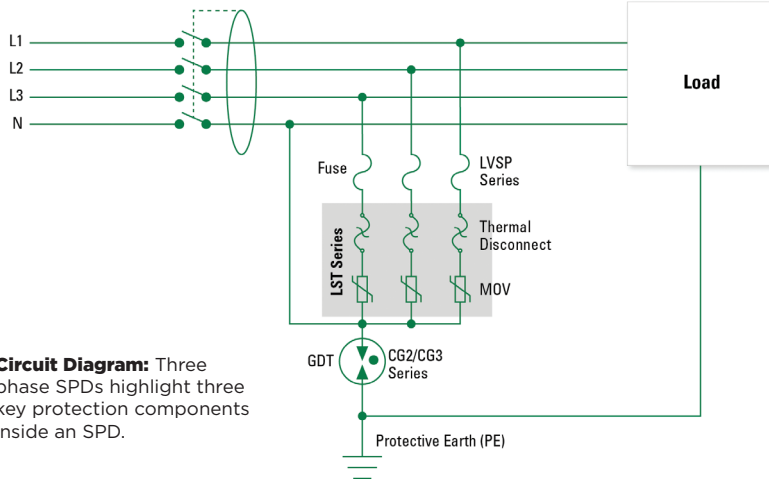


Figure 4. Three-Phase load protection



and Type 2 Surge Protective Devices (SPDs). Constructed with a proprietary thermally protected varistor technology (TMOV) developed by Littelfuse, this new varistor series incorporates both a built-in thermal disconnects function and electric arc shield. This combination provides additional robust protection to prevent catastrophic failure and fire hazard even under the extreme circumstances of abnormal overvoltage conditions or varistor end-of-life.

LST Varistor Series

The Littelfuse LST Varistor Series offers these key benefits:

- Facilitate meeting UL1449 listed Type 1 or Type 2 standards by incorporating 200 kA SCCR, 20 kA In,

UL1449 Type 4 recognized component assembly.

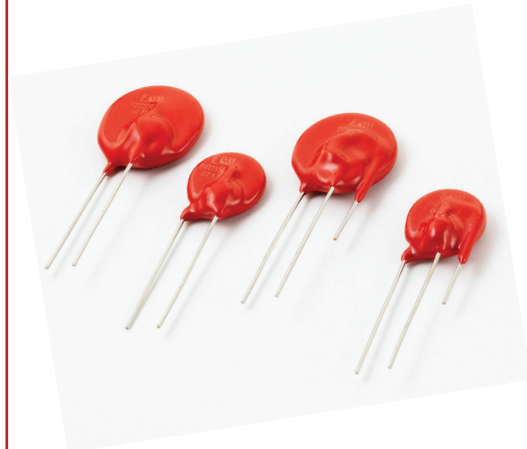
- Flexibility of using 50 kA and 75 kA Imax rated devices with the same footprint on PCB.



- More options for designing remote indication/monitoring of SPD product or system through mechanically triggered AC and DC rated microswitch (Normally Open/ Normally Closed, pin length, 2 pin/3 pin/without pin).

• Clear LST working status indication through a visual tab option that notifies service technicians and maintenance engineers to replace LST at end-of-life in order to continue optimal surge protection for the end-product.

- Wide operating voltage range up to 690 Vac for 50 kA version, up to 550 Vac for 75 kA version.



TMOV Varistor Series

The Littelfuse TMOV Thermally Protected Varistors represent a new development in integrated circuit protection. TMOV is comprised of radial leaded MOV (Metal Oxide Varistor) with an integrated thermally activated element designed to open in the event of overvoltage, limited current, conditions outlined in UL 1449.

- Patented integrated thermal protection device - Patent #US6636403.
- Designed to facilitate compliance to UL1449 3rd Edition for SPD product.
- High peak surge current rating up to 10 kA.



LVSP Fuse

A Fuse is integrated into an SPD for overcurrent protection (some SPDs have an external fuse). The Littelfuse Varistor Surge Protection (LVSP) Fuses are intended for the protection of SPDs. The LVSP Series has been designed to survive the 8x20 μ s lightning surges described in various Standards (UL1449, IEC61000-4-5, and IEEE C62.41) without opening. This allows the SPDs to perform the necessary suppression.

