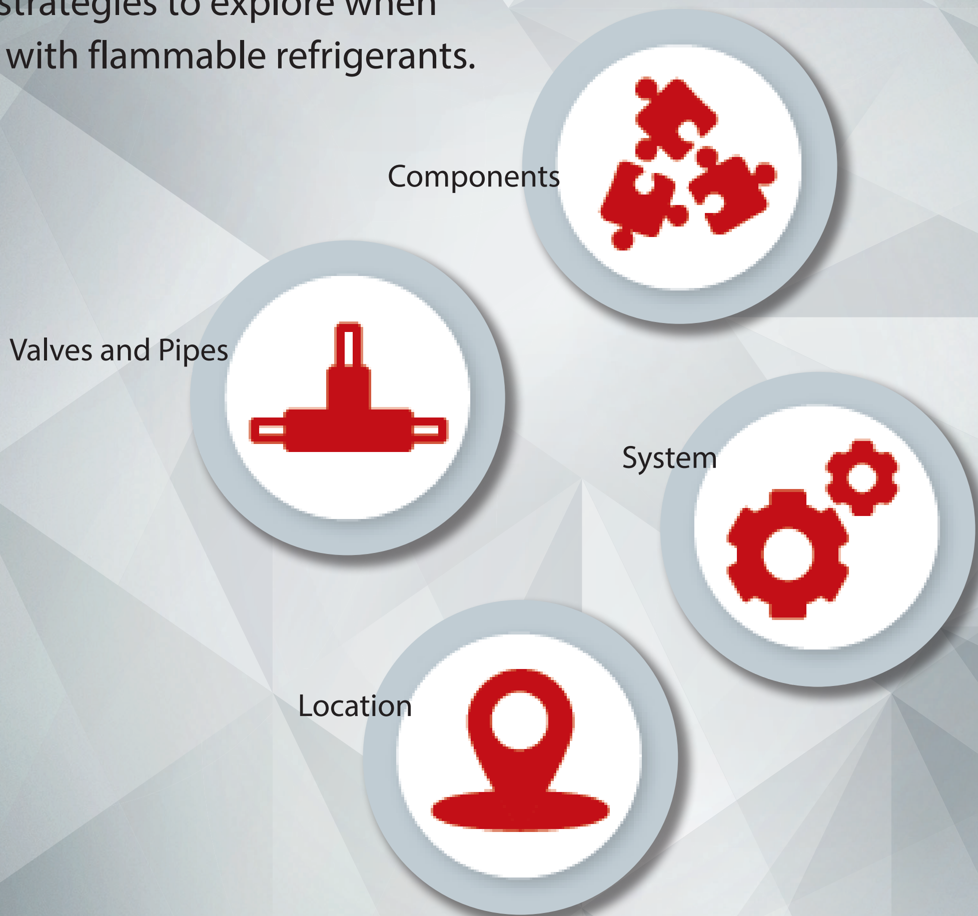
ENGINEERING
TOMORROW

Possibilities and Limitations for **Flammable Refrigerants**

As the world moves to reduce Global Warming Potential, flammable refrigerants will play an increasingly important role.

Design strategies to explore when dealing with flammable refrigerants.



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High global warming potential (GWP) refrigerants can have a considerable environmental impact. So to help reduce this risk, major legislation has been introduced to regulate and restrict their use.

Several refrigerants with a lower GWP are flammable – and factors which influence system design such as temperature, pressure, refrigerant charges, and ignition sources – need to be carefully identified and controlled. Cooling equipment manufacturers, specifiers and installers need to understand the network of rules that aim to limit risk.

In response, the International Standards Organization (ISO), and the International Electrotechnical Commission (IEC) have introduced standards governing the use of flammable refrigerants and components in HVAC systems.

Generally, the standards are more precise about what you can and cannot do. And while that may restrict some designs, it also opens up new opportunities.

How are Refrigerants Classified?

