

ENVIRONMENTAL PRODUCT DECLARATION

CENTRIFUGAL CHILLERS

MAGNITUDE® MAGNETIC BEARING CHILLER MODELS WMC & WME



Magnitude is up to 40% more efficient than standard centrifugal chillers and can save up to \$4 million over the life of the chiller. Facility managers can count on their chillers running at peak efficiency year after year with a design that wipes out the risk of contamination from efficiency-robbing oil buildup on to heat-transfer surfaces.



Daikin Applied, a member of Daikin Industries, Ltd., designs and manufactures technologically advanced commercial HVAC systems for customers around the world. Customers turn to Daikin with confidence that they will experience outstanding performance, reliability, and energy efficiency.

Magnitude magnetic bearing chillers, manufactured in Staunton, VA, define industry leading sustainable efficiency. Every day throughout the world thousands of customers benefit from the reliable performance and energy savings of Daikin technology.

Daikin Applied is committed to sustainable practices as part of our corporate culture. We believe it is the right thing to do for our customers, our community, the environment, and ourselves. As an HVAC company, Daikin Applied has a unique opportunity to make a difference in sustainable initiatives.

For more information visit www.DaikinApplied.com



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on a Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.



| | |
|---|--|
| PROGRAM OPERATOR | UL Environment |
| DECLARATION HOLDER | Daikin Applied |
| DECLARATION NUMBER | 4787052246.101.1 |
| DECLARED PRODUCT | Magnitude® Chiller Product Portfolio |
| REFERENCE PCR | UL Provided |
| DATE OF ISSUE | June 7, 2016 |
| PERIOD OF VALIDITY | 5 Years |
| CONTENTS OF THE DECLARATION | Product definition and information about the building's physical properties Information about basic materials and the materials' origins Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications |
| The PCR review was conducted by: | UL Environment Review Panel |
| | UL Provided |
| | UL Provided |
| This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories <input type="checkbox"/> INTERNAL <input checked="" type="checkbox"/> EXTERNAL |  Wade Stout, UL Environment |
| |  Thomas P. Gloria, Industrial Ecology Consultants |

ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Product Definition

The Magnitude product is a high-efficiency, oil-free water-cooled centrifugal chiller. A chiller is a machine that removes heat from a liquid via a vapor-compression cycle. The cooled liquid can then be circulated through a heat exchanger to cool air or equipment as required. A water-cooled chiller utilizes the vapor-compression cycle to chill water and transfer the heat collected from the chilled water plus the heat from the compressor to a second water loop cooled by a heat rejection device. This declaration represents the average of two individual chiller models: Magnitude WMC 250 ton unit and Magnitude WME 500 ton unit (see Figure 1). These specific models were chosen as they constitute the WMC and WME lines' respective best-selling chillers during the 2014 reporting year.

Daikin Magnitude® Magnetic Bearing Centrifugal Chiller Model WMC 250 ton unit

Daikin's advanced centrifugal chiller design utilizes magnetic bearings for oil-free operation, integral variable-frequency drives, and direct drive technology to deliver optimal efficiency. The advanced magnetic bearing compressor technology eliminates the oil management system, reducing risk of costly downtime and minimizes maintenance costs associated with traditional designs. This design offers sustainable performance with no degradation due to oil contamination in the heat exchangers.

Daikin Magnitude® Magnetic Bearing Centrifugal Chiller Model WME 500 ton unit

Daikin extends the offering of the oil free, magnetic bearing centrifugal chiller into larger capacities with the model WME. Available in capacities up to 1,500 tons, the model WME delivers industry leading efficiency and performance.

