Refrigeration and Heat Pump Technology

VDMA

Energy Efficiency of Refrigerating Systems – Information No. 3

Guideline with Measures for Optimizing Refrigerating Systems

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Clear instructions, good tips and useful information for operators of refrigeration and air conditioning systems.

Learn how to implement measures from the refrigeration check (Information No. 6).

Work with your specialist company to decide which optimizations are best for your system.

Content

Content

Costs and benefits

Over an assumed operating period of ten years, refrigeration and air conditioning systems incur electricity costs amounting to ten to 15 times the investment costs.

A planned optimization measure is always preceded by the question: What does it cost and how much can be saved?

Measure 1:
Cleaning the heat exchangers

**Evaporators/air coolers and condensers/recoolers with plate fins get dirty over time. A film of dirt forms on the plate fins, grows continuously and impairs heat transmission.
This increases the energy consumption and operating costs.**

In the case of condensers/recoolers located outdoors, a "carpet of dirt" of varying severity made from organic materials forms on the air inlet in spring and summer.

In evaporators and air coolers, accumulation of bacteria and spores can collect in the dirt film and can lead to hygiene problems, especially around food.

It is therefore worth paying particular attention to cleaning the heat exchangers.

How often should heat exchangers be cleaned?

Regularly cleaning all heat exchangers is recommended. The frequency of cleaning depends highly on the environmental influences. Evaporators/air coolers located in truck delivery areas, for example, are exposed to a great deal of pollution in the form of diesel emissions from the vehicles and wood dust from the pallets. Flour dust, soil from lettuces, fat vapors, lint in laundries and feathers in abattoirs can all also lead to significant pollution of the evaporators/air coolers.

Where there are impermissible deviations in the temperature differences on the cold and warm sides, the heat exchangers must be assessed for their contamination and cleaned. If an assessment of this kind is not possible, cleaning intervals should be defined together with the refrigeration expert, taking into account the local requirements and conditions.

A visual inspection of the plate fin surface is recommended at least once a year, together with the statutory leakage testing, so that any necessary cleaning can take place.

Condensers and recoolers at installation locations with average dirt and spore loads should be cleaned once at the start of every summer.

The cleaning method must be defined together with the refrigeration expert, taking into account the manufacturer's information.

Note
In CO_2 systems, it is important to ensure that the pressure in the heat exchangers does not rise impermissibly during cleaning.

The following should be adhered to for the cleaning methods listed below. As a general rule, cleaning must be conducted in the opposite air flow direction to operation wherever possible.

High-pressure cleaner:
Cleaning with a high-pressure water cleaner is possible. It is important that the water is always sprayed straight onto the evaporator/air cooler so that the plate fins do not become deformed.

Compressed air:
Cleaning with compressed air is suitable wherever dirt is not adhered. It is important that the air is always blown straight onto the evaporator so that the plate fins are not bent.
Note that, indoors, the compressed air blows dry dust into the room.

Water:
Cleaning with a garden hose can be conducted for air coolers up to a construction depth of max. 30 cm.

Broom, brush and vacuum cleaner:
Condensers/recoolers can be coarsely cleaned (dusted) with a broom, brush or vacuum cleaner.

Fig. 1: Soiled condenser; the plate fins close slowly.

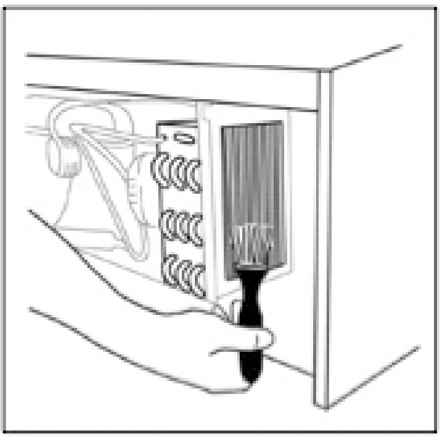

Fig. 2: Cleaning the condenser with a brush and vacuum cleaner in a refrigerated cabinet

Important
The best time to clean condensers/recoolers is after the pollen season (June).

Cleaning evaporators/air coolers

Moisture from the air condenses on cold evaporators/air coolers. This can result in dirt particles from the air adhering to the damp surface. The heat exchanger must therefore be cleaned more frequently by a refrigeration expert.