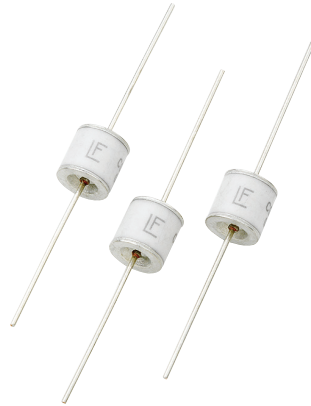
The LVSP Series is not rated for continuous current, and the ratings are to specific 8x20 μ s surge capability.

- Very current limiting under AC short-circuits conditions.
- Available in multiple mounting configurations (cartridge, bolt-in, PC board mount).
- Provides short circuit protection in SPDs and complements the Littelfuse line of overvoltage products (HA, HB34, TMOV®, and iTMOV® varistors as well as the AK10 series TVS diodes).

High Voltage GDT-CG3 Series

Gas discharge tubes (GDTs) are often used between neutral and ground to minimize leakage current. Littelfuse CG2 or CG3 GDT Series provide a high degree of surge protection in a small size making them ideal for SPDs.

Littelfuse CG3 two electrode high voltage (1.0–7.5 kV) devices are designed for surge protection and



high isolation applications, and for applications for which bias voltages or signal levels of several hundred volts are normally present.

- Rugged ceramic-metal construction.
- Low capacitance (<1.5 pF).
- Available in Tape and Reel packaging.
- Available with or without leads.

Apart from these key protection components, some of the latest SPDs can offer features such as voltage surge data and protection status through Wi-Fi which would also require ESD protection. Littelfuse AQ1003-01LTG Unidirectional Discrete TVS Diode Arrays can be used for ESD protection.

Conclusion

Surge protection is an important consideration for homes, commercial buildings, and industrial facilities. Using best practices and key components will support good designs and safeguard end-product solutions.





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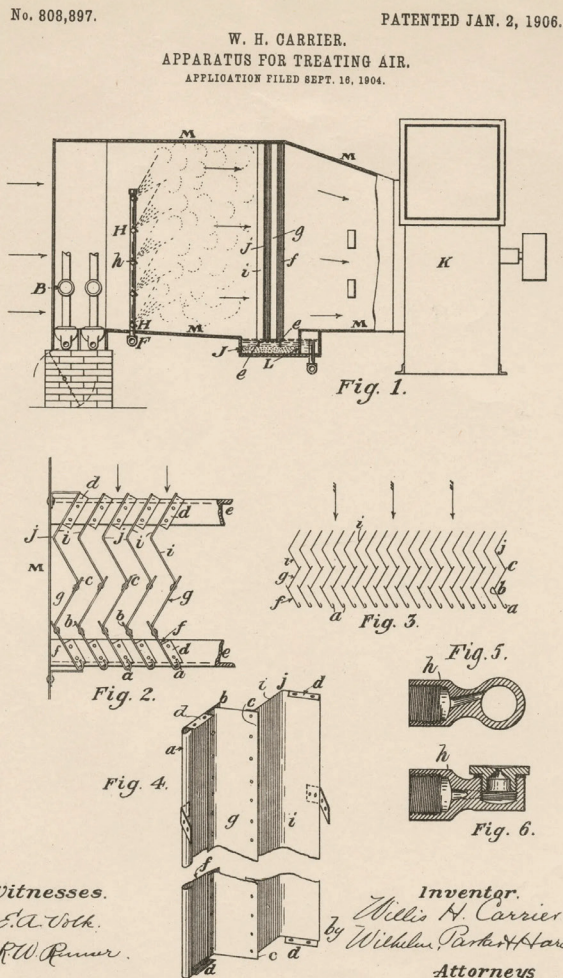


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Figure 1. Drawings for the US Patent “Apparatus for Treating Air” by W.H. Carrier [2]



problem: removing the heat from the environment, rather than adding cool air.

The first commercial air conditioning for home use was designed by Alfred Wolff, working with Willis Carrier, and Reuben Trane. Eventually the trio went their own separate ways forming Carrier Corp and Trane Corp.

In 1913, the first electric refrigerators for home and domestic use were patented (US Patent #US1126605 - A Refrigerating Apparatus) and produced by Fred W. Wolf of Fort Wayne, Indiana, with models consisting of a unit that was mounted on top of an ice box [3].