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has defined classification for refrigerants which is a combination of both flammability and toxicity levels of each given refrigerant.

The refrigerant flammability assessment is based on a matrix that compares flammability limit, maximum burning velocity, and heat of combustion. It varies from 1 to 3.

For example, if a refrigerant has a risk of flammability but a lower burning velocity, it will be a class 2L refrigerant, which means it is at risk but would take some time to burn.

A and B are the two toxicity categories that will be linked to the flammability level.

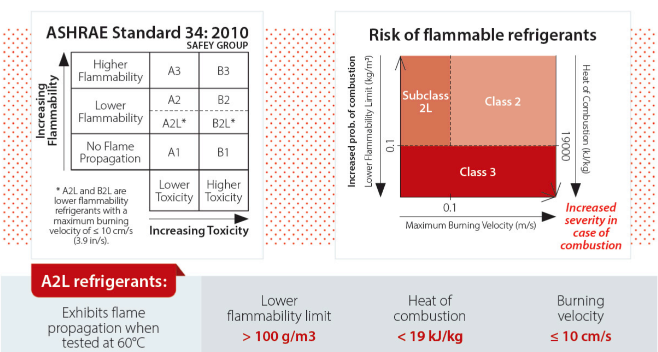

Figure 1. ASHRAE refrigerant classification principle.

For example, lower flammability and high toxicity will be assigned a refrigerant group of B2L, whereas no flame propagation and lower toxicity is classified as A1.

Both methods are simple ways of evaluating and grading refrigerant class and making risk easy to understand. Flammable refrigerants belong to the A2L, A2, A3, B2L, B2 and B3 categories.

ASHRAE goes beyond this. The ASHRAE has several standards that classify and regulate safety for components and systems.

However, in addition there are some other standards relevant for safety of refrigeration and air-conditioning systems.

Which Standards Should HVACR Professionals be Aware of?

Standards vary significantly depending on the equipment, where it's situated, and how it's used. And while some are better-known than others, every OEM and installer should be well-acquainted with each standard, and the potential effects they can have on every component and its installation.

Not only will this enable you to ensure safety and compliance, but it will also help you to be clear about what is permitted, and the options you do have. Worldwide, there are two main standards that OEMs and installers need to take into account, regarding the safety and flammability of refrigerants.

EN 378:2016 / ISO 5149:2014

This is the main standard for commercial refrigeration in Europe (EN) and worldwide (ISO). It covers all 1, 2L, 2 and 3 refrigerant classes, for both A and B, but doesn't cover Dangerous Substances and Explosive Atmosphere Regulations (DSEAR).

It sets charge limits based on:

- **Toxicity** – potential harm to organisms and the environment
- **Flammable class** – how quickly and easily the refrigerant combusts
- **Access level** – who has access to the system and how
- **Location** – where the system is located and how it is fitted
- **Type of application** – whether it's stationary or mobile

EN / IEC 60335

This is a separate regulation, which covers the safety of household and similar-sized electrical appliances.

The standard is also split by appliance type. For example, IEC 60335-2-24 concerns refrigeration and ice/ice cream maker appliances, IEC 60335-2-40 covers heat pumps, air conditioning and dehumidifiers, and IEC 60335-2-89 covers commercial refrigeration appliances with an internal or remote refrigerant unit or compressor.

From 2019, charge limits for A3 (flammable) refrigerants in 60335-2-89 commercial applications will likely rise from 150g to 500g – subject to final approval by the IEC.

EN / IEC 60335 charge limits are based on:

- **Lower Flammability Level (LFL)** – the lowest refrigerant concentration for an ignitable atmosphere
- **Location** – where the system is located and how it is fitted based on surface, access level etc.
- **Ventilation** – whether the system is in the open air or housed inside a building/structure
- **Type of application** – whether it's stationary or mobile

In addition to these main standards, there are also other important regulations that should be taken into account when manufacturing or installing a new system.