This generally requires the following steps:

- Defrost the evaporator/air cooler if required
- Disconnect fans and defrost heating from the electricity supply
- Fold down or remove the drip pan
- Clean the plate fins, fan blades and protective grid, drip pan and siphon
  A cleaning agent that is mild, degreasing, biodegradable, food safe and suitable for use with copper and aluminum should be used for the cleaning.

Important

There is a danger of short circuit when fans and electrical socket connections and terminal boxes are cleaned with water. These parts and connections are usually listed in safety class IP54.
This means that, if these parts are subjected to a direct water jet or played under water, the components will fail and the electrical fuse be blown.

Cleaning outdoor condensers/recoolers

Outdoor condensers/recoolers become contaminated with particles from the ambient air, such as dust, pollen, leaves and exhaust gases. They must therefore be cleaned more frequently by a refrigeration expert.

This generally requires the following steps:

- Disconnect condenser/recooler fans from the electricity supply
- Dismantle the fan or use cleaning openings if available
- Clean plate fins from both sides with steam, compressed air or a high-pressure cleaner, first in the opposite direction to the air flow of the fans (reverse flow cleaning)
  A mild cleaning agent that is suitable for use with copper and aluminum can be used for cleaning.
- Clean the housing and grids

Deformed plate fins – what now?

If the plate fins on the heat exchanger become deformed, this reduces their performance and energy efficiency. Deformation can occur, for example, when the high-pressure cleaner sprays water onto the plate fins at an angle. Deformed plate fins must be realigned using plate fin combs.

Important

Leave cleaning cooling towers and hybrid recoolers to the experts!
Cleaning cooling towers requires specialist expertise on water quality (hardness, dosage, disinfection).
Failed attempts to clean these heat exchangers can be expensive.
Therefore, have this work conducted regularly by a specialist who is familiar with the relevant occupational safety measures.

Cleaning heat exchangers in refrigerated display cabinets

The role of refrigerated display cabinets is to present the goods to be refrigerated in an attractive manner, in perfect condition and at the prescribed temperature. The number of products sold depends heavily on attractive, clean presentation at a reliable temperature.

In order to retain the energy efficiency of a new device for as long as possible, heat exchangers must be cleaned regularly.

A distinction is made between cleaning the evaporators/air coolers and cleaning the condensers in ready-to-use refrigerated display cabinets.

Cleaning evaporators/air coolers in refrigerated display cabinets

Evaporators/air coolers should be cleaned at the intervals recommended in VDMA Specification 11499 “Operation and use of refrigerated display cabinets”:

Refrigerated serving counters	Daily
Multi-deck refrigerated commercial cabinets for fruits and vegetables	Daily to weekly
Multi-deck refrigerated commercial cabinets for dairy products	Weekly to monthly
Multi-deck refrigerated commercial cabinets for meat	Weekly
Multi-deck refrigerated commercial cabinets for convenience food	Weekly to monthly
Island and chest type frozen food storage cabinets	Weekly to monthly
Frozen food storage cabinets and combinations	Weekly to monthly

Cleaning should largely be conducted with warm water and usual cleaning agents. Non-aggressive, degreasing cleaning agents that are compatible with the material can also be used. Abrasive or very aggressive cleaning agents must not be used.

Cleaning air-cooled condensers in refrigerated display cabinets

Ready-to-use refrigerated display cabinets with integrated air-cooled condensers should be cleaned at the intervals recommended in VDMA Specification 11499 “Operation and use of refrigerated display cabinets”:

Refrigerated serving counters	Daily to weekly
Multi-deck refrigerated commercial cabinets for fruits and vegetables	Weekly to monthly
Multi-deck refrigerated commercial cabinets for dairy products	Quarterly
Multi-deck refrigerated commercial cabinets for meat	Monthly to quarterly
Multi-deck refrigerated commercial cabinets for convenience food	Quarterly
Frozen food island site cabinets and chest type frozen food storage cabinets	Six-monthly to annually
Frozen food storage cabinets and combinations	Six-monthly to annually

The cabinets must be disconnected from the electricity supply during cleaning of non-visible internal parts, interior surfaces and functional components. This work may only be conducted by trained specialist staff.

The use of high-pressure cleaning devices and strong water jets must generally be avoided when cleaning these parts, fans or electric/electronic components.