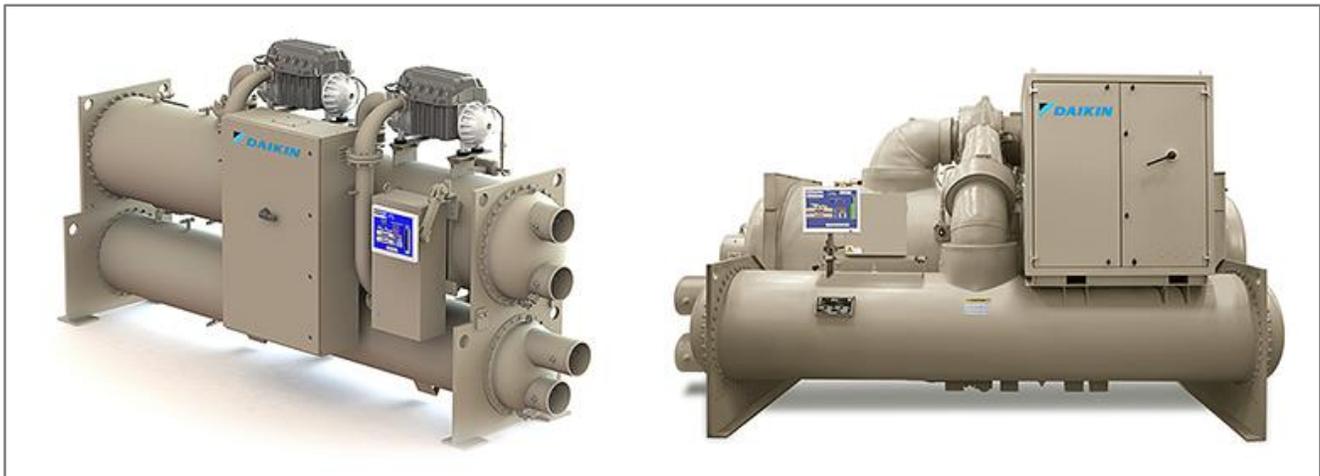


Figure 1: Daikin Magnitude chiller models WMC 250 ton unit (left) and WME 500 ton unit

Scope of Validity

The chiller models informing the "average model" declared in this EPD as well as all other model configurations in the WMC and WME lines are manufactured in a single US facility. This EPD is intended for business-to-business (B2B) communication in the US.

ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Application

The function of the chiller is to provide chilled water for cooling a commercial building.

Product Standards and Certifications

The rating and testing of chillers used in comfort cooling applications are governed by the following standards:

- AHRI Standard 550/590 (I-P)-2011 with Addendum 3: Performance Rating of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle
- ANSI/ASHRAE Standard 147-2013: Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems
- ANSI/ASHRAE Standard 34-2013: Designation and Safety Classification of Refrigerants
- ASHRAE Standard 90.1 Energy Standard for Buildings, Except Low-Rise Residential Buildings
- IBC/OSHPD Seismic Certification
- ISO 9001:2008, Quality Management System

Magnitude® chillers are also certified by independent verification programs:



Rated within the scope of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) certification program for Water-Cooled Water-Chilling Packages.



DNV certified to meet the ISO 9001:2008 standard for Quality Management Systems.

Delivery Status Properties

The average dimensions of the two declared chillers are: width: 1.97 m (77.6 in); length: 3.86 m (152.0 in); height: 2.29 m (90.2 in).

Technical Properties

The average cooling capacity of the two declared chillers is 375 tons. The energy efficiency is calculated based on different combinations of percent load and Entering Condenser Water Temperature (ECWT), as described in the background report.

For variable-speed chillers, the evaporator water pressure drop is 4.8 meters (15.7 feet) and the condenser water pressure drop is 3.6 meters (11.9 feet) of water.



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Declaration of Basic Materials

The chiller assembly is broken down into major assemblies and shown in Table 1 in kg per declared unit (one ton of cooling capacity) for the declared average, representative model.

| Assembly | Average Mass (kg) |
|---------------------------|-------------------|
| Compressor | 1.03 |
| Condenser | 2.60 |
| Controls, incl. power box | 1.63 |
| Evaporator | 2.58 |
| Shell | 2.86 |
| Unit assembly | 1.44 |
| Total | 12.14 |

Table 1: Average mass of major chiller assemblies in kg per declared unit (one ton of cooling capacity)

The raw materials used in the average chiller model are shown in Figure 2.

