thermofin®
heat exchangers - GERMANY

Assembly and Operating Manual Hybrid Dry Cooler

Series THDD
thermofin® Hybrid Dry Cooler

thermofin GmbH, Am Windrad 1, 08468 Heinsdorfergrund Phone: +49 (0)3765-3800-80 0
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1. Preliminary notes

The purpose of assembly and operating manuals is to prevent dangers to persons and to the environment, which may be caused by a machine and by the work performed in connection with the machine, particularly during transport, assembly, commissioning and operation of the machine. Therefore, all points of this manual must be carefully read and observed.

This documentation was created in all conscience. thermofin® is not liable for any faults in this documentation or for resulting consequences

1.1 Fundamentals

The present assembly and operating manual refers to machines of the following type series:

→ **THDD: Hybrid Dry Cooler**

as well as units with installed switching and control components (wired or unwired).
The corresponding technical data can be seen from the current catalogue, the machine data sheet and the type plate.

For the fan motors and controllers, the data given on their identification plates primarily apply.

1.2 Range of application

Air cooled dry coolers/condensers and closed evaporative cooling systems as a combination of units turn the hybrid dry cooler into a variably applicable unit. Thanks to the coaction between wet and dry cooling, the hybrid dry cooler is an efficient unit. Typical applications are in the technology of refrigeration, air-conditioning and processing in order to cool condensating cooling agents, cooling circuits in technological lines or in technical building equipment.

The hybrid cooler is principally used in industrial processes. Both in dry cooling of refrigerating machines and compressors and in air conditioning and refrigeration technology, it offers the user considerable advantages.

thermofin® hybrid dry coolers of the series THDD are provided for external installation.

1.3 Applied standards and directives

The manufacturer certifies the compliance with the standards according to the order-related declaration of incorporation and/or declaration of conformity included in the documents of the units.
Furthermore, both the installation company and the operating company of the system should be familiar with the contents of the following standards, regulations and instructions:

- EU directive 97 / 23 / EC for pressure equipment (Pressure Equipment Directive)
- EU directive 2006 / 42 / EC for machines (Machinery Directive)
- EU directive 98 / 83 / EC relating to the quality of water intended for human consumption
- EU directive 80 / 68 / EC for the protection of ground water
- EU directive 2006 / 11 / EC for the discharge of dangerous substances
- German Equipment and Product Safety Act (GPSG); including the regulations (GPSGV) applicable in the Federal Republic of Germany
- EN 378; parts 1 to 4; "Refrigeration systems and heat pumps, safety and environmental requirements"; state: June 2008
- DIN EN 806 Drinking water supply systems
- DIN EN 1717 Protection of the drinking water
- DIN EN 12056 Gravity drainage inside of buildings
- DIN 1986-100 / DIN 1986-3 Drainage systems for buildings and property
- DIN EN 476 General requirements for wastewater pipelines and sewers
- BGR 500 "Operation of work materials"; chap. 2.35: "Operation of refrigeration systems, heat pumps and refrigeration systems"; applicable in the Federal Republic of Germany
- VDI 3803 Waste heat recovery (Recommended reference values for circulating water in open water conducting systems)
- VDI 6022 Hygiene requirements to RLT systems and units
- VDI 2047 Hygiene in recooling systems
- VDMA 24649 Notes and recommendations for the effective and safety operation of evaporation coolers
- The present operating manual " thermofin® Hybrid Dry Cooler"
- The labels attached to the machine, which contain instructions and information of the manufacturer

The operator is obliged to observe – in addition to the regulations stated in this operating manual – all possible local particularities and / or applicable regulations.

2. Technical Data

2.1 Method of operation

Dry operation:
Such as in case of conventional finned dry coolers, the cooling process in dry operation is effected without moistening of the heat exchangers. During this process, energy is emitted by convection to the ambient air.

Wet operation:
In case of high outside temperatures or high system loads, the performance can be doubled or tripled by moistening the heat exchangers. The cooling of the system is ensured by convection and additionally by evaporation.

A changeover between both operation modes allows an optimal use of the device performance in case of changing ambient conditions. The hybrid dry cooler can be designed according to its application and optimised for the planned operation of the system.
The climatic conditions at installation site, the year temperature range and the conceivable load characteristic of the system are considered during the planning.
With it, an optimal dimensioning of the dry coolers/condensers and the minimisation of the operating costs of the complete system can be reached.

2.2 Application and intended use

The units as partly completed machine according to MRL 2006/42/EC is designated for the incorporation into a cooling system. Despite meeting the requirements of intended use and handling the machine properly, residual risks cannot be completely avoided.
In principal, the machine is suited for outdoor installation.
The machine may only be used in places where the materials applied are not affected by the surrounding atmosphere or the medium flowing inside.
Any cases of application differing from the one described above require consultation with the manufacturer.
The manufacturer does not assume liability for any damages resulting from the non-compliance with these provisions.

The unit may not be put into operation until the conformity of the complete plant has been declared according to EC Machinery Directive!

2.3 Structure / Material

Already with the construction of the hybrid dry cooler special attention was given to a high corrosion resistance.

The dry cooler consists of finned heat exchangers with core tube. An electrophoretic deposition increases the durability also in case of difficult ambient conditions.

The devices are executed in innovative lightweight design in V-form. All parts with water contact are equipped with stainless steel housing. The casing of the hybrid dry cooler consists of powder coated stainless steel and is UV and corrosion resistant.

The tubes are made of copper or stainless steel and brazed or welded in system.