Note
VDMA Specifications can be ordered from Beuth Verlag, 10772 Berlin, phone: 030/2601-2260, fax: 030/2601-1260.

Measure 2:
Optimizing heat recovery

If the waste heat arising from the refrigerating system is used, it can make a valuable contribution to reducing the energy costs for building heating, warm water or process heat. The decision whether or not to use the waste heat of a "cooling and heating" system from refrigeration plants must always be based on a detailed assessment of the pros and cons of heat recovery and their influencing factors on the economic efficiency. However, this does not often happen in practice: either the waste heat is not put to optimum use or it causes unwanted costs.

Use the lowest possible temperature level

The lower the temperature of the heat recovery and thus the condensation temperature, the more efficiently the system will run. Therefore, check the temperature requirement of the heat recovery and reduce it to a minimum.

Work with your refrigeration expert to set the lowest possible condensation temperature for your heat recovery application.

Before you raise the condensation temperature to be controlled, ask him to check whether the de-heating heat from the refrigerating system is sufficient for your application.

Do not use higher condensation temperatures when no waste heat is required

Ensure that the condensation temperature is only increased when there is a need for waste heat.

When the waste heat is not being used, the refrigeration plant should not be operated with a higher condensation temperature.

Extra tip
Examine the option of retrofitting heat recovery

If the waste heat of your refrigerating system is not being used, it may be worth examining the option of retrofitting heat recovery. The basic prerequisite is that there must be a demand for heat in the direct vicinity – be it for heating, for generating warm water or for preheating (e.g. in butcheries or commercial kitchens), for ramp heating, process heat (e.g. laundries) or other applications.

If you need heat, proceed as follows:

- Examine which sources of waste heat you have in operation in addition to the refrigerating system (e.g. compressed air system, waste process heat from ovens, melting processes).
- Clarify which of the sources delivers the waste heat at the time you want to be able to use the heat and which best meets your temperature requirements.
- Have the costs of retrofitting and the yield (cost/benefit) of heat recovery calculated for this version.

Important

If the refrigerating system has to be run at a higher condensation temperature for heat recovery, each one-degree increase in temperature causes additional energy consumption of up to 3.5%.
In this case, the waste heat is not for free. Increased energy costs are incurred when the refrigerating system is operated, in addition to the investment costs for heat recovery.
You can find more information in the principles document "Guidelines for Planning Refrigerating Systems" and in VDMA Specification 24019 "Heat Recovery from Refrigeration Plants".

Note

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Measure 3:
Optimizing the electric defrosting process

If the refrigerating system defrosts too frequently, electricity is consumed unnecessarily. If the refrigerating system does not defrost frequently enough, the evaporator/air cooler will ice up, heat transfer will worsen and the system will become inefficient. Setting the defrosting process correctly or retrofitting defrosting on demand reduces the energy consumption of the defrosting process and the refrigeration significantly.

Generally it is recommented that the refrigerating system should not defrost more than twice a day. However, rooms with a higher humidity load (e.g. when the door is opened frequently in summer) may need more defrosting. Defrost on demand should be preferred here.

Evaporators/air coolers should not be installed over doors if possible, as the warmer external air enters the room when the door is opened, the humidity settles immediately on the plate fins and ice forms at temperatures below 0°C. The suction effect of the evaporator/air cooler installed over the door increases the incoming heat and humidity!

Is the defrost sensor positioned correctly?

If ice nests form on the plate fin surface or in the connection or elbow area, the defrost sensor may be incorrectly positioned or calibrated. It will then report too early that the evaporator/air cooler is defrosted. Raising the defrost limiting temperature does not solve the problem and causes excessive steam formation and ice sheets. A refrigeration expert should be consulted in this case.

Fig. 3: Iced evaporator.
Only part of the surface receives an air flow.

Defrost with forced air in rooms over 4°C

At room temperatures of more than 4°C, electric defrosting is often unnecessary. It is important to check whether forced air can be used for defrosting.

Investigate alternatives when replacing

When replacing evaporators/air coolers, have an expert check whether you could also use alternative systems with heat carriers from waste heat or hot-gas for defrosting.