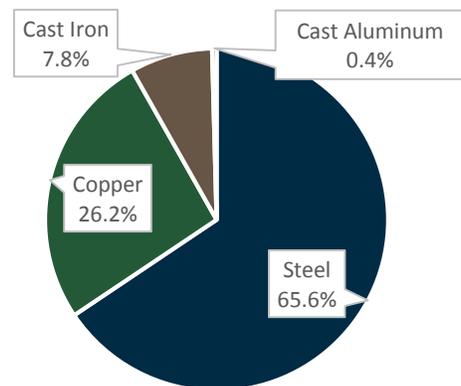


Figure 2: Percent breakdown of material input for the average chiller model

Auxiliary Substances / Additives

The two chiller models require an average initial charge of 1.17 kg of refrigerant per ton of cooling capacity with a total of 438 kg for the average chiller. Additional refrigerant recharges may also be required at a maximum of 0.5% per year. The refrigerant used is R-134a.

Material Explanation

The chiller heat exchangers are primarily made of steel sheet with copper tubes used for heat transfer. The compressor is made of cast iron components that form the enclosure, with steel and aluminum cast internal components. The controls are assumed to consist of 90% steel sheet and 10% copper wiring (best estimate).

Raw Material Extraction and Origin

The major components of the chiller are metals and metal parts that come from the global metal markets. Global averages are used for input materials where possible. All the materials used in the manufacture of this chiller are available in the earth's crust as non-renewable materials.

Manufacturing Process

Manufacturing inputs consist of two activities: electricity consumption and thermal energy from natural gas. Of the chiller models considered in the LCA, all are produced in the United States. All production components arrive when needed (including raw castings, plate steel, copper tubing and labor) to reduce inventory and allow for a smaller manufacturing footprint. This minimizes and better aligns the resources necessary to meet customer requirements, including transportation costs and waste, and material obsolescence.

Plate steel is flame-cut, rolled, drilled, and sub-arc welded into shells and water boxes. Gray-iron and aluminum castings are machined and assembled into a compressor. These primary components, along with subassemblies (i.e. starters, controls), are assembled using a combination of welding, brazing, bolting, and testing to create the chiller.



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Installation

Handling recommendations for Magnitude chillers can be found in product and application literature and available from the internet: www.DaikinApplied.com.

Environmental Protection

During the entire production process, extra measures are taken to minimize the unintentional release of halogenated refrigerants. These measures are consistent with those identified in ANSI/ASHRAE Standard 147-2013, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*.

Packaging

The chiller is packaged in a single, large heat-shrink recyclable plastic bag to protect it from damage during shipment. Packaging is excluded from the scope of the LCA based on the mass cut-off rules.

Energy Consumption during Use Stage

In order to calculate average annual chiller electricity consumption, the PCR requires four performance scenarios to be considered. As defined by AHRI Standard 550/590 (I-P), those are 100% load at 85°F entering condenser water, 75% load at 75°F entering condenser water, 50% load at 65°F entering condenser water, and 25% load at 65°F entering condenser water. In addition to the load scenarios, the annual hours of operation are determined in the PCR.

This calculation methodology is applied to 55 cities in 30 countries: Atlanta, Bangkok, Beijing, Berlin, Boston, Buenos Aires, Cairo, Cancun, Cape Town, Caracas, Chicago, Dallas, Denver, Dubai, Hanoi, Ho Chi Minh, Hong Kong, Houston, Jerusalem, Kansas City, London, Los Angeles, Madrid, Manila, Melbourne, Mexico City, Miami, Minneapolis, Moscow, Mumbai, New Delhi, Ottawa, Paris, Perth, Phoenix, Raleigh, Riyadh, Rome, San Diego, San Francisco, San Juan, Sao Paulo, Seattle, Seoul, Shanghai, Singapore, Sydney, Taipei, Tokyo, Toronto, Vancouver, Venice, Vienna, Warsaw, and Washington, D.C.

Those 55 cities cover the 17 different ASHRAE climate zones. They are representative of every climate in the world and of large chiller markets around the world. This procedure was developed to determine the average energy usage impact, globally. The values resulting from the calculation are not intended to reflect actual energy consumption for specific applications. The intent is to provide a global and universal method of determining average energy usage of chillers by manufacturer. For specific energy usage and life cycle evaluation, a complete analysis must be completed for each application.