The domestic refrigerator quickly became an essential household item. In 1921, approximately 5,000 mechanical refrigerators were manufactured in the United States. In the following decade, the number reached to a million, gradually making the refrigerator a staple of every household [4].

Following the invention and the commercialization of refrigerators and air conditioning equipment, ASHVE Research Bureau founded in 1919 and have published their first guide in 1922 [5]. In December 1958, members of ASRE and ASHAE vote to merge into the American Society of Heating, Refrigerating, and Air-

Lowering Global Warming Potential in the HVAC Industry with the Help of Safe Components

BY LANNY SCHUBERG & JANSET SAVAS

Air conditioning dates to Ancient Egypt. Passive cooling techniques have been widely used in the warmer climates around the world for thousands of years. However, air conditioning and refrigeration has progressed exponentially with the help of invention

and commercialization of electricity.

First modern electrical air conditioning unit was built by American inventor Willis H. Carrier in 1901 [1]. The reason he is dubbed as the father of modern air conditioning is the revolutionary new approach, he used in order to tackle the temperature

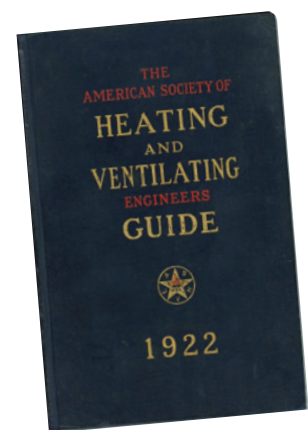


Figure 2. “The American Society of Heating and Ventilating Engineers Guide” [5]

Conditioning Engineers (ASHRAE).

ASHRAE have published the Standard 90-75, "Energy Conservation in New Building Design" in 1975 which had a major impact on U.S. building codes. To this day, ASHRAE teams up with industry professionals and the Department of Energy to develop new standards and guidelines for safe and sustainable refrigeration technology.

As the refrigerators and air conditioning equipment became domestic staples, UL became involved in setting standards in this industry as well. In 1995 UL published the standard 1995 / CSA C22.2 No. 236 - a harmonized standard for the United States and Canada for heating and cooling equipment. The scope of the standard covers a broad range of HVAC/R equipment, including both residential and commercial fan coil units, heat pumps, liquid chillers and more.

However this standard has a date of withdrawal set for December 31, 2023 to be replaced by UL 60335-2-40 that is based on the international IEC 60335-2-40 standard. IEC 60335-2-40 is currently being used as the basis for the design, evaluation, testing and certification of HVAC equipment using Low GWP refrigerants in places like Europe. Overall, UL 60335-2-40 has adopted more conservative safety requirements than the IEC standard to address the unique product usage of the North American market [6].

A coalition of state governors has formed the US Climate Alliance to promote the Kigali Amendment to the Montreal Protocol and the Paris Climate Agreement. Through the advancement of responsible climate change legislation, the Alliance aims to demonstrate leadership on this issue. It has been imperative for the Alliance to reduce greenhouse gas emissions, such as those from hydrofluorocarbon (HFC) refrigerants.

There are several states that have

taken steps to reduce their use of these products, including California Air Resources Board (CARB), which proposes to set a Global Warming Potential (GWP) limit of 750 for HVAC products starting January 1, 2023, and chillers starting January 1, 2024, as well as additional requirements for refrigeration systems beginning in 2021. State government regulations have led manufacturers to develop lower GWP refrigerant alternatives. The challenge in deploying alternatives to traditional HVAC/R refrigerants is that these lower GWP refrigerants typically exhibit more flammable properties than refrigerants designated as ASHRAE A1.

The air conditioning and refrigeration industry has been actively working to address this issue since 2006 by developing a new classification of refrigerants, known as A2L, to meet the lower GWP challenge.

To classify refrigerants according to their hazards, ASHRAE Standard 34 assigns identifying letters and numbers to each refrigerant. Classification of toxicity based on allowable exposure is indicated by the capital letter. The numeral denotes flammability. According to Standard 34, toxic substances are classified into two categories based on their safety. Refrigerants classified as class A have a lower toxicity, while refrigerants classified as class B have a higher toxicity. For flammability, there are three classifications and one subclass.