Correct setting of defrost thermometers by the refrigeration specialist company

The aim is to find the minimum defrost temperature at which no more ice is found on the evaporator/air cooler after the defrost process. Your specialist company is familiar with the steps needed to optimize the defrost process in each type of defrosting. Ask them to inform you about defrost initiation (on demand, frequency), defrost duration (demand, temperature limit, time limit), restarting the refrigeration (refrigeration and fan delay) and ask which optimization steps they have taken.

Replacing the defrost control often helps.

Older systems only defrost the evaporator after a specified time, regardless of whether it is needed.

If the defrost control needs to be replaced, check whether a control that defrosts on demand can be retrofitted. In systems with multiple evaporators, they should not be defrosted simultaneously.
The defrost control should be able to take current electricity prices into account. Talk to your energy supplier.

Versions for defrost on demand:

Version A: Cumulating the operating time of the refrigerating system
The control adds up the operating time of the evaporator/air cooler and only initiates defrosting once a specified total of operating phases is reached.

Version B: Defrost on demand at the best time for an energyefficient operation
If the performance of the evaporator/air cooler is impaired by ice, the control initiates the defrost process and ends it at the ideal time.

High-quality defrost on demand coordinates the initiation of defrosting.

If these measures are conducted properly, they can pay off after just one year.

Measure 4:
Optimizing the control of refrigerating units

Does a compressor switch on and off more than six times an hour?
Do various smaller refrigeration units cause the compressor to switch on and off too frequently?
This kind of operation reduces the life span of the compressor and the energy efficiency of the system.
In general, compressor performance must be selected depending on the evaporator performance.

Provide locking

Check the control if your system works in cycles. If no minimum load applies, individual refrigeration units should not be able to switch on the entire refrigerating system. A minimum operating time of the compressor(s) in accordance with the manufacturer's specifications should be adhered to.

Converting the control in the switchgear cabinet allows the power regulation to be set in such a way that the compressor only switches on when a minimum load is reached.

If these measures are conducted properly, they can pay off after just one year.

Retrofitting switch-on frequency regulation

If the regulation needs to be replaced, examine the option of retrofitting switch-on frequency regulation simultaneously.

This ensures that the compressor is protected, the electricity consumption reduced and operation becomes more efficient.

If these measures are conducted properly, they can pay off after just one year.

Compressor with frequency converters

If the compressor needs to be replaced, examine whether installing a compressor with an integrated frequency converter would increase the efficiency of the system.

The frequency converter adapts the performance of the compressor to the current demand and prevents the evaporation temperatures from deviating from the target value.

Operation with a frequency converter up to 60 Hz allows a smaller compressor to be selected.
In systems with multiple compressor, only one of them needs to be equipped with a frequency converter.

If these measures are conducted properly and attention is paid to vibrations in the full rotational frequency range, they can pay off in less than one year.

Measure 5:
Optimizing control of the fans

The fans of the condensers or recoolers need 8 to 15 % (up to 50% in the case of partial loads) of the electric power of the refrigerating system.
The lowest possible condensation and recooling temperatures are very important for energy-efficient operation of the system. Reducing the condensation or recooling temperature by 1K reduces the refrigerating system's energy requirement by 2 to 5%.

Staged control of the condenser/recooler fans should be replaced with continuous controls.

Aim for low condensation and recooling temperatures

Ensure that every condenser and recooler sucks in cool air. The heat exchanger block is ideally positioned one meter above the ground.

In addition, no air that has already been heated by another heat exchanger block should be sucked in (short circuit). If this is the case, examine whether partitioning off with metal sheets would work or whether a different installation location would be more suitable.

When setting the condensation pressure control, ensure that the lowest possible condensation temperature is set. This depends on the system configuration.

Use EC fans

If a fan needs to be replaced, choose a highly-efficient motor (IE 3).

EC (electronically commutated) fans have proved themselves in practice. They are characterized by their sparing use of energy and outstanding controllability. The integrated control electronics enable the speed of EC motors to be adapted continuously to the performance requirements.

They are also highly effective in the partial load range. and therefore use much less energy than AC drives at the same air capacity.

When replacing an old condenser/recooler, always request a quote for a version with EC fans.

Measure 6:

Controlling of air conditioning refrigerating system

A lot of different trades are involved in air conditioning projects. For example, architecture, heating, ventilation, lighting and shading all influence the need for refrigeration and the design of the refrigerating system.
When the refrigerating system is optimized, its control (MSR) must also always be included.