- **Directive 2014/68/EU** – Pressure Equipment Directive (PED) in Europe
- **Directive 2014/34/EU** – ATEX, covers equipment and systems used in potentially explosive atmospheres in Europe
- **EN / IEC 60079** – covers explosive atmospheres equipment and requirements
- **ISO 817:2014** – refrigerants, designation, and safety classification

This is where it can open up opportunities. For example, A3 refrigerant charge is limited to 150g – and this is the case when the unit is used in public areas, inside buildings for usage in any circumstances. But sometimes, with the right precautions and knowledge of the context of use of equipment, larger charges can be used.

Do I Need ATEX-Compliant Components?

This is one for the very frequent questions that HVACR professionals have.

The ATEX "Equipment" Directive 2014/34/EU covers equipment for use in flammable atmospheres which sets minimum requirements

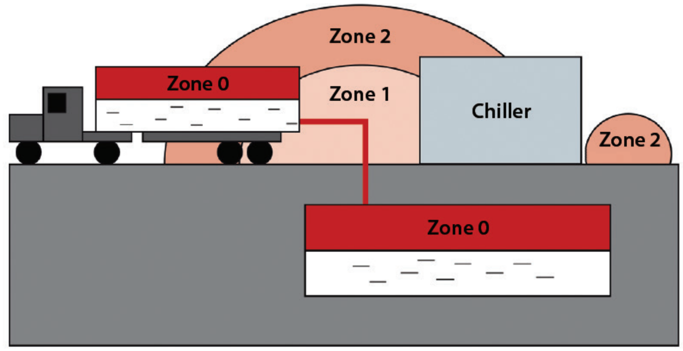

Figure 2. Zone classification according to ATEX.

for equipment which is to be used in an ATEX zone. ATEX consider three zones for gasses:

- Zone 0 is a place in which an explosive atmosphere is present continuously or for long periods or frequently
- Zone 1 is a place in which an explosive atmosphere is likely to occur in normal operation occasionally,
- Zone 2 is a place in which an explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

In general, if a refrigeration system is not installed within an ATEX zone, then no ATEX approved equipment is required.

An ATEX zone 2 may only be given when opening the system during service. Usually the system will cut off during service and only the service engineer and his equipment need to fulfil ATEX requirements.

Another case for ATEX is the outlet of a safety valves and has therefore be put to the outside.

Safety requirements by standards like EN 378:2016, ISO 5149:2014, EN IEC 60079 are done with respect to the specific demand of refrigeration systems itself and the rare event of leakage.

So, ATEX regulates components for use with A2L and A3 refrigerants only under certain circumstances:

- **Mechanical valves** – no ATEX approval needed since surface temperature will not exceed the limit of 100 K below the ignition limit temperature. R1234ze has the lowest auto ignition temperature, which is still far higher than maximum surface temperatures under normal operating conditions,
- **Electrical valves and compressors** – the same as for mechanical valves. However, if there's a risk of electrical sparks and arcs in any operating condition and the system manufacturer cannot follow the relevant standards, an ATEX approval might be required,

- **Switches** – only need ATEX if the system manufacturer cannot follow the relevant standards and defines the location of it as ATEX zone.

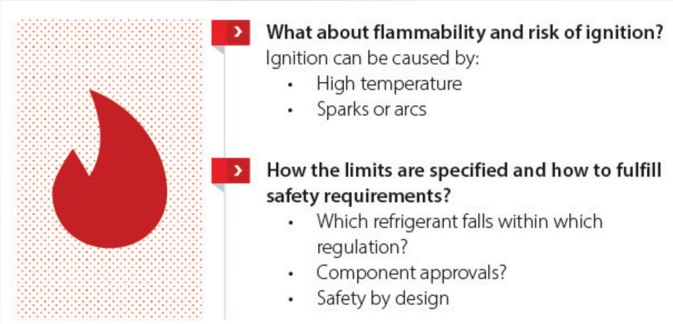

Figure 3. The different factors of dealing with flammability.