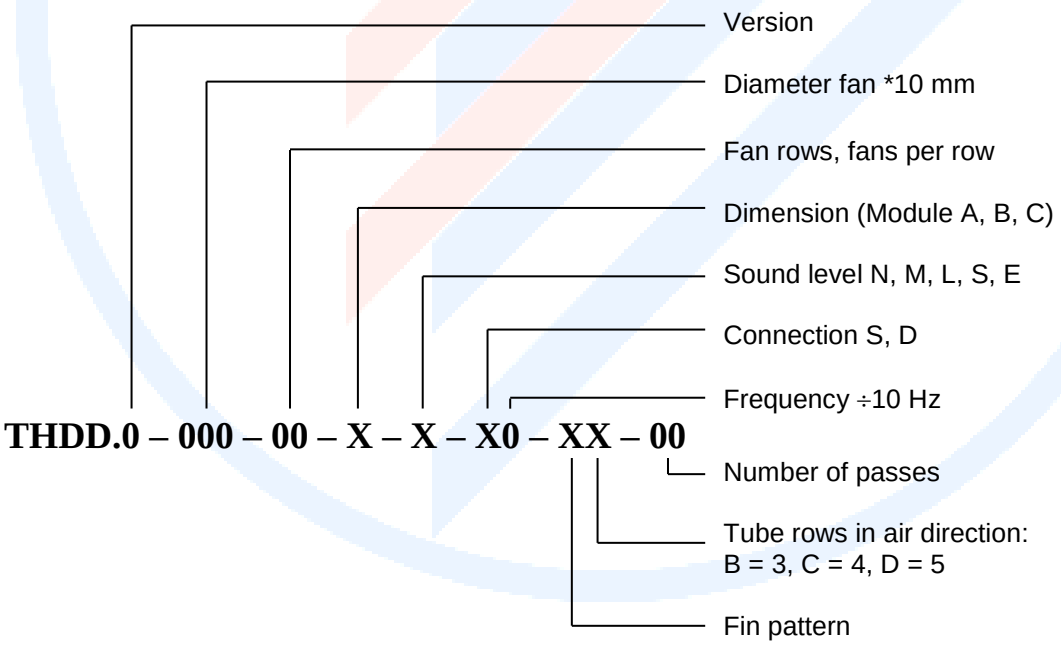
Already with the selection of the suitable wetting water, damages due to corrosion can be prevented (see chapter 6.).

With the alignment of the fins in packages and the subsequent pressing, the hole collars of the fins are tightly jointed. Consequently they form a protective sheath preventing the influence of environmental influences on water-carrying tubes.

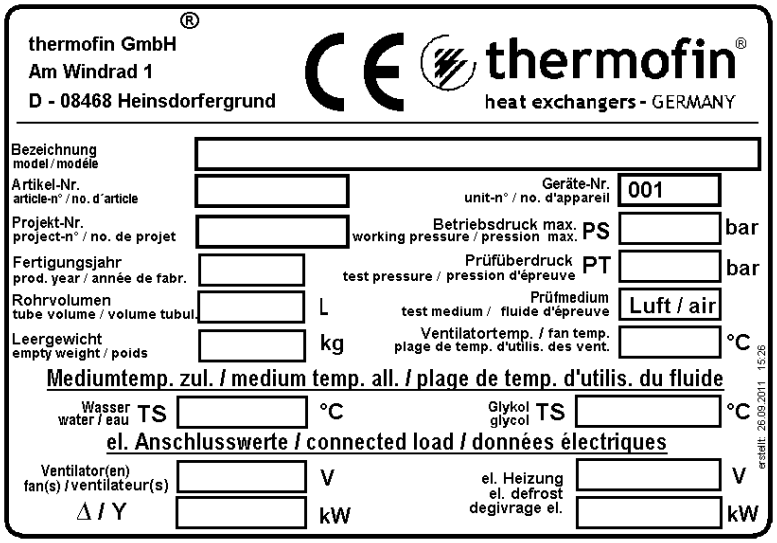
2.4 Sound information

The sound pressure stated was determined by calculation on the basis of the enveloping surface method according to DIN EN13487 at a defined distance.

2.5 Unit key



2.6 Data on the type plate



The type plate contains the following data:

- model description according to the unit key (see 2.5 Unit key)
- article number of the manufacturer
- project or serial number
- month / year of manufacture
- tube volume of the heat exchanger
- empty weight of the machine
- test overpressure PT
- maximum working pressure PS
- allowed temperature range of the medium TS
- allowed temperature range of the fan
- pressure test medium of the heat exchanger
- connected loads of the fans

3. Safety

3.1 General safety instructions

The unit is state-of-the-art and reliable in operation. The machine may only be used in accordance with the specifications in the catalogue and the data given on the type plate. The unit may only be installed, commissioned and maintained by competent personnel. For installing the system, the installation conditions according to standard DIN EN 378 and VDMA 24649 must be observed. Furthermore, the applicable national rules and regulations, such as the water resources law, accident prevention regulations etc. are to be complied with. The company installing the system has to ensure the observance of all pressure and temperature limit values given on the type plate.

Compliance with the instructions of this operating manual does not release the plant operator from the obligation to install an appropriate warning system indicating each kind of malfunction immediately. In addition, emergency measures must be planned and prepared in order to prevent consequential damages in case of malfunctions.

3.2 Safety instructions for the installation site

The erection and installation conditions according to DIN EN 378 are to be observed. Pipes and fittings must be protected against misuse. Emergency facilities, such as lighting, venting, escape routes and the marking of which according to DIN EN 378 must be provided and VDMA 24649.

The machine must be lockable in case of leakage.

No smoking at the installation site. Open fire is prohibited.
The fire extinguishing equipment must meet the requirements of DIN EN 378-3 and the local requirements.

There must be sufficient free space around the machine in order to prevent dangers to the machine and its connections and to ensure smooth execution of maintenance and repair work on the machine as well as on all fittings and components.

The hybrid dry cooler must be installed in such a manner that escaping aerosols can not enter suction openings of HVAC systems and recreation rooms by opened windows.

3.3 Safety instructions for the unit

Before performing installation, repair and maintenance works, the power supply must be interrupted at all circuits. An unauthorized and / or unintentional (automatic) restart must be prevented. Zero potential must be checked and - if applicable - ensured by the means of earthing or short circuiting. Adjacent energized parts need to be covered.

