

iea



Annex 51



Noise and seasonal variations, based on interlaboratory results

François BESSAC

With the support of
Thomas GINDRE



Task 2: Round Robin Test

- Interlaboratory heat pump measurements, in order to:
 - **Compare the robustness of noise standards and their laboratory implementation**
 - **Gain knowledge on heat pump operation and the corresponding noise characterization, to be used as input for other Annex 51 tasks**
- Selection of test heat pumps → based on european market shares

Market share	EU	AT	DE	DK	FR	IT	SE	Total	Annex 51 /EU share
Air-to-water (outdoor)	28.1%	54%	60%	14%	34%	15%	23%	30%	67%
Water(brine)-to-water	8.7%	20%	24%	8%	1%	0%	23%	8%	59%
Air-to-air (outdoor)	50.6%	0%	0%	78%	28%	83%	54%	46%	57%
Heat pump water heaters (outdoor + exhaust)	12.6%	25%	16%	0%	37%	2%	0%	16%	81%
Sub-total	100.0%	100%	100%	100%	100%	100%	100%	100%	63%
% of population		4%	35%	2%	29%	26%	4%	100%	46%

Standards relative to heat pumps

- Capacity characterization

- **EN 14511-2** (2018): Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors
 - **Part 2: Test conditions**
- **EN 14825** (2018): Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - **Testing and rating at part load conditions and calculation of seasonal performance**

- Noise characterization

- **EN 12102-1** (2017): Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - **Determination of the sound power level** - Part 1: Air conditioners, liquid chilling packages, **heat pumps for space heating and cooling**, dehumidifiers and process chillers
 - Annex A.4 gives the requirements applying to Ecodesign and Energy labelling regulations



Test program

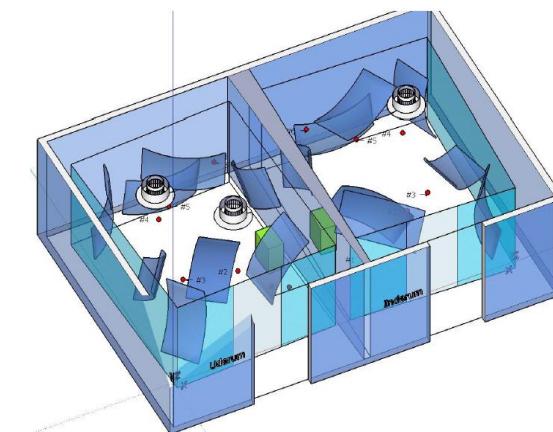
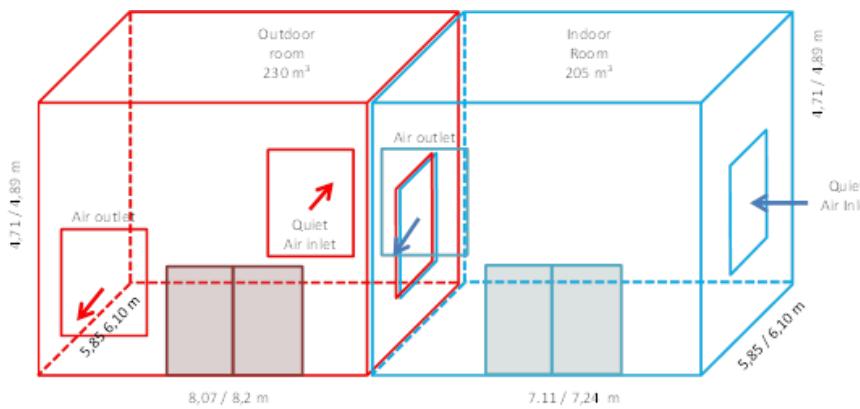
- Usual operating conditions
 - EN 14511: A7(6) W30/35
 - Variations (e.g. max freq)
- Acoustics
 - EN 12102-1 A.4 at the capacity of EN 14825 point C and in the same conditions as EN 14511
- Part load conditions
 - EN 14825
 - Ambient Air Temperature 12° / 7° / 2° / -7° / -10°