In general, flammability is classified in three classes: class 1, which includes refrigerants that will not propagate a flame when tested to the standard; class 2, which includes refrigerants of lower flammability; and class 3, which includes highly flammable refrigerants like hydrocarbons. While there are classifications, extreme ambient conditions can lead to greater toxicity due to the refrigerant's nature and the atmospheric conditions.

Table 1. Refrigerant Safety Group Classification [8]

	Lower Toxicity	Higher Toxicity
Higher Flammability	A3	B3
Lower Flammability	A2	B2
No Flame Propagation	A1	B1

According to the latest update of ASHRAE's safety classification matrix, flammability subclass 2L is now defined for refrigerants with flammability class 2 but low burn speed.

Several Hydro Fluoro Olefins (HFOs), with low global warming potential and are mildly flammable are classified as A2L. This indicates that they are of lower toxicity and have low burning velocity. [7]

A = Non-toxic

2 = Flammable

L = Low burning velocity

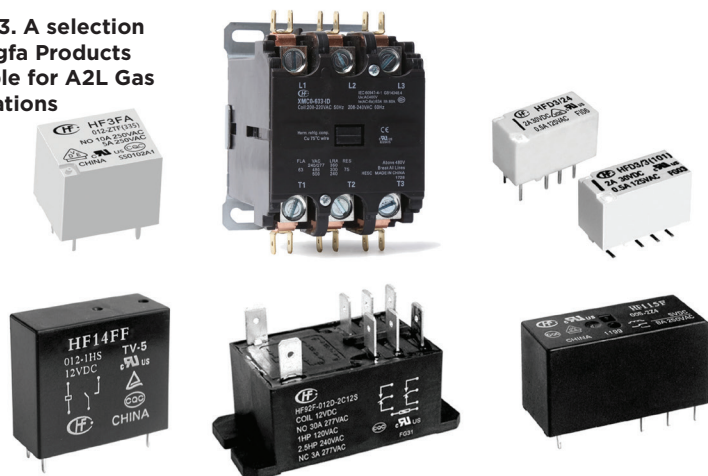
While having slightly higher flammability characteristics as compared to traditional A1 refrigerants, A2Ls are much harder to ignite and are much less flammable than A3 hydrocarbon refrigerants, such as R290 (propane).

A binational (U.S. and Canada) consensus group was formed to update the product safety and application standards to allow for the safe use of these more environmental friendly refrigerants within HVAC systems. For many existing air conditioning products that use R-410A, the most promising lower GWP alternatives include R-32 and R-454B, which are ASHRAE A2L classified.

As the standards and regulations change based on environmental concerns, component manufacturers are finding innovative ways to answer the needs of the home appliances & HVAC industries. Manufacturers have started offering variety of relays and contactors that are compliant with A2L gas environment requirements.

Hongfa relays and contactors,

Figure 3. A selection of Hongfa Products Available for A2L Gas Applications



for example, use special sealing & venting methods to limit the ignition in flammable environments. The use of special molding materials also allow compliance with Glow Wire Test in IEC60335.

Conclusion

It is important to note that the use of refrigerants in refrigeration and air-conditioning equipment may pose

a variety of health risks, including toxicity, flammability, asphyxiation, and physical hazards as well as contribution to global warming. Compared to the refrigerants they replace, A2L refrigerants have favorable performance and operating efficiencies, which allow users to transition to safer and lower GWP solutions.

It is imperative for manufacturers

to provide solutions that can meet the challenges of efficiency, safety, and environmental concerns as the industry evolves. In addition to continuing to invest in research and development, responsible manufacturers are dedicated to deploying products and technologies that minimize environmental impact while meeting customer needs. ●

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- [3] US Patent # US1126605A
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- [5] <https://www.ashrae.org/file%20library/about/mission%20and%20vision/ashrae%20and%20industry%20history/american%20societyofheatingandventilatingengineers.pdf>
- [6] <https://www.ul.com/news/understanding-ul-60335-2-40-refrigerant-detector-requirements>
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- [8] ANSI/ASHRAE Standard 34-2019
- [9] IEC 60335-2-40
- [10] IEC 60079-15