Do not touch the fin edges – risk of cuts!

Any unauthorized reconstructions or modifications affecting the functions or the safety of the dry cooler are prohibited!

Any external forces acting on the equipment must be avoided. In particular, equipment connections and manifolds may not be stressed (e.g. do not step on them).

Walking on the machine is only permitted with an appropriate falling protection!

It is not allowed to push objects through the safety guard of the fan or to put them in the circle of rotation of the fan blades.

In circumstances, dry coolers cannot be completely drained. During operation after leakage test or rinsing with water for cleaning purposes, there is a risk of bursting in case of frost.

Before performing welding and soldering work the machine must be depressurized!
Ethylene glycol is combustible and explosive in vaporous or gaseous condition in case of high temperatures.

In the event that refrigerants escape, use your personal protective equipment. Avoid any contact with glycol. In case of eye contact, seek medical advice immediately!

Beware of the lateral inspection openings or slewable fans! **Before opening the covers, the fans must be turned off and a restart must be prevented!**

Do not climb on the pipelines and connections. Do not walk on the fans!

If the temperature difference between the ambient temperature and the medium inlet temperature exceeds 70K, the max. permitted temperature slew rate must be observed:

starting temperature	max. temperature slew rate
$T\_{ambient} < +10°C$	1.5 K/min
$T\_{ambient} \geq +10°C$	3.0 K/min

3.4 Safety instructions for the operating supplies

3.4.1 Water

The applied operating supply item – water – is characterised by a very good specific heat emission as well as high cost-saving availability. Following instructions have to be observed when operating with water:

The operating supplies must be prevented from escaping.

Cooling water is not drinking water!

Cooling water may contain toxic or harmful additives (anti-corrosive agents) as well as residues or fractions of motor oil and may not contaminate soil or the sewage system.

During repair works avoid eye and skin contact as well as contact with clothes. Risk of irritations. Scald risk from coolant temperatures of 60°C and more. Release overpressure before opening the circuit.

The remarks of section 5.3 Water quality must be observed for the selection of the additional wetting water.

3.4.2 Glycol

Ethylene glycol is a colourless, slightly viscous, slightly volatile and hygroscopic liquid that can be mixed with water. It has a sweetish smell and taste.
Ethylene glycol vapours are heavier than air and thus they may enter lower spaces. At ground level, the concentration may increase in quiescent air. In case of high concentrations, there is a risk of suffocation due to the reduced oxygen percentage in the breathable air.

The operating supplies must be prevented from escaping.

Ethylene glycol is combustible! When in vaporous or gaseous state, it is potentially explosive at higher temperatures!

After skin contact, ethylene glycol causes a slight irritation with the risk of skin resorption. Eye contact causes mucous membrane irritations. After being swallowed, the substance produces states of agitation with disorders of the central nervous system as well as fatigue, loss of consciousness, coordination disorders and kidney damage.

Keep ethylene glycol away from ignition sources, do not smoke!
Avoid the contact of ethylene glycol with open flames or hot surfaces. Be careful when executing soldering and welding works!

During troubleshooting, avoid eye and skin contact as well as contact with clothes. Use your personal protective equipment. Take off soiled or soaked clothes immediately!

Further and more detailed information and direction for use and first aid as well as provisions resulting therefrom are to be found in the corresponding safety data sheet.

3.5 Safety instructions for the fans

Before performing any work on the fans and the motors including cleaning work between the fans and the heat exchanger block (inspection covers!), cut off power supply and prevent restarting!

According to DIN EN 60204-1, the machines must have a switch-off device in order to prevent unintentional restarting. It must be possible to secure this switch-off device while the system is de-energized (turned off)!

Observe the data given on the motor type plates!

Existing thermal contacts must be connected obligatory!

In case of fan motors with water condensation holes, the respectively lower holes must be opened!

After the completion of repair and maintenance work, all objects must be removed from the area around the fans, since such objects may cause malfunctions or damages of the fan and the heat exchanger after switching-on the system.

After the dismounting of fans and their reassembly please check for free-wheeling.

3.5.1 Advices on speed regulations

In case of regulating the fans with frequency converter, the use of an all-pole sinus filter must be provided.

In case of a phase angle control, electromagnetic motor noises can be originated in the lower speed range (buzzing). A noise filter should be provided in sensitive environments.

With the dimensioning of the phase angle control, a possible regulatory current increase must be observed. In case of doubt, the manufacturer must be contacted.

Pressure transducer and temperature sensor must be properly installed and connected. Density and/or a good heat transfer must be ensured. Shield the signal cables or lay them spatially separated from the power cables!

4. Assembly, Installation, Commissioning and Maintenance

4.1 General

The unit may only be installed, integrated in a refrigeration system, operated, maintained and repaired by qualified personnel of specialist companies according to the definitions of expertise from DIN EN 378, DIN EN 12056, DIN EN 806 and VDMA 24649.