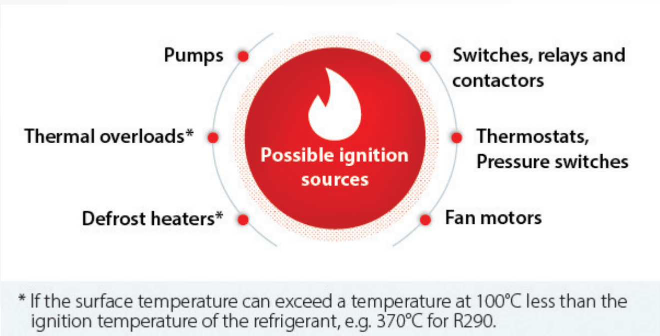

Figure 4. The different components that can be a source of ignition.

Flammable Refrigerants: Your Game-Changing Possibilities

The limitations on flammable refrigerants do not exist solely for the safety of the end user. They also protect the installer, and the manufacturer.

And just because there's strict standards governing the use of flammable refrigerants, it doesn't mean that OEMs and installers can't maximize their potential and use them in a greater range of applications.

Understanding the standards clearly is a solid base to work from.

Taking again the example with R290 refrigerant. Doing a calculation based on EN 378-2016 for a cold room of 40 ft x 25 ft, located above ground, with access only by supervised people. In this case, the condensing unit located outdoors or in a machinery room can be charged with 2.19 kg of R290 which is far above the 150 g standard limitation. And this way, a cooling capacity of almost 13 kW is possible, and all this with extremely good refrigerant thermodynamic properties, which means with high energy efficiency.

Alternatively, the drive to design for lower charges can help engineers to create systems that are quieter, more energy efficient, easier to install and service, and more flexible in their location and use.

To read the complete Technical Report on Possibilities and Limitations of Flammable Refrigerants, including information on Flammability Impact and System Design, please visit refrigerants.danfoss.com.

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Product Description

Danfoss Turbocor® model TT400 is a nominal 114 ton / 400 kW capacity compressor designed for HVAC applications. Danfoss Turbocor® compressors incorporate oil free technology using magnetic bearings and standard variable speed motors in place of traditional oiled lubrication methods.

The model TT400 is optimized to operate under standard water-cooled and low lift chiller operation for air conditioning applications. The oil free, magnetic bearing design along with standard variable speed motor increases part load efficiency (IPLV) by to 40% improvement vs traditional fixed speed screw compressors.

The TT400 compressor has sound pressure levels as low as 70.0 dBA at 1.5m (5ft) distance, or 8 dBA lower than a typical screw compressor which helps to minimize customer complaints and reduces the cost of expensive sound treatment typically required of noisy screw compressors.

The TT400 compressor model is available with environmentally friendly refrigerant HFC-134a with no Ozone Depletion Potential or non-flammable R-513A refrigerant with low Global Warming Potential (GWP) as standard.

The model TT400 is **optimized** to operate under **standard water-cooled** and **low lift chiller** operation for air conditioning applications.

Case Study: Rush Hospital

Engineering Tomorrow Boosts Medical Center's **Energy Savings**

Smardt Chillers with Danfoss Turbocor Compressors Ride Elevator to Boost Medical Center's Energy Savings

Founded in 1837 and named after the only physician to sign the U.S. Constitution — Benjamin Rush — **Rush University Medical Center (RUMC)** is now Chicago's second-largest hospital with multi-story buildings that dominate the city's medical district. But that prestigious location posed problems when RUMC's 11-story Professional Building 2 needed to replace two aging centrifugal chillers. It appeared the only alternative was to move a crane down a crowded street to lower new chillers through the roof. But some simple surgery made it possible for Smardt split-shell chillers with Danfoss Turbocor® compressors to simply take an elevator up to the penthouse mechanical room, a solution that cut installation costs while boosting energy savings.

