DOI: 10.61782/fa.2025.0460

FORUM ACUSTICUM EURONOISE 2025

IMPROVE HEAT PUMP PLACEMENT CONSIDERING FREQUENCY RESOLVED ACOUSTIC DIRECTIVITY DATA: CREATION OF AN OPEN DATABASE

Reichl Christoph[1*] **Bessac Francois**[2] **Klein Georg**[1]
Stöckl Luisa[1] **Czuka Martin**[1]
[1] Center for Energy, AIT Austrian Institute of Technology, Vienna, Austria
[2] CETIAT, Villeurbanne, France

ABSTRACT

Heat pumps are becoming increasingly popular due to their efficiency, carbon neutrality and use of renewable energy resources. Air-to-water heat pumps are often chosen because of their low cost and ease of installation. However, optimal placement to minimise acoustic emissions is mandatory for a barrier-free deployment. At present, the assessment of noise propagation for outdoor units suffers from a lack of information on the frequency content, and particularly the directivity of the sound source. During heat pump certification, standardised test procedures using the sound intensity measurement technique provide frequency-resolved partial sound power levels for the five different surfaces surrounding the heat pump. This gives the basic directivity information needed for optimised placement recommendations. In the framework of IEA HPT Annex 63, an anonymous database has been designed that combines dimensions, operating conditions and a generic description of each of the 5 sides (fan(s), heat exchanger, blind sides) with their corresponding frequency spectrums. Initially, about 30 heat pumps measured at CETIAT and AIT will be included in the database and a first exploitation will be presented. The database will be enriched by the authors during the year 2025 with the possibility of contributions from other interested laboratories during this period.

**Corresponding author*: *christoph.reichl@ait.ac.at.*

Keywords: air-to-water heat pumps, acoustics, directivity, database

1. INTRODUCTION

For many potential future users of heat pumps, noise remains one of the main reasons for their reluctance to switch to this method of energy production: noise to themselves, but more importantly, noise to their neighbours. The most reliable acoustic data available to end users is that obtained through certification. This is because the values displayed are verified by independent third party laboratories that follow a certification protocol based on international measurement standards. The certified value is the overall sound power level in $dB(A)$, which is already very valuable information. However, the laboratories all measure the sound power level spectrum in third octaves, which is not publicly available. This is a gap in the acoustic description of heat pumps, which may be missed by acousticians who want to implement noise attenuation measures, or optimise the placement of outdoor units. Another missing piece of data is the directivity of the units; this data can be very useful in a predictive calculation of the positioning of the outdoor unit in a dense urban environment. The noise requirements are such that the intelligent use of radiation directivity can become a parameter to be exploited. This data is not generally available, including from manufacturers, and is not directly part of the certification process. The EN 12102-1 standard authorises several acoustic measurement methods, the two most commonly used being the reverberation chamber and intensimetry. The latter, which measures the sound power level per surface, ultimately provides information on the directivity of the unit. Admittedly, it is a bit crude, but it is very interesting, because it gives the sound power level per surface for each 1/3 octave frequency. It is this level of directivity that is the constitutive idea of the database that we propose in the framework of IEA HPT Annex 51 [1] and IEA HPT Annex 63 [2] to build and make available to stakeholders in the field.

2. DATABASE CONSTRUCTION

The database is provided as an *Excel* sheet starting with anonymous results from two certification laboratories on outdoor heat pump units (sometimes reversible), see Fig. 1. It consists of a header part (lines 1-8 with the header in line 6, the items in line 7 and their corresponding units in line 8), and several blocks of data each consisting of 6 consecutive lines (e.g. lines 9-14 for entry 1, named *A06*, lines 15-20 for entry 2, named *B01* in the example given in Fig. 1).

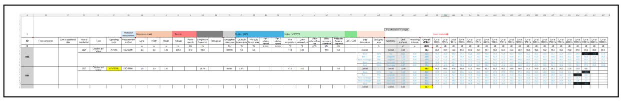

Figure 1. Overview of header line and two entries in the database

Most of the entries are free entries, only some of the fields contain formulas and are calculated automatically. Notes can (and should) be added to the fields to clarify specialities. Some items in line 6 contain notes detailing its usage. No field is mandatory but it is intended to include as much information as possible allowing for various ways of database exploitation, e.g. depending on the laboratory in charge of the measurements not all frequencies are reported, compressor frequencies have been recorded or fan speeds might be available. During discussions in the Task 2 meetings of IEA HPT Annex 63 several additional fields have been added (e.g. Coefficient of Performance, COP), which might be interesting for special analysis routes.