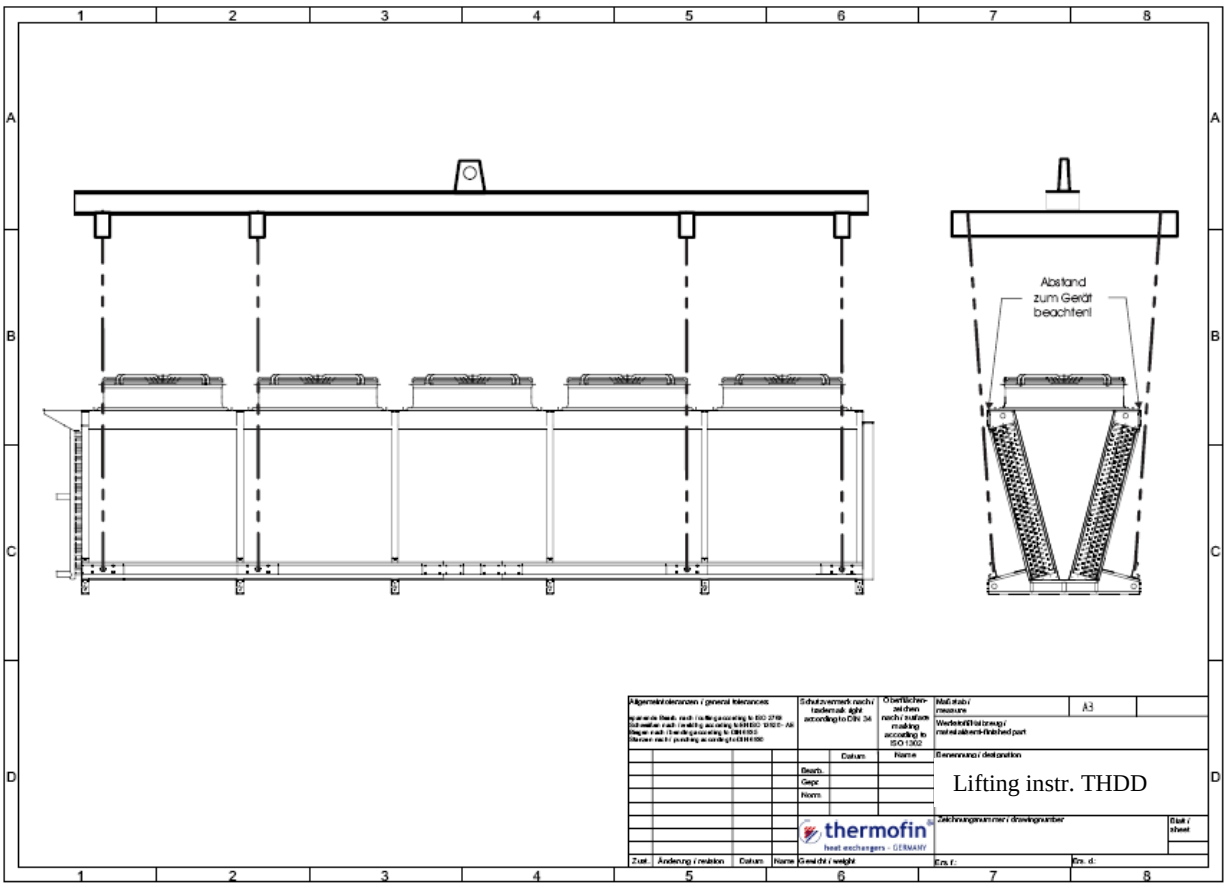
During production and before delivery, each machine is subjected to comprehensive quality testing. The machine is provided in good order and condition. With delivery and before assembly, the device must be checked for damages (damages in transit).

4.2 Transport, positioning, storage

4.2.1 Transport

During transport, the machine must be handled with special care. In particular, always place the unit very carefully on the ground!

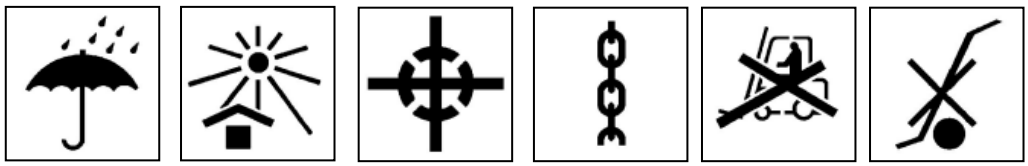
For transport, the lifting instructions attached to the unit must be observed. Appropriate slinging equipment must be used. Sheet metal constructions of the casings must not be pressed by belts. If a sufficient rope length (angle max. 30° to vertical) cannot be ensured, a traverse must be used. Only fix the slinging means to the provided lifting points. Never use tubes or mounted parts for lifting.



The transport weight calculated in the factory (unit net weight+packing) is noted on the label attached to the packing.

A transport with forklift trucks (forklifts) is not permitted.

If indications on transport or storage are attached to the device or the packaging, they must be absolutely observed!



4.2.1.1 Packaging

Decisive factors for packing are the route of transport, the size of the equipment and the regulations applicable in the country of importation.

The pallets, crates and export boxes used for thermofin® machines meet the requirements of the HPE and VDM standards (HPE – German Federal Association for Wooden Packages, Pallets and Export Packaging; VDM – Association of the German Furniture Industries). If required they can be tailored to the standards of ISPM 15.

thermofin® transport packages are made of environmental friendly materials and they are suitable for recycling.

According to the German regulation on packaging, we are prepared to take back our packages if they are returned to us, delivered free to our location in Heinsdorfergrund.

If parts are delivered separately because of transport or for other reasons, they must be assembled on site according to the enclosed order-specific drawings.

Loading on road vehicles is performed in accordance with the VDI guideline 2700 "Securing of loads on road vehicles".
In case of groupage traffic, responsibility lies with the forwarder.