This methodology for calculating the annual energy use during the use stage is scaled by the 25 years of service life and load profiles as dictated by the PCR and summarized in Table 2. The full calculation methodology is documented in the accompanying background report.

| Model | kWh/yr | kWh / lifetime (25 years) | kWh/declared unit |
|------------------------|---------|---------------------------|-------------------|
| Daikin WMC250 ton unit | 323,711 | 8,092,770 | 32,371 |
| Daikin WME500 ton unit | 591,251 | 14,781,286 | 29,563 |
| Declared average | 457,481 | 11,437,027 | 30,499 |

Table 2: Annual electricity use, electricity use over the lifetime of the chiller, and use per declared unit for each model and the average chiller model



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Refrigerant Charge and Replenishment

Each chiller model has a specified refrigerant charge. However, there is an assumption that a maximum of 0.5% of the total amount of refrigerant leaks every year and requires replenishment to maintain the refrigerant at its original level. Daikin's WMC and WME chiller models use R-134a refrigerant. Refrigerant charge, leakage and replenishment are shown in Table 3.

| Model | Refrigerant | Refrigerant charge per declared unit | Annual leakage | Replenishment amount over lifetime |
|-------------------------|-------------|--------------------------------------|----------------|------------------------------------|
| Declared average | R-134a | 1.17 | 0.00585 | 0.140 |

Table 3: Refrigerant type, initial charge, annual leakage and total lifetime replenishment [kg], per declared unit

Environmental Protection

During the entire production process, extra measures are taken to minimize the unintentional release of halogenated refrigerants. These measures are consistent with those identified in ANSI/ASHRAE Standard 147-2013, *Reducing Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*.

Maintenance

Maintenance for this product is described in the WMC and WME Installation and Operation Manual, which can be provided upon request. The checklist covers aspects relating to the compressor motor, starter, condenser, control circuits and leak test chiller.

Reference Service Life

The reference service life (RSL) is 25 years in an outdoor application (ASHRAE 2011).

Singular Effects – Fire and Water

Product is not flammable. The chiller is designed with NEMA 1 construction for use in indoor applications. The product is also conformant to the International Code Council (ICC) and National Fire Protection Association (NFPA).

Hazardous Materials

The chiller does not contain substances considered to be hazardous by Resource Conservation and Recovery Act (RCRA), Subtitle 3.

Recycling and Disposal

Metal components of the chiller can be recycled into other systems. Steel, aluminum, cast iron and copper scrap generated during manufacturing and at end-of-life were considered valuable co-products and were addressed with system expansion. 100% of metal scrap at the end of life is assumed to be recycled. All refrigerant remaining in the chiller at the end of life is assumed to be recycled as well.



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Life Cycle Assessment Description

Declared unit

The declared unit refers to **one ton of cooling capacity** based on a 375-ton “average chiller.”

System boundaries

The system boundaries studied as part of this LCA include extraction of primary materials, raw materials manufacture, chiller manufacture, use phase electricity and refrigerant emissions, and end-of-life recycling as shown in Figure 3.