From left to right, content per block is organized in the following sections:

- leading part, *col. A-G*
- dimensioning, electrics & refrigerant, *col. H-N*
- boundary conditions & fan speeds, *col. O-Y*
- geometric description, *col. Z-AD*
- acoustic data description, *col. AE-AZ*

These blocks are described in detail in the following subsections.

2.1 Leading part - general information

The leading part (see Fig. 2 first assigns an unique identifier (*col. A*), which is constructed using a capital letter followed by two numbers. The letter is used to differentiate the contributing sources (e.g. laboratories) to the database. A field for free comments is presented in *col. B*, links to additional data should be given in *col. C*. All additional data should be made available as *zip*- or *7z*-archives with their names beginning with the identifier given in *col. A* followed by the dash symbol, e.g. *A06-waves.zip*. A detailed description should be placed in a *readme.txt*-file inside the corresponding archive. The leading part concludes with the year of production (*col. D*) and the type (*col. E*) of the unit as well as the point, which the unit was operating in (*col. F*). This operating point of the unit includes the temperature conditions on the ambient air, for example 7(6) °C , and on the water, for example 47-55 °C , summarized in the abbreviation *A7W55*.

	A	B	C	D	E	F	G
6	5						Method of measurement
7	ID	Free comments	Link to additional data	Year of production	Type	Operating point	Measurement method
8	#						
9				2021	Outdoor air / Water	A7W55	ISO 9614-1
10							
11	A06						
12							

Figure 2. Leading part of the database

Finally the leading part includes the measurement method in *col. G*. It is highly recommended to use data acquired utilizing either the ISO 9614-1:1993(en) Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points or the ISO 9614-2:1996(en) Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning.

2.2 Dimensioning, electrics and refrigerant

First, in *col. H-J* the unit dimensions (see Fig. 3 in m are provided (length, width, height). This is followed by the necessary voltage supply to operate the unit (*col. K*) in V

and the power supplied to the unit *col. L* in kW. The compressor frequency in Hz is provided in *col. M* and the refrigerant entered in *col. N* using the ASHRAE 23-2022 standard [3], e.g. R290 for propane.

H	I	J	K	L	M	N
Dimensions of **unit**			Electric			
Long	Width	Height	Voltage	Power supply	Compressor frequency	Refrigerant
m	m	m	V	kW	Hz	
1,1	0,5	1,01	230,0	2,42	78,0	

Figure 3. Dimensioning, electrics and refrigerant section of the database

2.3 Boundary conditions & fan speeds

The atmospheric pressure during the measurements is given in Pa in *col. O*, followed by the data characterising the outdoor unit. This includes the dry (*col. P*) and wet (*col. Q*) bulb temperatures in °C as well as the fan speeds in turns/minute (rpm) for up to two fans in (*col. R* and *col. S*), see Fig. 4. The boundary conditions for the indoor unit are the inlet (*col. T*) and outlet (*col. U*) temperature of the water given in °C , the water volume flow rate (*col. V*) given in m^3/h, the static pressure difference (*col. W*) in kPa and the measured heating capacity (*col. X*) in kW. Finally a field for the Coefficient of Performance (COP) is included in *col. Y*.

O	P	Q	R	S	T	U	V	W	X	Y
	Outdoor (AIR)				Indoor (WATER)					
Atmospheric pressure	Dry bulb temperature	Wet bulb temperature	Fan 1 rotation speed	Fan 2 rotation speed	Inlet temperature	Outlet temperature	Water volume flow rate	Static pressure difference	Measured heating capacity	COP / EER
Pa	°C	°C	tr/min	tr/min	°C	°C	m^3/h	kPa	kW	-
100008	7,6	6,3			47,0	54,9		72,0	6,6	

Figure 4. Boundary conditions & fan speed section of the database

2.4 Geometric description

From here on the single data line (see Fig. 5, line 9) expands to 6 lines (lines 9-14). The unit is expected to consist of five faces (top, two long sides and two short sides). Each of these five faces is then described with the following options in *col. Z* (see Fig. 5, lines 10-14. For a better post processing workflow (avoiding typing errors and ambiguities), these options are made available via a drop-down menu.