4.3 Assembly instructions

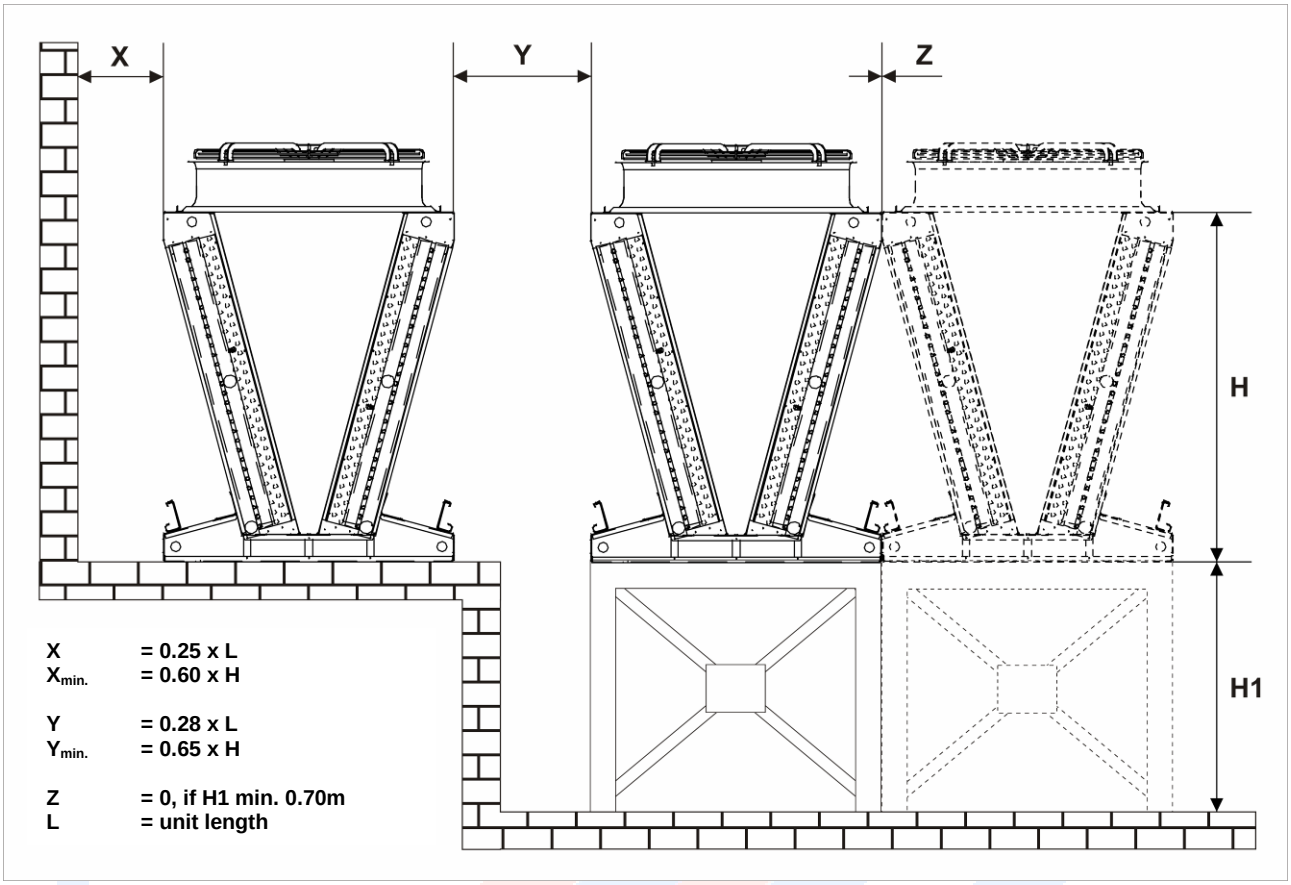
4.3.1 Installation

The suitability and the load bearing capacity of the foundations, brackets, machine frames etc. – provided by the customer – are not the responsibility of the equipment manufacturer.
It has to be ensured that the machine rests evenly on all contact points. It must be fixed on the supporting structure by using appropriate fasteners. For this purpose, the mounting holes provided on the machine feet are to be used.

Optionally, sylomer strips adapted to the size of the unit are available. These strips consisting of polyurethanes serve the sound and vibration isolation.

After installation and before commissioning all existing package parts and transport protection devices must be removed.

Please pay attention to sufficient distances to walls, sheathings or the like. The air flow must not be obstructed in any way.



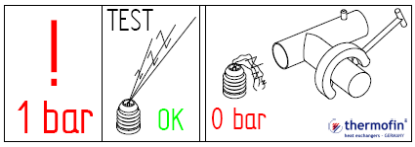
If a free air suction cross-section cannot be insured or if several units shall be installed, it must be coordinated with thermofin®.

4.3.2 Pipe connections

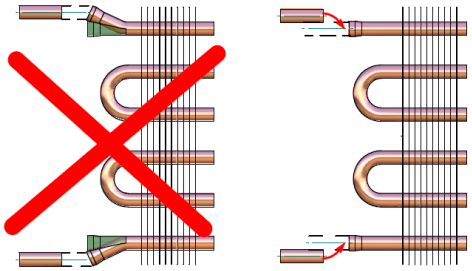
Soldered or welded devices or devices closed with counter flanges are delivered with an overpressure of approx. 1 bar (cleaned and dried air) (according to the regulation for the transportation of hazardous material ADR 1.1.3.2 c).

Before removing the closing caps or the counter flanges, it must be verified that the overpressure is present. A depressurized device indicates a leakage (Damage in transit! Leak test!).

In case of depressurized devices, the manufacturer must be consulted immediately.
Before the assembly, the transport pressure must be released and the closing caps must be removed.



Pipe connections are to be designed in such a way that any force, stress and vibration effects on the machine are prevented.



Inlet and outlet according to the marking.

4.3.2.1 Special features of dry coolers

Dry coolers are delivered by default with dust caps for preventing the entry of mechanical contamination in the machine. However, the do not offer protection against ingress of humidity. Particularly in case of longer intervals between installation and connection, condensate may form inside, which could cause the formation of ice plugs in case of frost. Appropriate measures must be taken in order to avoid this problem.
Complete drainage of the system cannot be fully ensured. Therefore, the system must be flushed with anti-freezing agent – when there is danger of frost – after performing a leak test with water. For flushing, a pump is used, which is coupled to the outlet connection of the machine via a hose line. Previously, the machine must be disconnected from the heat transfer medium circuit. The water mixed with the anti-freezing agent is discharged via the vent connection and conducted to a collecting tank, from which the pump sucks water again. In order to ensure sufficient mixing, a 10-fold circulation is at least necessary. The achieved frost resistance can be determined by means of the mixture in the collecting tank.

4.3.3 Electrical connections

The electrical connection of the fans and/or the electrical accessories, if existent, must be performed in accordance with the applicable national regulations and the provisions of the local energy supply company!