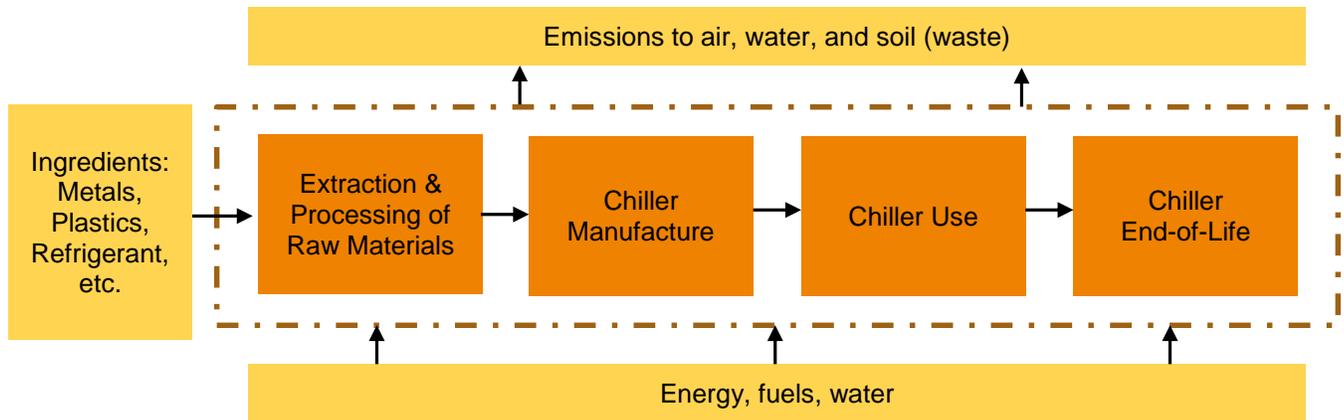


Figure 3: Chiller product system boundary flow diagram

As per the guiding PCR, the life cycle stages reported in this study align with the EN15804 life cycle modules, as shown in Figure 4.

| Product Stage | | | Construction Stage | | Use Stage | | | | | | | End-of-Life Stage | | | | Benefits and loads beyond boundary |
|----------------------|-----------|---------------|--------------------|--------------|-----------|-------------|--------|-------------|---------------|------------------------|-----------------------|-------------------|-----------|------------------|----------|------------------------------------|
| A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | C1 | C2 | C3 | C4 | D |
| Raw materials supply | Transport | Manufacturing | Transport | Installation | Use | Maintenance | Repair | Replacement | Refurbishment | Operational energy use | Operational water use | De-construction | Transport | Waste processing | Disposal | Recycling Credit |
| X | X | X | | | X | X | | | | X | | | | X | X | X |

Figure 4: EN15804 life cycle modules, X identifies modules considered in the study



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

According to the guiding IBU-UL PCR, life cycle stages A1-A3 are required to be reported, while all subsequent life cycle stages are considered optional. Table 4 summarizes the life cycle activities included and excluded in this study.

| Included | Excluded |
|---|---|
| ✓ Raw material extraction | ✗ Human labor |
| ✓ Energy inputs parts manufacture | ✗ Employee commute and executive travel |
| ✓ Inbound transportation to final assembly | ✗ Foam sheathing and packaging material |
| ✓ Electricity consumption during use | ✗ Transportation to installation site |
| ✓ Refrigerant charge and replenishing over 25 year lifetime | ✗ Installation of chiller |
| ✓ Refrigerant leakage | ✗ Repair, refurbishment and replacement over 25 year lifetime |
| ✓ Recycling or disposal of materials at end-of-life | ✗ Disassembly requirements and transport to disposal site |

Table 4: Supply chain activities and life cycle aspects included and excluded from the study's system boundary

Excluded activities were considered outside of the system boundary. ISO 14025 states that if life cycle stages have insufficient data and reasonable scenarios cannot be modeled, life cycle activities may be excluded (2006). Moreover, if the life cycle stages are expected to be environmentally insignificant, they may be excluded as well.

Temporal Coverage

Primary data collected from Daikin for their operational activities are representative for a 12-month average in the year 2014.

Geographical Coverage

The geographical coverage differs between life cycle stages for this study, as follows:

- Raw material procurement and manufacturing – United States
- Use phase – The PCR considers chillers to be used in 55 cities across 30 different countries (see Energy Consumption during Use Stage). Therefore, country-specific electricity grid mixes were modeled.

Technological Coverage

The technologies and technical coverage are specific to Daikin Magnitude® WMC 250 ton unit and WME 500 ton unit chillers, respectively.



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Assumptions and Estimations

The operation energy use was calculated using the methodology required by the PCR which was developed by another chiller manufacturer and may not be representative of typical load profiles. Daikin's participation in the development of the PCR would have resulted in different performance scenarios and/or different assumptions within the scenarios. In spite of the flawed load profiles in the PCR, Daikin has chosen to publish this EPD under the existing PCR as it is the singular PCR covering chillers at this time.

No allocations were performed at the manufacturing stage beyond those in the secondary data. Primary data were collected on the material input; however, manufacturing energy/material inputs are based on secondary data (GaBi datasets). This was deemed acceptable due to the dominance of the use phase impacts in relation to the overall impacts.