Refrigerant designation	Description	Formula	Safety group
R152a	1,— Difluoroethane	CHF ₂ CH ₃	A2
R.454C	R-32/1234yf	(21.5/78.5)	A2L
R1234yf	2,3,3,3-tetrafluoro-1propene	CF ₃ CF=CH ₂	
R1234ze(E)	Trans-I ,3,3,3-tetrafluoro-1	CF ₃ CF=CHF	
R142b	1 -chloro-1. 1 -difluoroethane	CH ₃ CClF ₂	
R143a	1,1,1 — Trifluoroethane	CF ₃ CH ₃	
R32	Difluoromethane	CH ₂ F ₂	
R-444A	R-32/152a/1234ze(E)	(12/5/83)	
R-444B	R-32/152a,'1234ze(E)	(41.5/10/48.5)	
R-447A	R.32,'125/1234ze(E)	(68/3.5/28.5)	
R-447B	R.32/125/1234ze(E)	(68/8/24)	
R-451A	R.1234yf/134a	(89.8/10.2)	
R-451B	R-1234yf/134a	(88.8/11.2)	
R-452B	R-32/125/1234yf	(67/7/26)	
R-454A	R-32/1234yf	(35/65)	
R-454B	R-32/1234yf	(68.9/31.1)	
R-457A	R-32/1234yf/152a	(18/70/12)	
E170	Dimethylether	(CH ₃) ₂ O	A3
R1150	Ethylene	CH ₂ =H ₂	
R1270	Propylene	CH ₂ =CHCH ₃	
R170	Ethane	CH ₃ CH ₃	
R290	Propane	CH ₃ CH ₂ CH ₃	
R50	Methane	CH ₄	
R600	n-Butane	CH ₃ CH ₂ CH ₂ CH ₃	A3
R600a	Isobutane	CH(CH ₃) ₃	

Table 2. Annex BB - IEC60335-2-40 [9]



Lanny Schuberg is presently a Senior Staff Field Applications Engineer for Hongfa America. He has over 30 years of experience in industrial and automation systems. In addition, he has sat on several standards development boards.

Janset Savas is an electrical engineer with 5 years of industry experience. She was born and raised in Istanbul, Turkey and received her MSc degree in Electrical Engineering from Istanbul Technical University. She currently works as Application Engineer for Hongfa America specializing in power, signal and latching relay applications.



FOR THE APPLIANCE INDUSTRY



Fabricated Stainless Thermostat Probe

For 60 years, Peterson Manufacturing, LLC. has been producing precision deep drawn metal stamping components for customers in a wide range of industries.

As a result of our ability to deliver quality parts, a manufacturer of appliance thermostats came to us for a precision deep drawn metal stamping of this 305 stainless steel part. This part was previously produced by cutting and forming tubing, then welding the tip closed. We utilized our high-speed transfer press technology to produce parts "complete to print", esthetically superior and eliminating any quality issues with "leaking" parts. The parts are then degreased and burnished, ready for assembly. We ensured the stainless steel tube met tolerances of $\pm .002$ " and utilized a gage block and "Z" Mike laser micrometer to confirm that it met the necessary specifications.

In addition to custom deep drawn metal stamping, our company also provides value-added services, which allows us to expedite manufacturing start to finish. This ensures that every aspect of the project, such as design engineering, deburring, slotting and heat treating, is the best it can be.

FOR THE HEATING, VENTILATION & AIR CONDITIONING INDUSTRY



Precision Deep Drawn Copper Thermal Bulb

Peterson Manufacturing, LLC. specializes in precision deep drawn metal stamping, utilizing multiple transfer presses that can manufacture components in a wide range of materials. Our ISO-registered facility can also provide SPC, bar coding and special customer packaging in addition to design engineering and various finishing services.

In this example our client required a 122 copper thermal bulb. Converting the manufacturing process from cut tubing that required spinning and brazing the closed end, to our high speed deep draw technology, quality issues were eliminated and cost per part was reduced by 40%. We complete the part with a bright, burr-free finish and ensure the thermal bulb will meet tolerances of $\pm .005$ " as well as the customer-supplied specifications.

FOR THE SMALL APPLIANCE INDUSTRY



Precision Deep Drawn Brass Terminal Pin

In this example, our customer previously purchased this CDA – 230 brass terminal pin using "cold heading" technology. By converting this project to our high speed deep drawn technology, the customer saved in excess of \$75,000 per year.