The electrical installation may only be carried out by qualified personnel.
The local regulations must be observed.

The data given on the respective identification labels are binding.

Wiring may only be performed in accordance with the circuit and wiring diagrams provided.

The existing strain-relief devices must always be used.

The direction of rotation of the fans must be observed!

The thermal motor protection is either already integrated in the electrical feed line of the fans or has to be integrated in the electrical control system by the company installing the machine (see wiring diagram of the fans).

A suitable all-pole circuit breaker must be installed in the system.

Please note that in case of an installation in cold spaces humidity can condense out, which can lead to an accumulation of dripping water inside the socket as well. In case that the fans are equipped with condensation water holes, the lower ones must be opened!

For the installation of the unit or subsequent installations assure compliance with the degree of protection.

4.3.4 Start of operation

Before starting operation, the system's readiness for operation must be verified according to the following points:

1. Has the machine been properly installed and fixed in accordance with the instructions of the present manual?
2. Have all fluid-carrying lines been connected and checked for tightness? Are the shut-off devices open?
3. Are all cables properly installed and completely connected? Has cabling been done according to the wiring diagrams provided?
4. Has the electrical protective installation been checked for proper functioning?
5. Have all bolted connections (e.g. fans, cable entries), fastenings, electrical connections etc. been checked for tight fit?
6. Do the fans rotate freely and in the right direction?
7. Are all terminal boxes and cable entries firmly closed and tight?

During start of operation the following measures have to be taken:

1. Check and, if necessary, adjust the direction of rotation of the fans.
2. Measure the current consumption of the fans and check for compliance with the type plate data.
3. Adjust the electrical switching and control devices and check for correct functioning (see the specific operating instructions of the respective control device).
4. Check the switch point settings of the safety equipment.

4.3.4.1 Return to service after a longer period of standstill

If the machine is intended to be put into operation again after being shut down and standing still for a longer period of time, the following points must checked in addition to those mentioned under „4.3.4 Start of operation":

1. visual inspection of the heat exchanger block; check for fouling and damages
2. leak test of the heat exchanger block
3. visual inspection and functional test of the fans; check for free running, check the terminal boxes for tightness, check for corrosion and noise (bearings)

4. check all pipe connections (including pipe clips), electrical components, housings and attachment parts for tight fit

4.4 Maintenance and hygiene

The manufacturer recommends performing particular maintenance works at regular intervals. The form and frequency of the measures strongly depend on the respective installation site of the heat exchanger.

4.4.1 Cleaning of the fins

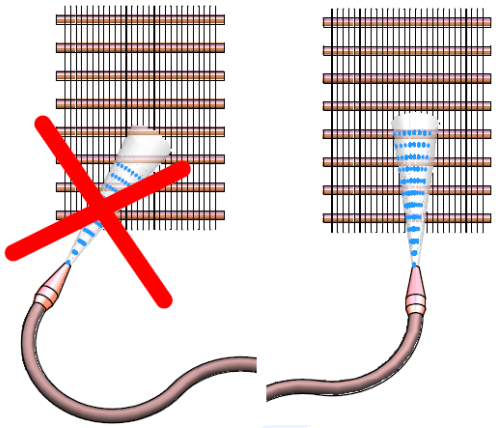
Depending on the installation site, mode of operation and the season, the heat exchanger fins are subject to soiling (varying degree). As this directly affects the performance and thus the current consumption of the machine, the cleanliness of the fin block must always be ensured.

Dry cleaning: with a broom or a soft brush from the outside towards the fins or from the inside towards the outside by using compressed air – opposite to the direction of the air flow of the fans.

Switch off the machine (regarding refrigeration and electricity)!

Depending on the soiling degree of the ambient air, the coolers should be hosed several times with water during the wetting period and the wetting water basin should be cleaned from sludge.

Wet cleaning: with a water jet from the inside towards the outside and opposite to the direction of the air flow of the fans; and from top to bottom. The jet of the cleaning device must be vertical to the heat exchanger coil (max. deviation ±5°), in order to prevent fin deformations.



Switch off the machine (regarding refrigeration and electricity)!

Use of high pressure and steam pressure washers up to 80bar max.

Electrical components may not be exposed to the water jet!

When using cleaning agents, the compatibility of materials must be ensured. Never use aggressive or corrosive cleaning agents! In case of doubt, consult the manufacturer. Application rules of the manufacturer with regard to handling and use, especially dosage, reaction time and after-treatment, must be strictly respected.

Mechanical cleaning with hard objects, such as steel brushes or screwdrivers may destroy the heat exchanger, therefore it is not permitted. Damages to the KTL coating should be prevented and repaired immediately.

The experiences show that the soilings in wet operation coming from the ambient air are considerably lower than in case of a dry cooling. Possible soilings are mostly washed out in wet

operation and fouling is avoided. In case of strong soilings of the atmosphere and after a long dry operation of the unit, we recommend to clean the cooler using a water jet. In order to rinse out impurities, the blow-down valve must be opened. Pollen can contribute to a strong alga formation. For this purpose, we recommend to use an algicide in case of a high pollen concentration.

More problematic are long-fibred flowers fibres such as of poplars leading to entanglements on the air entry and the water applying point of the fins and impacting the operation of the unit (unequal wetting, dripping). For cleaning, we recommend a soft brush or an industrial aspirator. Please be careful in order to do not damage the fins.

4.4.2 Cleaning of the tray

Wetting water is applied to the fins through open pipes and is recirculated. Individually escaping water drops are collected in the water tray. The air pollutants washed out from the circuit are accumulated as fine sludge in the collecting tray. These accumulations require the cleaning of the tray at necessary intervals.

For this purpose, manually open the blow-down valve and move the sludge towards the valve. Please observe that the wetting water pump is deactivated. Rinse out the remaining sludge from the tray using a water jet.

4.4.3 Cleaning of the casings

The units should be cleaned with water or a mild soap leach.
In order to comply with special hygienic requirements, devices with a casing made of stainless steel must be used where necessary.