Optimizing the rated values and approval for cooling

Excessively low rated values for the room temperature demand unnecessary refrigerating performance. The optimum rated value for cooling depends on changeable ambient, operating and usage conditions in the rooms. It can be useful to approach the optimum rated values by increments.

Proceed as follows:

- Increase the rated value for the room temperature in logical increments (e.g. by 0.5°C) during the time interval to be examined (e.g. in summer when there is a high thermal load).
- Observe the change of the room temperature of exposed rooms over several days (e.g. server rooms, south-facing offices).
- Taking the comfort level into account, repeat the increase in the room temperature rated value up to the permissible limit; in technical rooms, such as server rooms, up to the maximum room temperature that is technically feasible.
- In some cases, this iterative approach may make it necessary to reduce the room temperature rated value again by one increment (e.g. 0.5°C).

Check the switching point for free cooling

Determine the optimum operational switching point from free cooling to mechanical cooling at the highest possible outside temperature. Proceed as described above.

Simultaneous heating and cooling?

A room should not be heated and refrigerated at the same time. Fast, successive switching (oscillation) must be prevented.

If some rooms are to be heated and others refrigerated, it is important to check whether heat transfer is possible in the building.

Check cold water rated values

Larger refrigeration performance is required in the case of higher outside temperatures and humidity. A lower cold water temperature is therefore required in the existing refrigerating system (cooling ceiling, refrigeration panels, coolers…). If outside temperatures fall and/or demand for dehumidification is low, the rated value can be increased. Flexible modification of the rated value enables the refrigeration system to be operated in an energy efficient and thus more economical way with the highest possible cold water temperature.

Outside temperature-led target value shifting

The refrigeration curve of a cooling water control must be set for summer and winter operation in such a way that the cold water temperature for the respective refrigerating system (cooling ceiling, refrigeration panels, component activation…) is controlled based on demand.

Free cooling

Free cooling is refrigeration without compressor operation.

Indirect systems

The cooling water is cooled by outside air via recooling plants. When the outside temperature is very low, the cooling water (e.g. cooling tower recooling water) is so cold that the heat can be discharged to outside via an intermediate heat exchanger. The compressor is not in operation.

Alternatively, in ammonia refrigerating systems, flooded evaporators and air-cooled compressor or evaporative condensers can be connected via a bypass to the compressor, in order to transport heat from the cold water circuit to outside.

Direct systems

The cool outside air is brought directly into the room (ventilation, open windows…) during the night. If the building has sufficiently high thermal storage capacity, this can reduce the refrigeration demand.

Important

Subsequent mixing of warm water with cold water (e.g. to raise the cold water temperature from 6°C to 8°C) is not energy-efficient practice and should be avoided.
Set the rated value for the cold water temperature to a higher value (8°C) and check whether rotational frequency controlled pumps can be used in the cold water circuit.

Measure 7:
Setting the expansion valve correctly

The expansion valve is usually installed with the values set at the factory and is not usually adapted to the specific system. It is highly probable that the overheating values are designed for safe operation, i.e. an excessive overheating temperature, and not for the optimized operation of the system. It is therefore worth having a refrigeration expert set the setting values correctly.

Electronic expansion valve

With an electronic expansion valve (EEV), overheating can be set precisely and simply on the control.

Have the refrigeration expert set the overheating on the expansion valve to the right overheating ratio. In an evaporator, for example, the incoming air temperature t_{L1}, the evaporation temperature to and the refrigerant temperature at the evaporator outlet t_{oh} should be used for this. An overheating ratio of 0.65 is the goal. This is calculated by the overheating at the evaporator outlet divided by the incoming air temperature difference.

overheating ratio = $(t_{oh}-t_o)/(t_{L1}-t_o)$.

Only EEVs whose overheating adapts to the load should be used.

If these measures are conducted properly, they can pay off in less than a year.

Thermostatic expansion valve

Setting a thermostatic expansion valve (TEV) takes time, but is worth it.
After each modification, the refrigeration expert has to wait around 15 minutes for the process to bed in.

Have the overheating on the expansion valve set to the right overheating ratio.

If these measures are conducted properly, they can pay off in two to three years.

Investment tip:

Replace thermostatic expansion valves with electronic ones

Switching from TEV to EEV allows the refrigerating system to be operated at lower condensation temperatures. Conversion is recommended. If this measure is conducted properly, it can pay off in just a few months.