As a company that consistently delivers superior quality, ISO-registered Peterson Manufacturing, LLC. applies more than 60 years of precision deep drawn metal stamping experience to multiple markets, including industrial, automotive, appliance components, controls & gages, plumbing, fire protection and many others. By performing statistical process control testing as well as visual inspections, we ensure that the terminal pin meets the customer supplied specifications which contain tolerances of $\pm .0015$. We also provide electroless nickel plating on the terminal pin.

On this project, we currently produce millions of parts annually via weekly releases, all part of our commitment to providing outstanding quality and just-in-time delivery at competitive prices. In our market niche, Peterson Manufacturing is known for carefully crafting long-term customer relationships "one part at a time".

Adhesive Compounds Play Key Role in Sensor Fabrication and Performance

BY ROHIT RAMNATH

Epoxy and silicone compounds play a fundamental role in the diverse sensor devices underlying the internet of things (IoT), smart products and advanced systems in a wide range of industry segments. By bonding and protecting sensor components, these compounds help simplify sensor fabrication and ensure continued performance of these devices.

Role in Sensor Systems

Sensors are the backbone of a digitized society, measuring a broad range of physical characteristics in every type of application from everyday consumer products to mission critical systems in aerospace, automotive, industrial, medical, optical and every other application that relies on smart, sensor-based devices. Sensor manufacturers offer sensors able measure every type of fundamental physical quantities like temperature and pressure as well as dynamic characteristics like acceleration and rotation.

For each type of measurement, product developers can find sensors with the required dynamic range, sensitivity and accuracy. Combined in single packages and modules, highly integrated solutions incorporate multiple sensors with signal conditioning chains, processors and even optical subsystems to support more complex measurement modalities such as biometrics, inertial measurement, and diverse monitoring capabilities. Active chemical biosensors go even further, embedding molecules in a matrix or membrane composed of epoxy resin that immobilizes the molecule without degrading its ability to interact with molecules of interest. In fact, epoxy and silicone compounds play a vital role in sensors of all types.

Whether based on simple junction devices, advanced microelectromechanical systems (MEMS) devices or even biosensing membranes, sensors are expected to deliver accurate data reliably

despite rough handling, harsh environments and continued stress from thermal, chemical, or mechanical factors through any combination of adverse operating conditions. Indeed, their performance and longevity depend critically on advanced manufacturing methods that combine multiple materials into precision assemblies. Within these assemblies, epoxy and silicone compounds serve a critical role as adhesives, underfill encapsulants, potting compounds, or conformal coatings needed to stabilize, bond, and protect sensor components during fabrication and continued use in their target applications. In fulfilling their role, these compounds need to support a combination of strict requirements that is unique to every application.

Meeting Diverse Requirements

Despite the diverse characteristics needed to support fabrication and deployment of different sensing devices, design engineers and manufacturers can find off the shelf or readily customized epoxy and silicone systems designed to match nearly any performance and handling requirement. For devices intended for temperature sensing applications, manufacturers can take advantage of available compounds that exhibit the high thermal conductivity needed to avoid compromising measurements. For example, to improve accuracy of temperature measurement, developers at Honeywell International bonded a MEMS temperature sensor directly to an application-specific integrated circuit (ASIC) that generates measurement data from the MEMS device output [1].

Thermal Conductivity and Low CTE

Honeywell's approach eliminates heat dissipation—and compromised temperature measurements—that arise in conventional



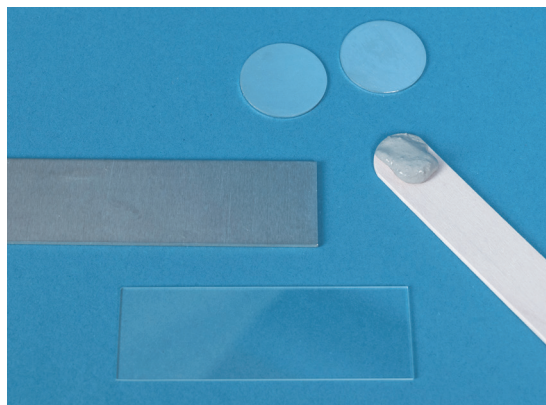
EP30LTE-LO is a two part epoxy that meets NASA low outgassing specifications. With its low coefficient of thermal expansion, it is ideal for bonding dissimilar substrates.

assemblies that place temperature sensors on the underlying printed circuit board (PCB). Yet, this approach brings its own set of requirements. For Honeywell's design, the bonding compound needed to provide high thermal conductivity and high electrical resistivity to ensure accurate measurements during sensor operations as well as suitable handling characteristics during fabrication. In bonding the sensor and ASIC, the compound needed to exhibit a suitable coefficient of thermal expansion (CTE) to ensure continued bond integrity despite expansion and contraction of the two different substrates with temperature changes. For this assembly design, Honeywell chose Master Bond EP30LTE-LO, which offers the required high thermal conductivity and low CTE.