- presence of fan (1 or 2), e.g. Fan x1, Fan x2;
- presence of a heat exchanger;
- ... or none of these elements, then the surface is described as ”blind”.

For the *fan* and *heat exchanger* elements, the proportion of surface area occupied by these elements is briefly described in *col. AA*, with four possible surface proportions: 25, 50, 75, or 100 %.

	A	Z	AA	AB	AC	AD
6	5					
7	ID	Side description	Occupied area	Geometry	Unit surfaces	Measuring distance
8	#	-	%		m^2	m
9		Overall	-	Overall	3,69	
10		Blind	100%	Top	0,51	0,50
11	A06	Fan x1	75%	Long side	1,12	0,50
12		Heat exchanger	75%	Long side	1,12	0,50
13		Blind	100%	Short side	0,47	0,50
14		Blind	100%	Short side	0,47	0,50
15		Overall	-	Overall	11,59	
16		Blind	100%	Top	1,98	0,50
17	B01	Fan x1	75%	Long side	3,13	0,50
18		Heat exchanger	75%	Long side	3,13	0,50
19		Heat exchanger	50%	Short side	1,68	0,50
20		Blind	100%	Short side	1,68	0,50

Figure 5. Geometric description including the unit and the distance of measurements

The grey cells in *col. AB* and *col. AC* should not be altered. The unit surfaces in *col. AC* in m^2 are extracted using the data in *col. H*-*col. J*, the overall unit surface is calculated and presented in the above the 5 unit surfaces in m^2. Finally, *col. AD* shows the distance between the surfaces and the measurement probe in m.

2.5 Acoustic data description

Six spectrums are required, one for the sound power level of the unit, as it is given as official result. The five other are partial sound power levels for each side (long side, short side, top side). Data are given in 1/3 octave bands, at least between 100 Hz and 5000 Hz, but the bands 50-63-80 Hz and 6300-8000-10000 Hz bands can be provided.

The acoustic data (see Fig. 6) consists of the (calculated) sound power level spectra of each face (*col. AE*), as well as the spectrum of the entire unit (*col. AF*-*col. AZ*). The sound power level corresponds to the fictitious surface located a few dozen centimetres from the actual surface of the machine which is given by the measurement distance for each face (*col. AD*).

The third octave band spectra data (blue values, *col. AF*-*col. AZ*) are entered in dB into the database for each of the five faces (e.g. into lines 10-14) allowing for a full set of 21 times 5 equals 105 entries. Black fields mark negative sound levels from intensity measurements (sound oriented from outside to the unit rather from being radiated from the unit to the outside and thus coming in to the mesh).

For each frequency band (100 Hz up to 10000 Hz), an overall sound level in dB is calculated automatically and presented in the first line (e.g. line 9) of the entry (above the data of the five sides). Out of these frequency resolved data, an overall *A-weighted* sound power level in $dB(A)$ is calculated and given in *col. AE*. Note, that the entry in the first line in *col. AE* (e.g. field *AE9*) will typically be the one reported on a certification label.

	A	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ
6	5		Sound levels in **dB**																				
7	ID	Overall dB(A)	Lw at 100 Hz	Lw at 125 Hz	Lw at 160 Hz	Lw at 200 Hz	Lw at 250 Hz	Lw at 315 Hz	Lw at 400 Hz	Lw at 500 Hz	Lw at 630 Hz	Lw at 800 Hz	Lw at 1000 Hz	Lw at 1250 Hz	Lw at 1600 Hz	Lw at 2000 Hz	Lw at 2500 Hz	Lw at 3150 Hz	Lw at 4000 Hz	Lw at 5000 Hz	Lw at 6300 Hz	Lw at 8000 Hz	Lw at 10000 Hz
8	#	dB(A)	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB
9		64,4	50,3	49,7	55,3	45,1	67,5	46,4	49,4	46,9	53,0	51,5	52,7	48,9	48,1	45,2	44,1	43,5	40,2	37,8	34,6	30,3	30,1
10	A06	54,3	40,2	36,9	48,0	37,1	61,1	39,4	41,9	39,8	43,4	42,4	39,9	35,3	36,4	33,6	33,1	32,5	28,4	24,5	-24,7	-9,4	17,0
11		58,9	42,7	41,6	47,7	38,4	62,0	38,3	44,0	40,0	47,2	45,9	47,7	42,0	42,9	41,3	39,6	38,3	35,1	33,8	30,3	27,5	26,4
12		59,9	47,8	47,3	50,0	40,7	62,6	42,4	43,7	40,5	47,7	45,2	46,9	44,5	43,3	39,9	39,3	38,3	36,0	32,8	29,5	24,8	25,1
13		55,5	36,4	39,3	42,9	35,3	57,3	37,8	40,8	40,0	45,2	42,8	43,4	42,1	39,3	35,8	34,9	33,5	31,1	28,0	26,1	19,6	21,2
14		56,5	41,1	40,9	49,7	36,8	55,9	36,7	39,8	38,8	45,4	45,1	46,8	41,5	40,3	35,6	35,1	36,8	31,1	28,9	27,3	20,6	19,0