Inbound transport to manufacturing for all material and component inputs was estimated to be an average 500 miles.

In accordance with ISO 14025, life cycle stages thought to be environmentally insignificant and lacking in data to be reasonably modeled were excluded (see System Boundaries).

Annual refrigerant leakage is assumed to be at a rate of 0.5%, identical to those used in other EPDs published under the current PCR. The leaking refrigerant is assumed to be emitted directly to the atmosphere.

When converting the inputs and outputs of combustible material into energy inputs and outputs, the lower calorific value of fuels were reported. The calorific values were applied according to scientifically based and accepted values specific to the combustible material.

Cut-off Criteria

If a flow is less than 1% of the cumulative mass of all the inputs and outputs of the Life Cycle Inventory model, it may be excluded, provided its environmental relevance is not a concern. If a flow meets the above criteria for exclusion, yet may have a significant environmental impact, it is evaluated with proxies identified by chemical and material experts within thinkstep Inc. If the proxy for an excluded material has a significant contribution to the overall Life Cycle Impact Assessment (5% or more of any impact category), more information is collected and evaluated in the system.

External foam sheathing of some chiller components as well as primary packaging material, which is understood to be a plastic wrap, are excluded from the system due to its insignificance in mass relative to the product.

Description of Data and Period under Consideration

The average chiller production is modeled based on a 12-month average in the year 2014.

For life cycle modeling, the GaBi Professional software system for Life Cycle Engineering was used. All background data sets relevant to production and disposal were taken from the GaBi software. Primary material data for steel and aluminum were sourced from World Steel Association and Aluminum Association, respectively.

Data Quality

The data used to create the inventory model are as precise, complete, consistent and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Data are as current as possible. Datasets used for calculations are updated within the last 10 years for generic data and within the last 5 years for producer-specific data.
- Data sets are based on 1 year of averaged data; deviations are justified in the background report.



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Allocation

Steel, aluminum, cast iron and copper scrap generated during manufacturing and at end-of-life were considered valuable co-products, and were addressed with system expansion. To be consistent with the World Steel Association dataset for steel plates, the scrap steel was given a credit based on the 'Value of Scrap' model as described in a study of recycling methodologies. This model is also included in the upstream production of other steel parts, which includes scrap input, and is consistent throughout the study. Aluminum, cast iron, and copper scrap were also given credits based on the production of the primary metal, less any energy and materials required for re-melting or alloying of these secondary materials.



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Life Cycle Assessment Results

Parameters Describing Resource Input, Output Flows, and Waste Categories

Life cycle inventory indicators required by the PCR for the average chiller per the declared unit of one ton of cooling capacity is shown in Table 5.

| Inventory Indicator | Unit | Total | A1-A3 | B1 | B2 | B6 | C3 | C4 | D |
|--|----------------|----------------------|---------------|----|----------|----------|----------|----------|-----------|
| Use of Resources | | | | | | | | | |
| Total use of renewable primary energy resources | MJ | 4.25E+04 | 3.04E+01 | 0 | 1.92E+01 | 4.24E+04 | 0 | 4.45E-02 | 5.45E+00 |
| Use of renewable primary energy as energy source | MJ | 4.25E+04 | 3.04E+01 | 0 | 1.92E+01 | 4.24E+04 | 0 | 4.45E-02 | 5.46E+00 |
| Use of renewable primary energy materials | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total use of non-renewable primary energy resources | MJ | 2.52E+05 | 4.99E+02 | 0 | 2.03E+02 | 2.52E+05 | 0 | 3.93E-01 | -1.17E+02 |
| Use of non-renewable primary energy as energy source | MJ | 2.52E+05 | 4.99E+02 | 0 | 2.03E+02 | 2.52E+05 | 0 | 3.93E-01 | -1.17E+02 |
| Use of non-renewable primary energy materials | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Use of secondary materials | kg | 2.08E+00 | 2.08E+00 | 0 | 0 | 0 | 0 | 0 | 0 |
| Use of renewable secondary fuels | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Use of non-renewable secondary fuels | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net use of fresh water resources | m ³ | not reported* | not reported* | 0 | 3.40E-02 | 2.16E+02 | 0 | 8.01E-05 | 7.31E-03 |
| Waste Categories | | 0 | | | | 0 | | | |
| Hazardous waste disposed | kg | 2.77E-02 | 1.59E-07 | 0 | 2.76E-02 | 1.60E-04 | 0 | 8.97E-09 | 7.64E-10 |
| Non-hazardous waste disposed | kg | 7.67E+01 | -4.47E-03 | 0 | 1.24E-01 | 7.48E+01 | 0 | 1.82E+00 | 6.52E-04 |
| Radioactive waste disposed | kg | 6.99E+00 | 8.51E-03 | 0 | 1.07E-02 | 6.97E+00 | 0 | 5.47E-06 | 4.07E-03 |
| Output Material Flows | | 0 | | | | 0 | | | |
| Components for re-use | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Materials for recycling | kg | 1.33E+01 | 0 | 0 | 0 | 0 | 1.33E+01 | 0 | 0 |
| Materials for energy recovery | kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Exported energy | MJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 5: Inventory Indicators Reported per PCR, per Declared Unit