"The professional building was using two fixed-speed 300-ton water-cooled centrifugal chillers," says Mike Scalleta, mechanical systems manager at RUMC. "They were installed when the building was built in the 1970s. Consequently, the old centrifugal chillers were using twice the energy compared to today's more efficient variable-speed chillers. It was time for them to go. The problem was we'd have to cut open the mechanical room and use a crane to drop in conventional replacement chillers. Fortunately, we learned Smardt had a solution. Their split-shell Smardt chiller design with compact Danfoss Turbocor centrifugal compressors could be taken apart to fit into our freight elevator. Using the elevator would minimize building disruption and reduce installation costs and the efficiency of a variable-speed Smardt chiller would dramatically cut our energy costs."

As the worldwide leader in oil-free magnetic bearing chiller technology, Smardt sought to significantly reduce installation costs and boost efficiency — helping the overall bottom line.

Smardt Split-Shell Chiller Fits Big Efficiency in a Tight Space

The energy efficiency of the Smardt chiller turned out to be a big plus that fit into a small space. According to Bullock, Logan and Associates' Curt Bullock, Jr., a Chicago representative for Smardt, the difference between the Smardt chiller and the old centrifugal chiller was night and day. Bullock calculates that when the old chiller was new, its integrated part-load value (IPLV) was 0.716 kW/ton but used oil-lubricated bearings. Because oil fouls heat exchanger tubes over time, actual efficiency was worse.

"In comparison, the IPLV of the Smardt chiller is 0.315 kW/ton — 57 percent more efficient," Bullock says. "That's partly because there are no oil-related heat transfer losses and no mechanical bearing friction losses. Another energy-saving feature is the compressor's ability to adjust automatically to off-design conditions. The Danfoss Turbocor TT400 compressor can turn down capacity to 10 percent of its total capacity. By automatically matching capacity to the load, the compressor reduces its speed, which also reduces energy consumption."

But all that efficiency wouldn't do any good if the chiller didn't fit into the mechanical room.

"Professional Building 2 is sandwiched between Harrison Street, other professional buildings and rail lines in the Medical District," says Carl Wigginton, vice president of service for Murphy & Miller, Inc., the Chicago-based HVAC contracting firm who handled the installation. "There is no easy access. The front of the building is a little cul-de-sac where they turn cars around and that's where the crane would have to go. It's a big reach — the crane would have to come in about 100 feet, then travel another 100 feet to the mechanical room doorway. But, there is a freight elevator that goes right to the penthouse mechanical room. It's so much easier that way — if a chiller can fit into the elevator."

The building's large freight elevator was rated to hold up to 7,000 pounds. A conventional 300-ton centrifugal chiller would weigh around 12,000 pounds empty. Consequently, the weight and size dimensions prohibit using the elevator. In contrast, the empty weight of a 300-ton WA0962HG4 Smardt chiller is about 8,500 pounds — and designed to be taken apart and easily reassembled.

"This Smardt chiller has a split-able shell design," Wigginton says. "That made it possible to disassemble the evaporator and condenser shells. Disassembly took about half a day. We transported the parts by elevator to the penthouse. It took six trips. The first two trips transported the evaporator and two more trips for the condenser. Then, the control panel and miscellaneous components took one trip and the compressors took one trip.

“Compare that with getting permits to shut down streets, disrupt traffic and block the building entrance with a crane. Plus, we would have to cut through the penthouse to give the crane access to the chiller site. You can see the advantages of this particular Smardt chiller configuration that uses two 150-ton Danfoss Turbocor TT400 compressors. The compressors weigh only about 300 pounds each, so we easily fit all four compressors into the elevator.”

Inside the mechanical room, it took two technicians five days to reassemble the shells, compressors and control panel and level the chiller. The next week, control and electric wiring were connected along with piping and valves.

Reducing Centrifugal Compressor Complexity with Oil-Free Magnetic Bearings

The installation was also simplified because Danfoss Turbocor compressors don’t require an oil management system.