Thermal Conductivity and Cryogenic Serviceability

While an essential requirement for temperature sensor assemblies, high thermal conductivity can play a vital role in other types of sensor systems. In aerospace and astrophysics applications in particular, both thermal conductivity and cryogenic serviceability can be critical requirements. Engineers at GL Scientific needed to develop a module to house infrared sensor chip arrays to be used in an adaptive optics imager instrument for a telescope [2].

Among design objectives, the ability to control temperature of the module baseplate and imager focal plane within 0.1 kelvin (K) using a combination of cryogenic and heat cycling to achieve thermal stability. In this design, temperature sensors and



EP21TDCN two part, nickel filled epoxy system features ideal performance properties for effective grounding, shielding and static dissipation applications.

heaters would be bonded to the focal plane and baseplate to monitor and control thermal cycling. Consequently, the design required an electrically insulating bonding compound with high thermal conductivity, and ability to withstand thermal cycling down to cryogenic temperatures while maintaining bonding strength as well as thermal and structural stability. Furthermore, the bonding compound needed to reliably form strong bonds with dissimilar materials. In this case, the focal plane was constructed from titanium-zirconium-molybdenum (TZM) and molybdenum and finally plated with gold; the baseplate was constructed from aluminum and nickel plated. For this application, the GL Scientific engineering team selected Masterbond EP37-3FLFAO—an epoxy system with high thermal conductivity, excellent electrical insulation properties, and good physical strength while retaining mechanical flexibility across temperatures ranging from 4K to 250°C.

Electrical Conductivity and Workability

In many applications, sensor fabrication often involves bonding of significantly different materials. For example, the availability of ferroelectric polymer (PVDF, which typically needs to be chemically etched for good adhesion) in thin foils, permits design of specialized pyroelectric sensors. Pyroelectric sensors are highly sensitive to radiated energy across a very broad spectrum ranging from ultraviolet through visible and infrared to millimeter wavelengths. Their applications are similarly broad, ranging in use from motion detectors in security systems to laser pulse detectors in high energy

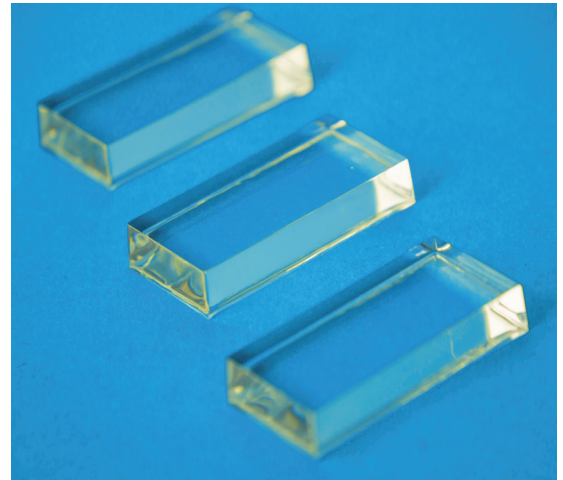
industrial and medical laser systems. By assembling PVDF foils with substrates in multilayered structures, sensor developers can create highly specialized pyroelectric detectors able to provide accurate laser energy output measurements required for precision instruments. In fabricating sensors based on these flexible foils, however, manufacturers face a challenge in creating a reliable electrical connection between the foil and a PCB or other substrate.