RRT1 Programme : Measurement Points						
Nr.	Standard	Condition	Air dry bulb (wet bulb) T° (°C)	Water inlet/outlet T° (°C)	Set temperature	Fan
1	EN 14511	standard rating	7(6)	30/35	30	Auto
2	EN 14511	standard rating Liquid circ. ▶ 2	7(6)	30/35	1	30
3	EN 14511	standard rating at max frequency	7(6)	30/35	21	Auto
4	EN 14825	C	7(6)	*/27	29	Medium III
5	EN 12102-1 A.4	reaching the same capacity as test C	7(6)	30/35		
6	EN 14825	D	12(11)	*/24	30	Medium III
7	EN 14825	B	2(1)	*/30	28	Medium III
8	EN 14825	A/F (Tbiv)	-7(-8)	*/34	27	Medium III
9	EN 14825	A/F (Tbiv) and maximum frequency	-7(-8)	*/34		
10	EN 14825	E (TOL)	-10(-11)	*/35	25	Medium III

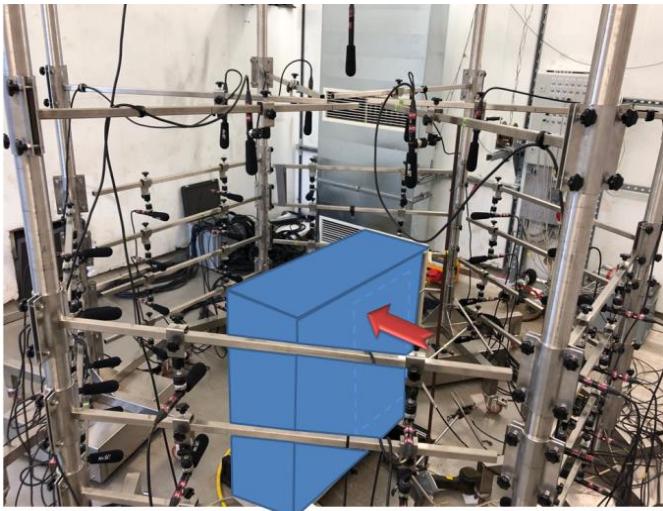
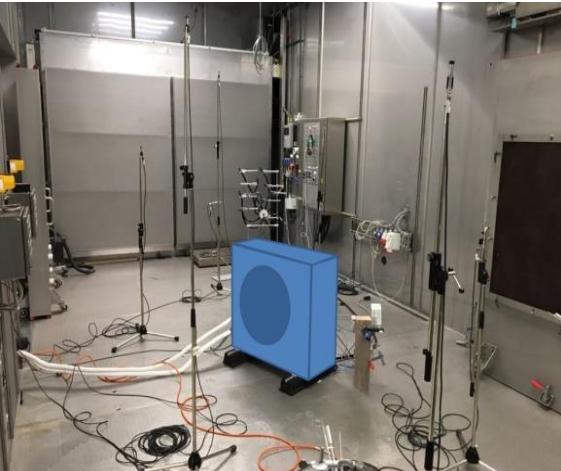
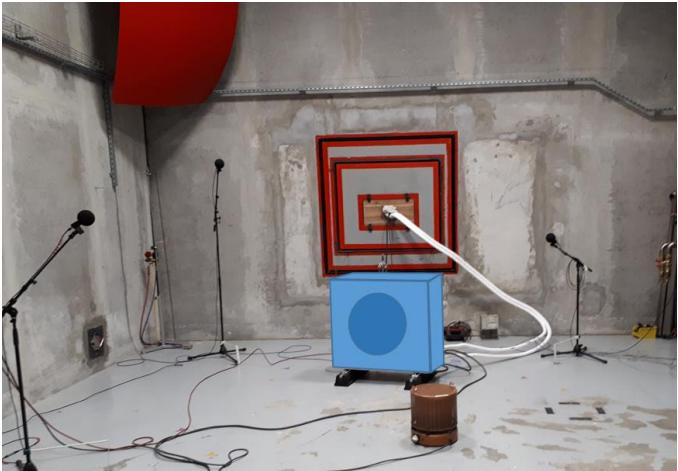
(*) The water flow rate determined from test # 1 shall be used with the indicated outlet water temperature

The laboratories

- Various acoustic environments:
 - **Pure climatic chambers (single or double)**
 - Used as hard wall rooms (diffuse field): ISO 3743-1
 - Used as free field (acoustic material on the walls): ISO 3744 or EN 3746
 - **Pure acoustic rooms**
 - Double reverberant rooms: ISO 3741
 - **In between**
 - Double climatic rooms adapted for acoustics: ISO 3743-1