* Water use impacted by WorldSteel data which represents best-available steel LCI data for North America while offering only incomplete water inventories.

ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Parameters Describing Environmental Impacts

The environmental impact categories required by the PCR are reported per declared unit for the average chiller, as shown in Table 6. The environmental impacts are expressed using characterization factors based on the current versions of U.S. EPA's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI – <http://www.epa.gov/nrmrl/std/traci/traci.html>), and CML-IA (<http://cml.leiden.edu/software/data-cmlia.html>). Note that Life Cycle Impact Assessment (LCIA) results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

| | | Total | A1-A3 | B1 | B2 | B6 | C4 | D |
|---|--|-----------------|----------|----------|----------|----------|----------|-----------|
| TRACI 2.1 | | | | | | | | |
| Global Warming Potential (GWP) | kg CO ₂ equiv. | 2.09E+04 | 4.30E+01 | 2.09E+02 | 1.38E+01 | 2.07E+04 | 2.89E-02 | -1.24E+01 |
| Ozone Depletion Potential (ODP) | kg CFC 11 equiv. | 3.18E-04 | 5.35E-07 | 0 | 3.15E-04 | 1.72E-06 | 3.41E-13 | 4.14E-07 |
| Acidification Potential (AP) | kg SO ₂ equiv. | 1.34E+02 | 3.99E-01 | 0 | 4.78E-02 | 1.34E+02 | 1.90E-04 | -3.28E-02 |
| Eutrophication Potential (EP) | kg N equiv. | 4.43E+00 | 7.58E-03 | 0 | 2.39E-03 | 4.42E+00 | 1.60E-05 | -2.51E-04 |
| Smog Formation Potential (SFP) | kg O ₃ equiv. | 1.34E+03 | 2.18E+00 | 0 | 4.50E-01 | 1.34E+03 | 3.69E-03 | -3.01E-01 |
| CML 2001 – April 2015 | | | | | | | | |
| Global Warming Potential (GWP) | kg CO ₂ equiv. | 2.09E+04 | 4.30E+01 | 2.09E+02 | 1.38E+01 | 2.07E+04 | 2.89E-02 | -1.24E+01 |
| Ozone Depletion Potential (ODP) | kg CFC 11 equiv. | 2.99E-04 | 4.89E-07 | 0 | 2.97E-04 | 1.62E-06 | 3.21E-13 | 3.80E-07 |
| Acidification Potential (AP) | kg SO ₂ equiv. | 1.42E+02 | 4.46E-01 | 0 | 4.99E-02 | 1.41E+02 | 1.75E-04 | -3.29E-02 |
| Eutrophication Potential (EP) | kg (PO ₄) ³⁻ equiv. | 8.06E+00 | 1.27E-02 | 0 | 3.24E-03 | 8.05E+00 | 2.38E-05 | -8.92E-04 |
| Photochemical Ozone Creation Potential (POCP) | kg ethane equiv. | 8.10E+00 | 3.18E-02 | 0 | 3.21E-03 | 8.07E+00 | 1.68E-05 | -6.63E-03 |
| Abiotic depletion potential, elements (ADPe) | kg Sb equiv. | 3.30E-03 | 1.26E-03 | 0 | 2.91E-05 | 2.14E-03 | 1.01E-08 | -1.33E-04 |
| Abiotic depletion potential, fossil (ADPf) | MJ, calorific value | 2.34E+05 | 4.75E+02 | 0 | 1.76E+02 | 2.34E+05 | 3.79E-01 | -1.30E+02 |