“The Danfoss Turbocor compressor uses oil-free magnetic bearings,” says Ken Koehler, key account manager for Danfoss Turbocor Compressors Inc. In a conventional hermetic compressor, the shaft rides on a thin layer of oil on mechanical bearings. Because the rotational speed of the shaft may exceed 35,000 RPM, oil is needed to minimize friction and heat buildup. The bearings also keep the shaft properly aligned with the stationary elements.

“In a hermetic compressor, oil circulates within the refrigerant gas. To maintain oil at proper levels, the oil management system uses elaborate piping, traps and risers. But Smardt chillers avoid all that complexity. Because the Danfoss Turbocor centrifugal shaft levitates within a magnetic field, the need for oil is eliminated.”

Koehler explains the Danfoss Turbocor shaft doesn’t physically contact bearings in normal operation. Instead, the shaft rotates within 10 separately controlled electro-magnetic cushions that continually change strength, slightly pushing or pulling the shaft to maintain its position.

“Danfoss Turbocor magnetic bearings use a digital controller that processes signals from 10 sensor coils,” says Rob Silecchia, director of healthcare and pharma applications at Smardt Chiller Group. “Shaft movements of less than 0.00002-inch are detected and the magnetic field is adjusted to maintain the shaft orbit. Backup

carbon or roller bearings are used only to hold the shaft when the compressor powers down."

The Danfoss Turbocor compressor's digital intelligence also incorporates a powerful but user-friendly control system that interfaces with the Smardt chiller controller. The full-color control interface simplifies system configuration and commissioning through the chiller controller.

"Danfoss' monitoring software presents all the compressor operational data we need," Wigginton says. "The software is pulling in data from multiple sensor readouts. Temperatures, pressures, heat transfer across bundles, load demand, max and min RPM, compression ratio and mass flow, amp draw — it's all there through the Smardt controller. It really simplifies setup and start-up. We appreciated the support the Smardt rep — Bullock, Logan and Associates — provided. And our techs took advantage of the training Danfoss provided. The compressors are so easy to work with, we had no problem finishing the job ourselves."

Smardt Benefits for a Hospital Application

What's more, RUMC's utility — Commonwealth Edison — gave the hospital a $24,000 rebate for using a variable-speed chiller. According to Bullock, the efficiency of the Smardt chiller beat out several competitive conventional variable-speed chillers.

"The size of the rebate is $10,000 more than they would have gotten with a competitive variable-speed chiller," Bullock emphasizes. "The Smardt chiller minimizes the number of amps used at startup and during peak electric periods. The calculated difference in efficiency meant that over the eight-month cooling season, the new chiller saved about $12,000 more in utility costs than the proposed replacement chiller. In comparison with the old chiller, however, the new Smardt chiller saved approximately $75,000.00 in annual operating costs. When you add in the installation savings, the cost difference between the split-shell Smardt chiller and the competing chiller paid for itself in the first year of operation."

Another benefit is the Smardt chiller's quietness.

"Sound transmission is always a concern with a chiller — especially in a hospital setting," Scalleta says. "With a Smardt chiller, the magnetic bearings position the shaft so precisely, there's hardly any noise or vibration. The chiller does not have vibration-damping springs or sound-attenuating blankets. In fact, when we first visited the mechanical room to see the Smardt chiller in operation, we weren't sure it was running — it's that quiet compared to our old fixed-speed centrifugal chiller."

Combining the installation, efficiency and acoustic advantages, it was not a difficult decision when RUMC accelerated the replacement of its second old centrifugal chiller with another split-shell Smardt chiller just three months after the first was installed.

"The Smardt chiller runs smoothly and quietly," Scalleta says. "That's important to us and so are the energy and maintenance benefits. All the problems with oil are a thing of the past, because there is no oil. There's very little maintenance with these units. Smardt and Danfoss have created a clean, compact chiller design that fits perfectly into our operation."

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