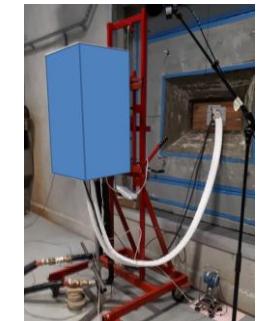


Experimental setups and tested unit



Heat pump under test:

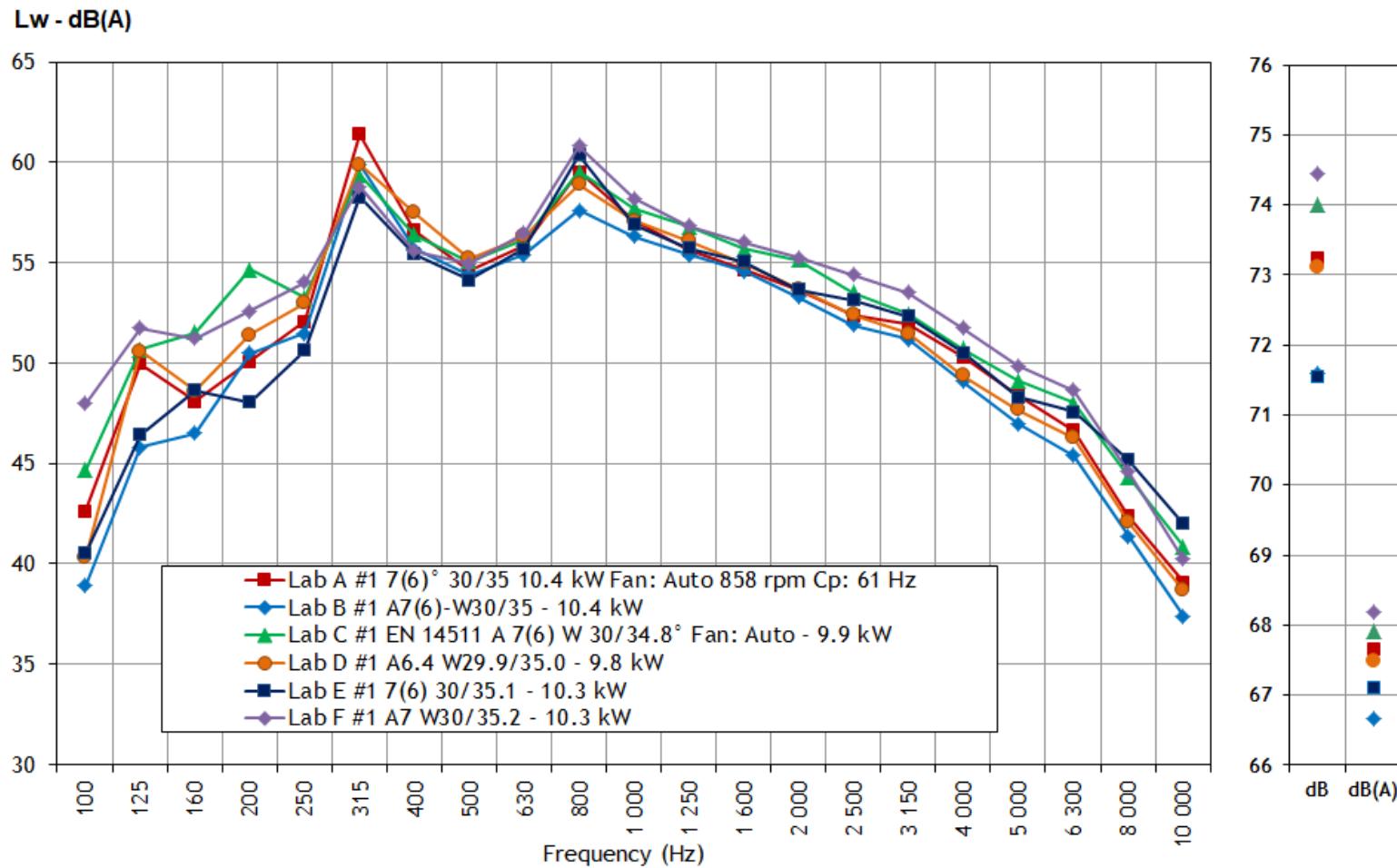
- **Air-to-water single split**
- **10 kW / 1.8 kg of R410A**
- **7.5 m refrigerant lines**
- **Focus on the outdoor unit**
featuring a single fan and a variable speed compressor
- **No test of the indoor unit**
(hydraulic kit)