Important

The thermostatic expansion valve is no longer suitable for the use of the lowest possible condensation temperatures, e.g. up to around 15°C. For this, it must be replaced with an electronic expansion valve. An electronic expansion valve is the only way to exploit the advantages of a lower condensation temperature, in order to reduce the energy consumption of the refrigerating system.

Information

Temperature differences on heat exchangers

Temperature differences in the refrigeration cycle and drive powers, including for auxiliary units, have an impact on operating costs.

Heat absorption (cold generation)

The evaporator construction and control type determine the temperature differences (see Fig. 4).

In indirect systems (air cooler with secondary refrigerant), further temperature differences in the secondary refrigerant are necessary for heat transportation and heat exchange in shell-and-tube and plate heat exchangers, so that the temperature differences between the evaporation and service temperatures increase. The total of these temperature differences should be as low as possible.

Drive power for fans and pumps also influences the operating costs. It should therefore be possible to control them depending on the load, if possible.

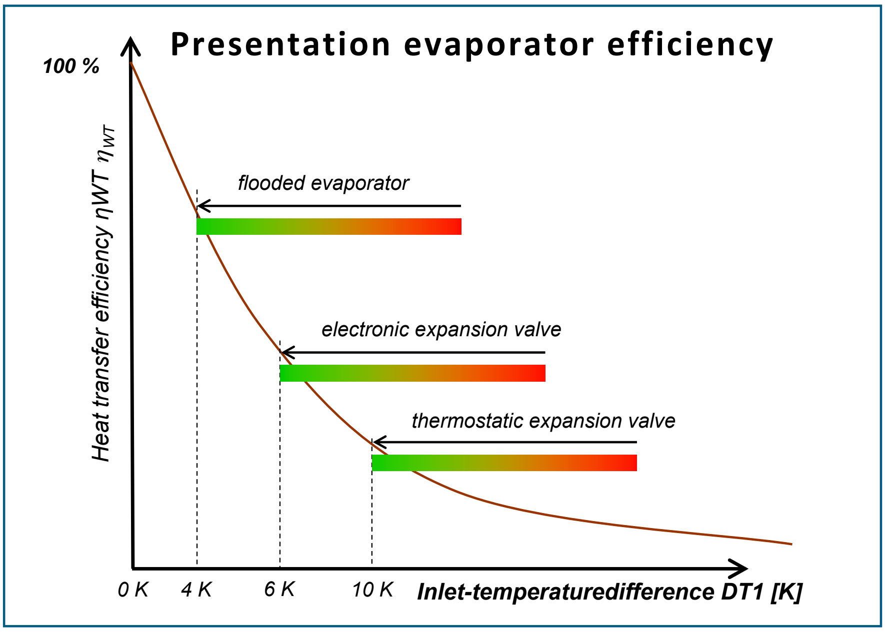

Fig. 4: Evaporator efficiency chart (source: VDMA 24247-8)

Heat transfer:

The condensation temperature has a greater impact on the operating costs than any other operating parameter. The temperature difference from the heat sink must be as low as possible. The goal for air-cooled condensers should be a difference of 8K between the condensation and incoming air temperature; for water-cooled condensers a difference of 1-2K between the condensation and cooling water outlet temperature.

In sprinkled plate fin condensers and evaporative condensers, the goal should be a difference of 6-8K between the condensation and wet bulb temperature. If the condensation heat is discharged via a heat exchanger, further temperature differences are required in the heat carrier and for heat transfer in recoolers, and must be determined taking the drive power for auxiliary units into account. Relevant assessment criteria can be found in VDMA 24247-2.

You will find more information on energy and cost efficiency at
www.kwt.vdma.org/Energieeffizienz

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- is based on the form and content of the SVK document "Leitfaden mit Maßnahmen zur Optimierung von Kälteanlagen".
- shows refrigeration experts and operators of refrigerating systems how they can optimize existing refrigerating systems and plan and implement new systems using practical measures.
- Increase awareness planners,installers and operators of refrigerating systems to the topic of energy efficiency and helps to enhance their skills.
- has been compiled in cooperation with the refrigeration industry (VDMA, Forschungsrat Kältetechnik e. V., cold storage operators (VDKL)) and technical service corporation (TÜV SÜD Industrie Service GmbH).

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