Figure 6. Acoustic data description using frequency resolved spectra

3. CONTRIBUTING TO THE DATABASE

Other parties than CETIAT and AIT, both inside and outside of the IEA HPT Annex 63 consortium are invited to contribute to the database. The template can be downloaded from the IEA HPT Annex 63 website following `https://heatpumpingtechnologies.org/annex63/database`. [4]. For further questions related to the format and usage of the database template, please contact `christoph.reichl@ait.at` (AIT) or `francois.bessac@cetiat.fr` (CETIAT). It is intended to initially expand the database till end of the first quarter of 2026.

4. EXAMPLE EXPLOITATION

A first exploitative analysis is done on the 27 available data sets (see Fig. 7). It focuses on the overall directivity based on the *max-min* of data from each side. The *max-min 5 sides* average corresponds to average of the *max-min* for the 5 sides (4 lateral + top), whereas the *max-min horizontal* average only includes the data for the 4 lateral sides, excluding the top. Then, *max-min vertical long side* and *max-min vertical short side* considers lateral sides and top side, either on the long side, or on the short side, respectively.

For the sake of readability, calculation & results are given based on the data transformed in octave bands, from 125 to 4000 Hz band. The overall directivity given by *max-min* (dark blue bars) shows, that it falls between 5 to almost 10 dB, the highest values being at higher frequencies. This means, that compared to the overall spectrum, a difference from ± 2.5 to almost $\pm 5\,dB$ can be extracted, depending on the location of the hearing point and on the frequency. The consideration of *max-min vertical* directivity is smaller, especially for the short side (light blue bar).

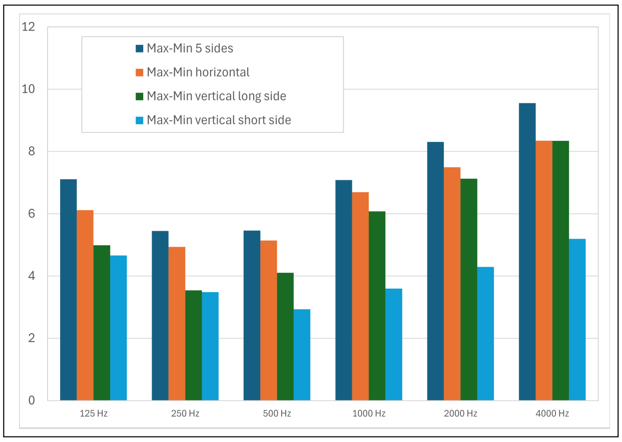

Figure 7. Max-Min directivity, averaged on the 27 data sets.

There are 16 results for lateral fan(s) units and 11 with top fan(s) units in the data set (see Fig. 8). When analysing the results considering the location of fan(s), the *max-min horizontal* average on all sides shows a bigger influence of the fan(s) located on the lateral side (orange bars). The overall directivity is then higher, especially at low and high frequencies, with a general envelope between 5.5 and almost 9 dB.

This is also the case when considering the vertical directivity (see Fig. 9), the top fan(s) configuration (dark green bars) being then smaller than the lateral fan(s) (orange bars) configuration.