→ Circulation of the heat pump amongst european laboratories

Intercomparison

- EN 14511-2: A7(6) W30/35

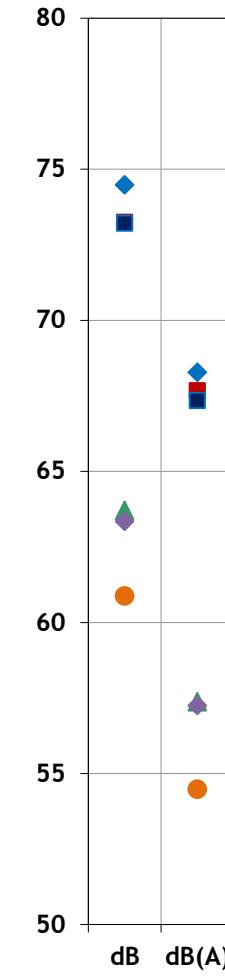
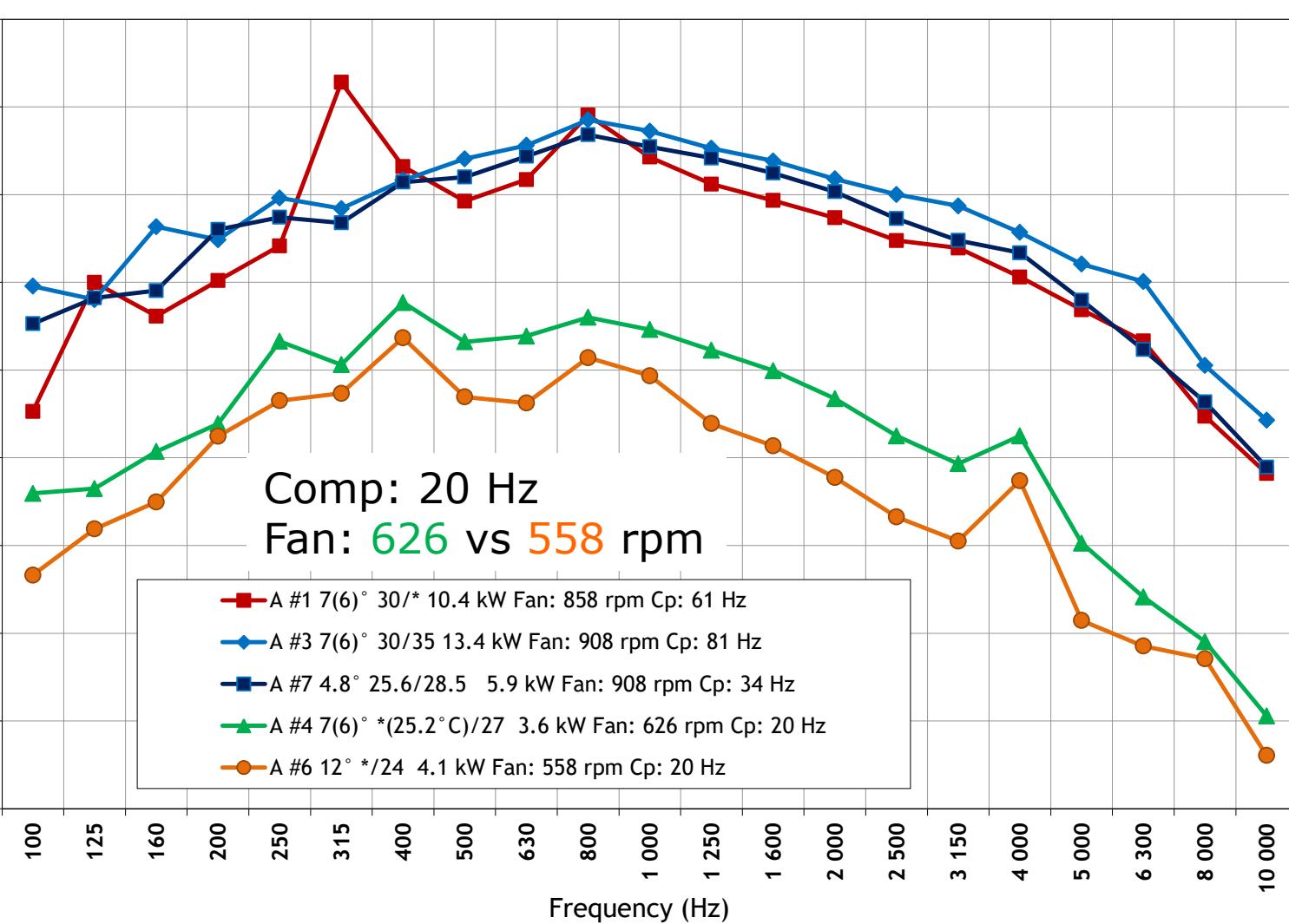