When using cleaning agents, please observe the compatibility of materials. Never use aggressive or corrosive cleaning agents. If necessary, contact the manufacturer or the supplier of the cleaning agent. Application rules of the manufacturer with regard to handling and use, especially dosage, reaction time and after-treatment, must be strictly respected.

Under no circumstances use sharp-edged tools or scrapers!

4.4.4 Chemical cleaning

A chemical cleaning should only be effected in case of emergency.

After control of the water quality, try to dissolve the deposited scale by temporarily increasing the dosage of the additives. Often, this is successful after approx. one week of wetting operation with increased dosage. Subsequently, the dissolved scale can be removed from the fins using a water jet. In case that the layer of scale increases, please contact the supplier of the dosing medium and/or the softening station. Inform the company thermofin® in any case.

If the measures taken should not achieve the desired result, a chemical decalcification should be effected. It must be effected by a recognised specialised company!

Regional and national regulations for the handling of acids must be strictly observed.

The chemical decalcification can be effected during operation and, if possible, in the presence of a qualified person. Please proceed as following: Deactivate the fresh water supply and add decalcifier NALCO 62513 (or Acitol Cl-937) to the water in the tray so that the pH-value falls to 3. Subsequently, put the wetting system into operation. During cleaning process, the pH-value must be continually checked and maintained in acid range by adding NALCO 62513 so that the cleaning agent rests active. After 1-3 hours, all lime residues should be dissolved from the fins.

NALCO 62513 and Acitol Cl-937 are decalcifiers specially adapted to aluminium. Do not use other unsuitable chemical agents which could lead to corrosions!

Subsequently, deactivate the wetting system and neutralise the acid mixture with a caustic soda solution. After regulation to pH 7, it can be fed into the waste water. Then, the unit must be spring-cleaned with fresh water in order to remove all decalcifier residuals.

The accumulations must be analysed in each case and be taken in order to avoid them during further operation!!

4.4.5 Testing of the fans

All series units delivered by thermofin® are equipped with maintenance free, energy-saving fans of renowned manufacturers. Notwithstanding the above, the fans should be checked for function, bearing noises, free running and unbalances. Furthermore, the terminal covers should be checked for tight fitting and tightness. Due to the fact that the bearing are maintenance free and permanently lubricated, a special check is not necessary. In case of longer down times of the system, e.g. storage, we recommend to operate the fans for approx. 3 to 4 hours per month in order to vaporise entered condensate and to move the bearings.

All components that were removed, loosened or disassembled for cleaning or inspection purposes must be properly reinstalled after work completion. They must also be checked for correct functioning!

Further preventive measures are in the discretion of the plant operator or the company installing the plant.

4.4.6 Electrical switching and control devices

thermofin® offers different variant options with maintenance switch or motor protection switch, phase angle control or frequency regulators as well as combinations thereof – on demand, fully pre-wired. Here, a function test should be performed at regular intervals. The cables and components must be subjected to a visual inspection, the terminals must be checked for tight fit. In addition, it must be checked whether the set parameters are still in line with the machine configuration.

All components that were removed, loosened or disassembled for cleaning or inspection purposes must be properly reinstalled after work completion. They must also be checked for correct functioning!

Further preventive measures are in the discretion of the plant operator or the company installing the plant.

5. Operation and shutdown

5.1 Normal operation

For running the machine, the entire plant including the electrical system must be operating. The machine is integrated in the cooling circuit by opening the corresponding shut-off valves. It is turned on by activating the electrical system.
After reaching the machine-specific operating point the machine is ready for operation.
In case of operating conditions which differ from those stated in the offer, the manufacturer must be consulted.

In order to ensure the required cooling water temperature, the hybrid dry cooler operates until a defined switching point as a conventional dry cooler.
The heat is exclusively dissipated in a convective manner. As soon as the outside temperature exceeds the mentioned temperature and is with it too high to reach the required cooling capacity in dry operation, the hybrid dry cooler switches to wet operation. In doing so, the finned surface of the refrigerating elements is wetted with processed water.

The majority of the wetting water is evaporated. The heat is dissipated in a convective and evaporative manner. Thanks to the generated evaporation heat, the heat exchange efficiency can be increased significantly. This wet operation is mostly determined by the wet bulb temperature. The dry refrigerating air temperature influences the function of the system only insignificantly. With an increased air temperature, the wetting degree increases constantly. If the highest possible wetting degree is reached, the unit operates exclusively as evaporating cooler. The wetting process is effected with excess water. The remaining water amount is collected in the tray below the cooling elements.

An excess water amount is essential to ensure a complete wetting and to rinse out possible air soilings.

The soiling degree of the water is determined with conductivity measurements. As soon as a certain soiling degree is arrived and the required water quality (see chapter 6 water quality) cannot be ensured, the soiled water is automatically drained.

Thanks to an optimally adapted regulation system, the system performance is always monitored and the wetting amount is adapted to the environmental conditions. With the continuous measurements of the filling level and the conductivity, the wetting water balance is maintained.
Frequency converters integrated in the control system regulate the speed of the fans for the optimal adaption of the cooling capacity. With it, the energy and water consumption can be optimised and the costs for the user can be significantly reduced.

The theoretically obtainable return temperature and with it the cooling limit of the hybrid dry cooler are approx. 4°C above the wet bulb temperature of the ambient air. For free cooling, the outlet temperature of the medium to be cooled can lay below the outside temperature.

By deactivating the wetting pump, the complete wetting circuit is drained into the water tray. In winter operation, the water tray is automatically drained before reaching the freeze point. In order to prevent possible damages to parts of the system, we recommend to check the drain in case of low temperatures. The fresh water supply is automatically blocked.