In studying the laser pulse detection capabilities of pyroelectric sensors, researchers at Università di Firenze, Italy, created sensor arrays by bonding PVDF film between two PCBs to create a rigid structure [3]. For this application, the researchers required a conductive bonding compound able to form reliable electrical connections between the film's gold pads and the PCB's copper pads. A further requirement for the bonding compound related directly to the fabrication process. In this case, the researchers used a programmable robot designed to dispense the bonding agent, requiring a compound with consistent viscosity to ensure a uniform flow in building the assembly. Here, the research team selected Master Bond EP21TDCN epoxy for the bonding compound. Master Bond EP21TDCN is a nickel filled, electrically conductive adhesive that provides a high strength bond to similar and dissimilar materials including gold, copper, other metals, composites, ceramics, and many plastics. Indeed, the research team found that Master Bond EP21TDCN epoxy met both performance and manufacturing requirements, noting that after two years, this bonding system continued to function reliably with no change in performance.

Electrical Insulation and Handling

The specific performance and handling characteristics of a bonding compound can vary dramatically from application to application. Few applications demonstrate the wide range of requirements facing bonding compounds that are found in biochemical or biophysical applications. In a series of experiments, researchers at Carnegie Mellon University (Pittsburgh, PA) used photolithographic techniques to create microscopic electrode arrays designed to measure changes in impedance of cells exposed to various drugs. Because this method can be readily automated, it can help laboratories dramatically speed the throughput of drug screening, providing a critical capability for healthcare.

Because of the sensitivity of this approach,



EP30HT is a two part epoxy offering high bond strength and optical clarity. This system resists temperatures up to 400°F

the research team needed to ensure that the measurement signal chain remained free of artifacts that could alter the results. In this case, the team needed a compound able to coat exposed portions of the electrode array to reduce parasitic capacitance that could significantly alter the measurements. At the same time, the compound needed to remain neutral to the biochemical environment to avoid affecting the biological target. For this application, the researchers chose Master Bond EP30HT—an epoxy system with excellent electrical insulation characteristics and superior chemical resistance. Here, the research team used Master Bond EP30HT to coat interconnect about 150 μm away from the electrodes, successfully reducing parasitics between the interconnect and liquid medium bathing the living cells used for this impedance-based bioassay method.

Meeting Broad Performance and Processing Needs

The examples cited above only scratch the surface of the range of performance and processing requirements facing sensor designers and manufacturers. Yet, suitable adhesive systems are readily available with characteristics fine-tuned through the use of filler materials that are combined with the base compound in different loading factors. Using different fillers, manufacturers can create adhesive compounds that are optimized for specific combinations of performance characteristics like electrical or thermal conductivity, chemical resistance, and stability as well as processing

characteristics like viscosity, work time and cure time.

Other types of specialized epoxy and silicone compounds are designed to ensure compatibility with key standards in medical, aerospace, and other industries. Engineers developing more sophisticated sensors designed for implant or placement on the skin have already taken full advantage of biocompatible adhesives compounds to provide a protective interface between instruments and bone tissue [5], enable measurement of dissolved oxygen [6], encapsulate a fully implantable biosensor array [7] and more. These specialized compounds not only provide the necessary thermal and electrical conductivity characteristics but also meet requirements for biocompatibility specified in USP Class VI and ISO10993-5 standards.

Similarly, engineers working on assemblies for aerospace systems or other applications with sensitive electronics can find adhesive compounds that meet ASTM E595 and NASA requirements for low outgassing. Using these compounds helps ensure that optical systems, sensitive electronics or other surfaces remain free from contamination from volatile compounds sometimes exuded by adhesives even after cure.

Sensor Trends and Adhesive Technologies

Sensor technology continues to advance rapidly, keeping pace with advances in material science and manufacturing engineering. Advanced strain sensors based on single-walled carbon tube nanocomposites or highly sensitive heat detectors using the pyroelectric properties of emerging gallium nitride (GaN) devices promise to drive novel applications using these nanosensors to detect subtle phenomena. Other sensor technologies bring similar benefits to a wide range of sensing modalities. Destined to be woven into textiles, painted on surfaces or fabricated with 3D printing methods, new types of sensors will enable development of smart products able to access more comprehensive measurement data. More than ever, these emerging sensors will require adhesive compounds able to meet specific requirements for conductivity, biocompatibility, and manufacturing. As with sensors, new compounds will continue to emerge, using new materials and methods for fillers based on advanced materials such as graphene, carbon nanotubes, nano-silicates, and more. ●

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Rohit Ramnath is a Product Engineer for Master Bond Inc., a custom formulated adhesives manufacturer. He analyzes application oriented issues and provides product solutions for companies in the aerospace, electronics, medical, optical and oil chemical industries.

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