→ Good agreement despite the variety of acoustic environments and measurement techniques

Max 1.5 dB(A) overall

Influence of component speed on noise levels

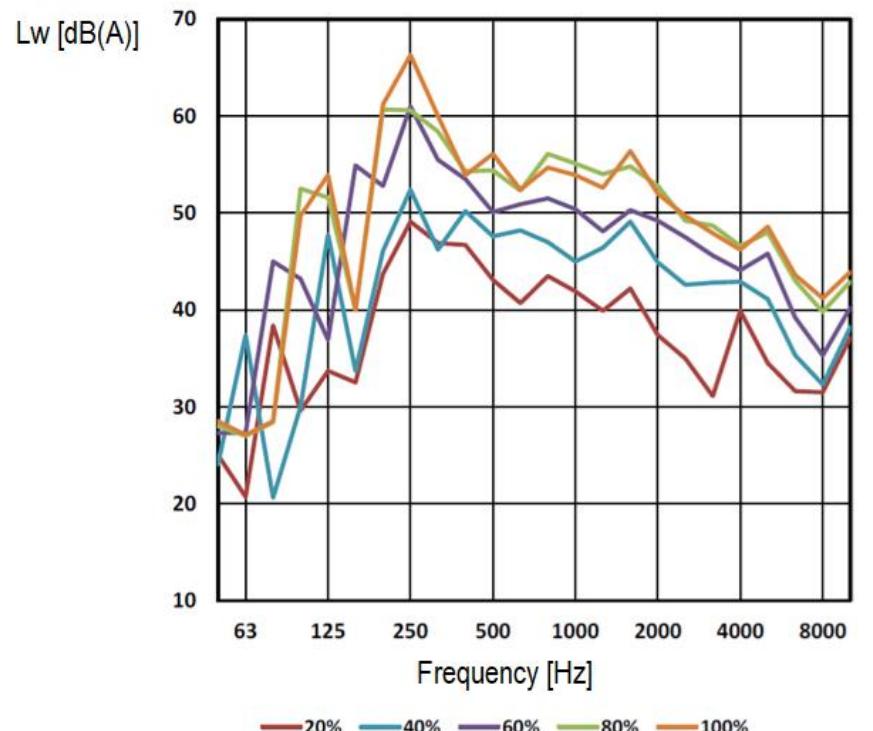
L_w - dB(A)



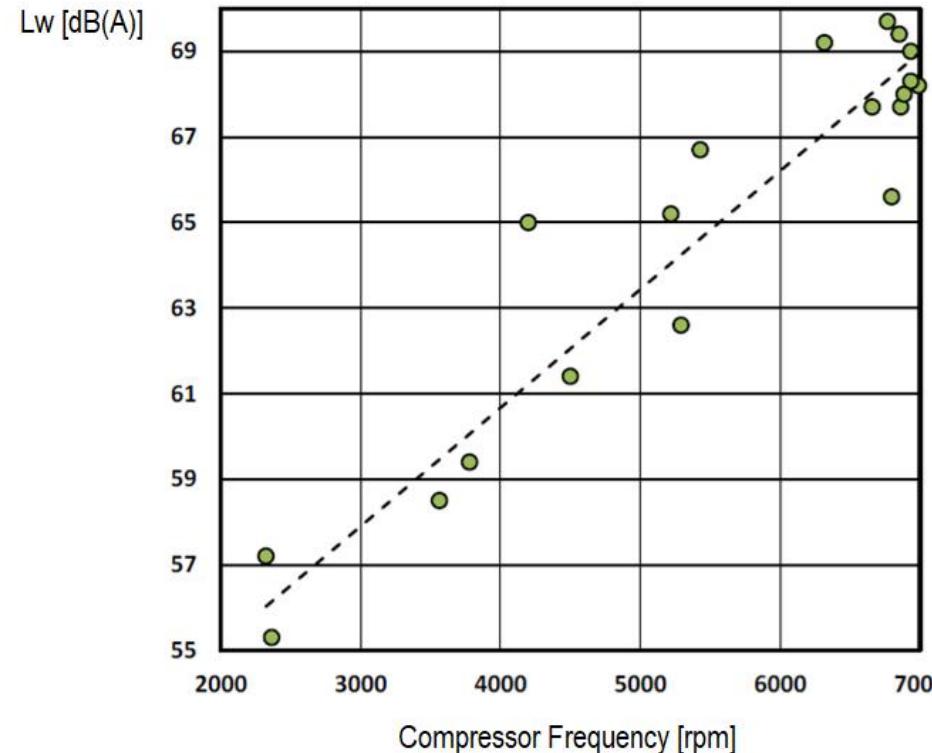
For this unit, the noise level predominantly depends on the fan speed, then on the compressor noise.