5.2 Shutdown

The machines are part of a cooling system. Machine shutdown and return to service must meet the system-dependent requirements as well as the requirements of the operating manual of the equipment manufacturer and of the applicable standards and accident prevention regulations (see also chapter „1.3 Applied standards and directives“). The shutdown is effected by closing the fluid-bearing tubes and by switching off the electrical system.

For dry coolers there may be a risk of freezing. In this case the machine must be drained (see also point „4.3.2.1 Special features of dry coolers“).

The following applies for all devices: Exceeding the maximum pressure must be prevented!

In case of longer standstill periods of the system, the fans should be operated for approx. 3 to 4 hours per month.

6. Water quality

The quality of the wetting water is a very important criteria for the excellent function of the hybrid dry cooler. During wet operation of the dry cooler, a large part of the applied water is evaporated. Since only pure water is evaporated in this process, the salt and soiling content of the circulating water is continuously increased. This so-called thickening can only be limited with a partial water replacement. A part of the water is lead to the sewerage system and replaced by water with a lower salt content and/or degree of hardness. In order to ensure this water replacement, a water supply should be available in proximity. This blow-down is effected in a manner regulated through a conductivity measurement.

Since a release of copper ions is possible especially in case of new installations, the supply line of the wetting water should not be made of copper.

Since the fins are subjected to different influences of the ambient air such as salts, pollen and soilings, different degrees of accumulations leading to corrosion are possible. Due to this fact, we recommend the use of a corrosion protection and dispersing agent. Since accumulations, sludge and biofilms form nutrients for bacteria such as legionella and their uncontrolled growth must be avoided, we recommend the intermittent use of a biocide (to limiting values and background see also VDMA 24649, VDI 3803 and 6022).

The water quality must be regularly checked according our maintenance instructions. For quality of the wetting water, also observe annex I with an extract of the VDI guideline “Recommended guideline values for the characteristics of the heat exchanger circulating water”.

In case of stronger accumulations, the thickening of the circulating wetting water must be reduced and the dosage of the additive must be adapted and periodically increased if necessary. In doing so, we recommend to contact the supplier of the dosing agent.

If there is a too high thickening degree, salt depositions are possible facilitating corrosion due to local elements and pH value movement. Visible salt accumulations can be dissolved with a light water jet. Limescale deposits on the fins reducing the performance of the cooler which are hardly removable (see chapter 4.4.4 Chemical cleaning) must be prevented. Since every residual hardness

during the thickling through the fins leads to lime precipitations, soft water must be applied to the hybrid dry cooler.

Depending on the local conditions, the osmosis water or softened water can be applied to the wetting circuit. Both types of water are described below.

6.1 Demineralised fresh water

The advantage of water processed with a reverse osmosis is the completely removed salt content. For this mode of operation, the risk of salt deposits is minimised. Depending on the ambient conditions, completely demineralised water can be thickened 8 to 12 times and, with it, the water consumption can be minimised.

Since soiling and organic material enter the wetting circuit, we recommend the low dosing of a dispersing agent as well as the temporary biocide addition.

For the designing of the reverse osmosis system by directly applying the permeate and the dimensioning of the fresh water line, the 1.3-fold nominal fresh water amount is deemed to be the basis for the maximum volume flow. However, we recommend the operation of the reverse osmosis with buffer storage. With this operation mode, the system can have a smaller size and costs can be saved.

Below, the values for the characteristics of the osmosis water are indicated. The limit values of the circulation water must be strictly observed. The values of the fresh water are a recommendation.

Osmosis water (thickening 8-12)	**Fresh water**	**Circulation water**
Hardness	0°dH	0°dH
pH-value	approx. 7	7 – 8.5
Electrical conductivity	0 - 10 µS/cm	< 200 µS/cm
Colony forming units		< 10000 KBE/ml
Corrosion protection, dispersant and hardness stabiliser Nalco WT-265 or similar	10 - 15 g/m³ additional water	100 g/m³
Biocide Nalco WT-040 or similar	3x per week (push)	50 g/m³ (application time approx. 2 h, min. 30 minutes)

6.2 Softened fresh water

If the raw water quality is suitable, the softening can be effected through an ion exchanger system. Here, hardness building calcium and magnesium ions are replaced by sodium ions. A reduction of the concentration of other water contents and with it the reduction of the conductivity and the pH-value do not take place. In order to ensure the economical operation of the hybrid dry cooler, a 3-fold thickening of the wetting water should not be exceeded.

Regarding the danger of corrosions, the permitted thickening degree depends strongly on the entire salt content and the chloride content of the wetting water. A too high chloride content can strongly influence the electrical conductivity of the wetting water.

Due to this fact, it is strictly necessary to periodically check and record the water quality, especially if the chloride content of the circulating water is above 100 mg/l. The maximum value must not exceed 120 mg/l for several days!

For the design of the water softening system and the dimensioning of the fresh water line, we recommend as basis for the maximum volume flow the 1.3-fold nominal fresh water amount.

The values for the composition of the softened water are mentioned below. The limiting values of the circulating water must be strictly observed, the values of the fresh water are recommendations.

Softened water (thickening degree 2-3)	**Fresh water**	**Circulating water**
Hardness	0°dH	0°dH
pH value	approx. 7	7 – 8.5
Electrical conductivity	0 – 1000 µS/cm	< 2000 µS/cm
Chloride	0 – 50 mg/l	< 100 mg/l
Sulphate	< 100 mg/l	< 325 mg/l
Colony-forming units		< 10000 KBE/ml
Corrosion protection, dispersant and hardness stabiliser Nalco WT-265 or comparable	30 - 50 g/m³ additional water	100 g/m³
Biocide Nalco WT-040 or comparable	3x weekly (batch)	50 g/m³ (reaction time approx. 2 h, min. 30 minutes)

7. Spare parts

After-sales services are to be performed by the responsible specialist company. Spare parts are stated in the spare parts list enclosed in the annex or in the specified drawing. They can also be requested from the manufacturer by indicating the device name and the project number on the type plate. Only use original spare parts for the replacement of equipment components.