Table 6: Impact Categories, per Declared Unit

Module A1-A3 – Raw materials supply, transport and manufacturing

Module B1 – Refrigerant emissions from leakage

Module B2 – Refrigerant supply for charge and replenishment*

Module B6 – Electricity consumption during chiller operation

Module C4 – Disposal

Module D – Net recycling credit

* ODP from R-134a arises from upstream losses in production of halogenated precursors, e.g., R-114, R-124 and TCE. Once R-134a is produced, its emission to air is not characterized as causing ozone depletion. The GaBi dataset upon which these results are based is representative of production and of high data quality.

The following section provides an interpretation of the results shown above.

ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

Interpretation

It is apparent from Table 6 that use-stage electricity (module B6) dominates most of the selected environmental impact categories. The exception is Ozone Depletion Potential (ODP), where upstream refrigerant production (module B2) drives results. Direct R-134a emissions from leakage (module B1) do not contribute to ODP.

Energy efficiency (in this case, oil-free operation with no performance degradation due to oil contamination) is the key driver for the environmental impact of a chiller. After the selection process, this means proper installation and maintenance to maintain the chiller *and* other system components at peak performance.

Proper maintenance will also address refrigerant containment, another key criteria to maintaining a minimal environmental impact.



ENVIRONMENTAL PRODUCT DECLARATION



Magnitude® magnetic bearing centrifugal chillers

According to ISO 14025

References

| | |
|------------------------------------|--|
| Bare 2012 | J. Bare, Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) - Software Name and Version Number: TRACI version 2.1 - User's Manual, U.S. EPA, 2012. |
| CML 2016 | Centrum voor Milieukunde, Universiteit Leiden (CML), Netherlands. CML-IA Characterisation Factors Database, 2016. Available at http://cml.leiden.edu/software/data-cmlia.html |
| Guinée 2001 | Guinée, J. B. (ed.): Handbook on life cycle assessment: Operational guide to the ISO-standards. Centrum voor Milieukunde, Universiteit Leiden (CML), 2001. |
| IBU and UL Environment 2014 | Institut Bauen und Umwelt (IBU) and UL Environment. Product Category Rules for Building-Related Products and Services. Part A: Calculation Rules for the Life Cycle Assessment and Requirements on the Project report, 2014. |
| IBU 2011 | Institut Bauen und Umwelt (IBU). Product Category Rules for Environmental Product Declarations: Water-Cooled Chillers, 2011. |
| ISO 14025 : 2006 | ISO 14025 Environmental labels and declarations – Type III environmental declarations – Principles and procedures, 2006. |
| ISO 14044 : 2006 | ISO 14044 Environmental management -- Life cycle assessment -- Requirements and guidelines, 2006. |
| IPCC 2007 | Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Available at www.ipcc.ch/report/ar4/wg1 |
| ASHRAE 2011 | ASHRAE. 2011. 2011 ASHRAE Handbook: HVAC Applications. |
| AHRI 2011 | Air-Conditioning, Heating, and Refrigeration Institute (AHRI). 2011 Standard for Performance Rating Of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle. AHRI Standard 550/590 (I-P) |
| ANSI/ASHRAE 2007 | ANSI/ASHRA. 2007. 140-2007 Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs. |
| EPA 2010 | U.S. Environmental Protection Agency: Municipal Solid Waste Generation, Recycling, and Disposal in the United States - Tables and Figures for 2010. Available at http://www.epa.gov/osw/nonhaz/municipal/pubs/msw_2010_data_tables.pdf |
| thinkstep | GaBi 6 dataset documentation for the software-system and databases, thinkstep AG, Leinfelden-Echterdingen, 2016. Available at http://www.gabi-software.com/support/gabi/gabi-6-lci-documentation/ |