Influence of component speed on noise levels

- At the example of a previous study, heat pump noise can be driven by the compressor:



Lw [dB(A)]	55.3	59.4	65.2	69.7
Comp. rpm	2364	3780	5220	6768
Fan rpm	302	302	550	546

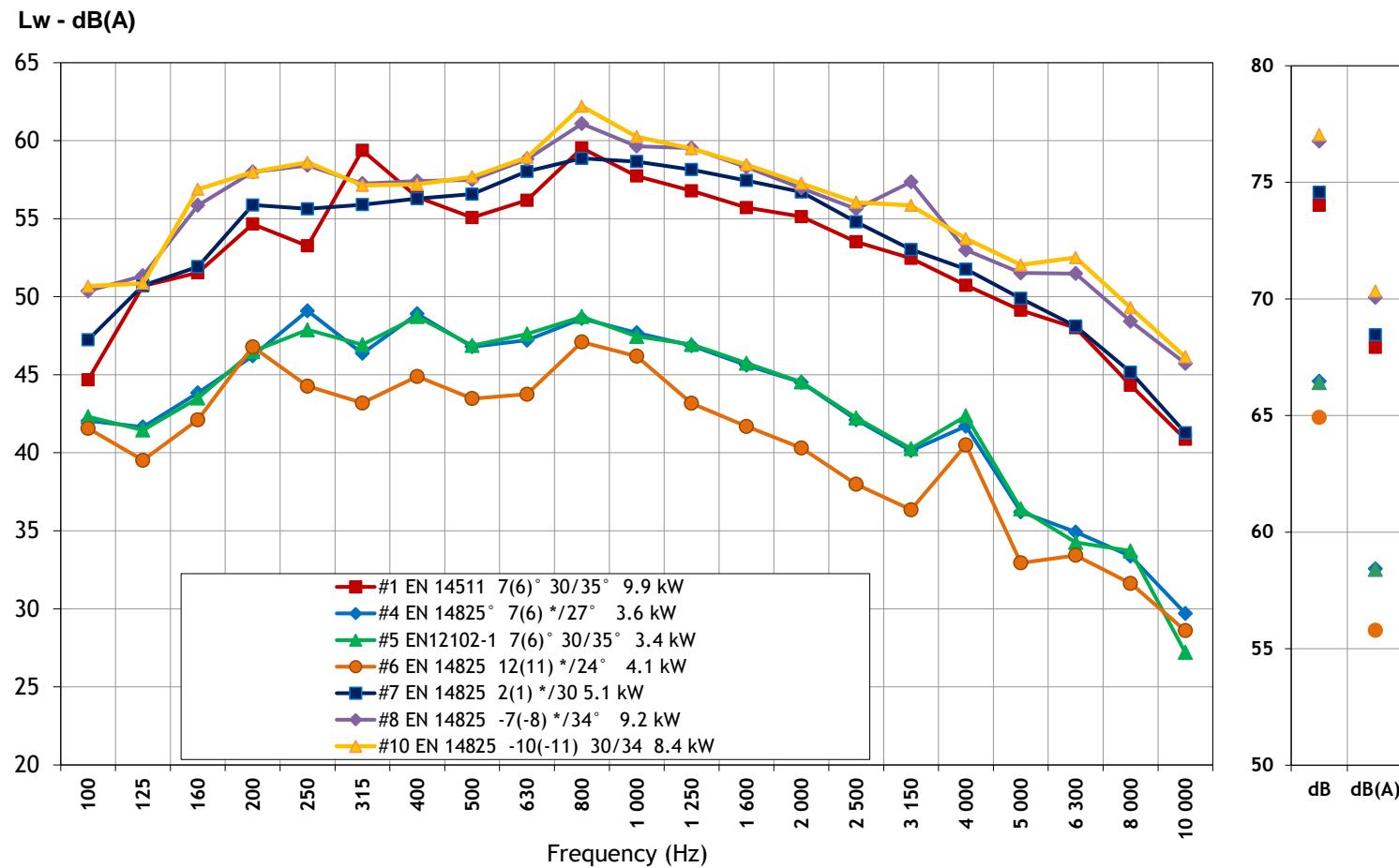


(Fraunhofer IBP/ISE)

Tests under all standard conditions

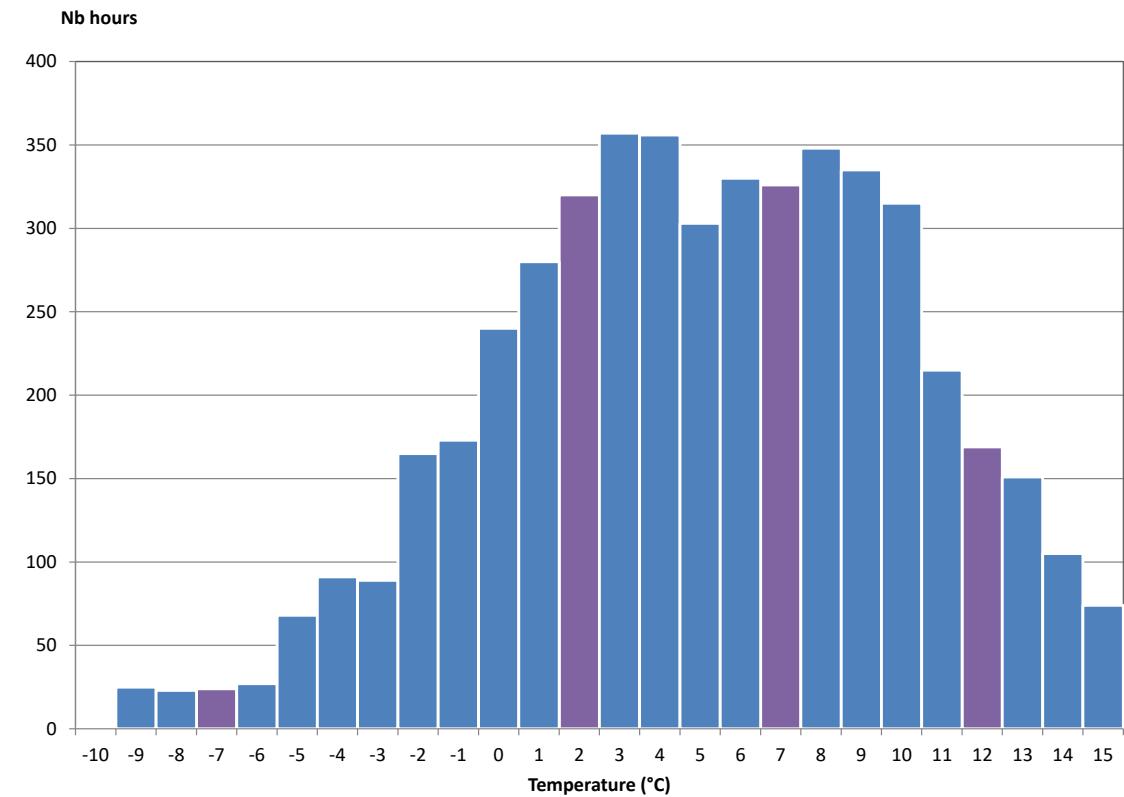
Tests got carried out at all operating conditions, including partial load EN 14825