5. CONCLUSION AND OUTLOOK

In the framework of IEA HPT Annex 63, a database consisting of frequency resolved acoustic directivity data to

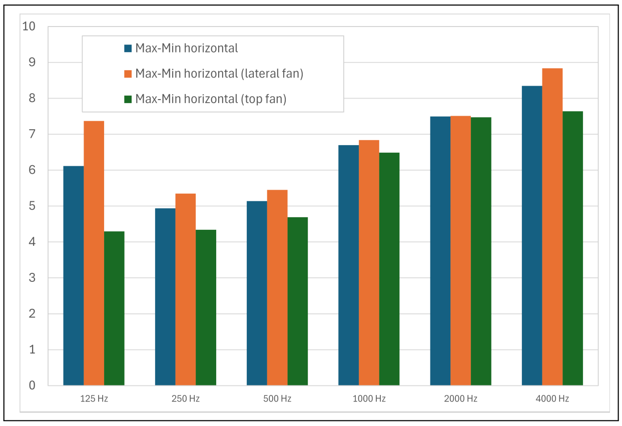

Figure 8. Max-Min directivity, on 5 sides, all data, and considering the location of fan(s).

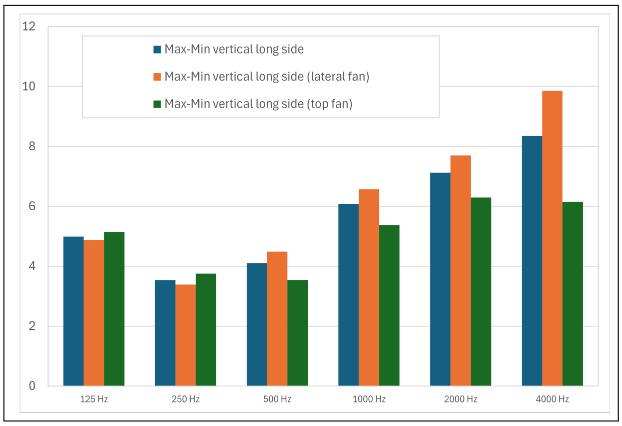

Figure 9. Max-Min horizontal directivity, all data, and considering the location of fan(s).

improve heat pump placement has been constructed. An initial set of 27 datasets from the laboratories of CETIAT, France and AIT, Austria consisting of a leading part, comments, dimensions, boundary conditions, geometric descriptions and acoustic data have been implemented. Both, the initial database and the template for contributing to the database are available for download on the IEA HPT Annex 63 website [4].

Although priority is currently being given to the collection of data measured according to the ISO 9614 protocol, additional content for measurements (e.g. more detailed data on dome measurements, wave files with raw acoustics, images) could be implemented, as well as (depending on request), inclusion of sound pressure level measurements is intended. These updated, will also be accessible through the database website.

An initial exploitation of the data base is presented based on *max-min* averages. The overall directivity falls between 5 to almost 10 dB with higher values extracted at elevated frequencies. These results, compared to the overall spectrum, to a difference from ± 2.5 to almost $\pm 5\,dB$.

It is intended to expand the database till the first quarter of 2026 with both entries from CETIAT and AIT and other parties. Further work with the data base will include expanded analysis on the directivity as well as utilization of the frequency content of the presented measurements.

6. ACKNOWLEDGMENTS

We want to express our gratitude to the consortium of IEA HPT Annex 63, especially to the contributors to Task 2 *Urban Acoustics Impact of Heat Pumps*. This work was funded in the framework of the Austrian FFG IEA cooperation project IEA HPT Annex 63, *Placement Impact on Heat Pump Acoustics* [2].

CETIAT thanks its industrial members for supporting its participation and work in the IEA HPT Annex 63.

7. REFERENCES

[1] IEA HPT Annex 51, "Acoustic Signatures of Heat Pumps." `https://heatpumpingtechnologies.org/annex51/`, 2024. Accessed: 2025-04-10.

[2] IEA HPT Annex 63, "Placement Impact on Heat Pump Acoustics." `https://heatpumpingtechnologies.org/annex63/`, 2024. Accessed: 2025-04-10.

[3] ASHRAE, "ANSI/ASHRAE 34-2022, Designation and Safety Classification of Refrigerants." `https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations`, 2022. Accessed: 2025-04-10.

[4] IEA HPT Annex 63, "IEA HPT Annex 63 database." `https://heatpumpingtechnologies.org/annex63/database`, 2024. Accessed: 2025-04-10.