RRT1 Programme : Measurement Points				
Nr.	Standard	Condition	Air dry bulb (wet bulb) T° (°C)	Water inlet/outlet T° (°C)
1	EN 14511	standard rating	7(6)	30/35
2	EN 14511	standard rating Liquid circ. ▶ 2	7(6)	30/35
3	EN 14511	standard rating at max frequency	7(6)	30/35
4	EN 14825	C	7(6)	*/27
5	EN12102-1 A.4	reaching the same capacity as test C	7(6)	30/35
6	EN 14825	D	12(11)	*/24
7	EN 14825	B	2(1)	*/30
8	EN 14825	A/F (Tbiv)	-7(-8)	*/34
9	EN 14825	A/F (Tbiv) and maximum frequency	-7(-8)	*/34
10	EN 14825	E (TOL)	-10(-11)	*/35



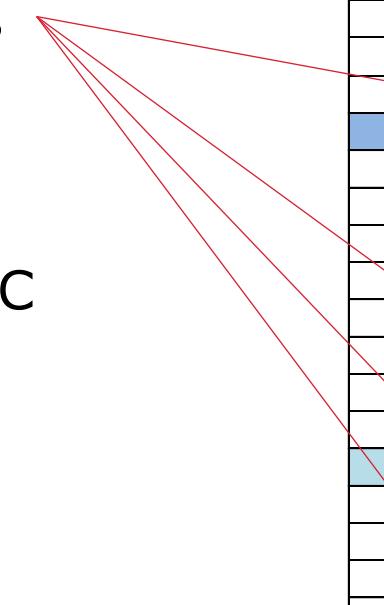
Towards a Seasonal Sound Power Level?

- Attempt inspired by EN 14825 SCOP
→ « **Seasonal Coefficient Of Performance** »
- Average climate:
 - **Between -10 °C and 15 °C**
 - **4910 hours of operation distributed amongst various air temperatures**
→ In total 56% of the 8760 hours in a year
- 4 target temperatures:
 - -7° point A
 - 2° point B
 - 7° point C
 - 12° point D
 - Only 1 hour at -10 °C point E
- Calculation:
 - **Log average of the different sound levels, weighted by their duration of operation occurrence**



Calculation

- Use of test results at target temperatures
- Interpolation of acoustic values between these temperatures
 - Remains constant below -7 °C and above 12 °C
- The relative contribution represents the combined influence of the **Lw** and their **amount of operation hours**
- Seasonal sound power level is the resulting weighted (log) average:
 → **66.2 dB(A)** for this unit, with the biggest contribution from air temperatures around 2°



Outdoor air temp. °C	Hours	Lw(A)	Relative contribution
Tj	h/j	dB(A)	
-10	1	71.5	34.6
-9	25	71.5	48.6
-8	23	71.5	48.2
-7	24	71.5	48.4
-6	27	71.2	48.6
-5	68	70.9	52.3
-4	91	70.6	53.3
-3	89	70.3	52.9
-2	165	70.1	55.3
-1	173	69.8	55.2
0	240	69.5	56.4
1	280	69.2	56.7
2	320	68.9	57.0
3	357	67.1	55.8
4	356	65.4	54.0
5	303	63.6	51.5
6	330	61.9	50.2
7	326	60.1	48.4
8	348	59.7	48.2
9	335	59.3	47.7
10	315	58.9	47.0
11	215	58.5	44.9
12	169	58.1	42.7
13	151	58.1	41.9
14	105	58.1	39.5
15	74	58.1	36.8
Total hours	4910	66.2	66.2

Intermittent work: frosting

- Defrosting:

During the defrosting process, the sound level strongly fluctuates

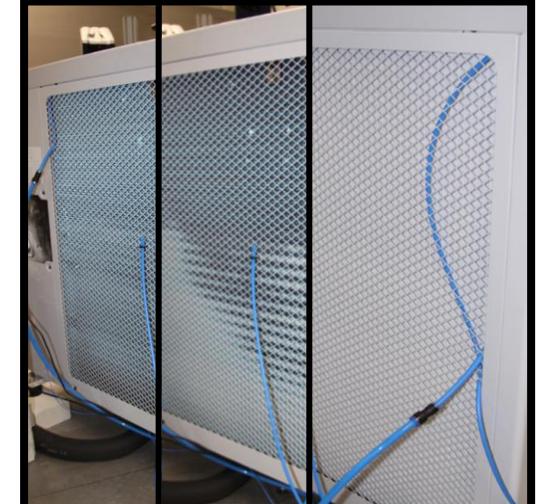
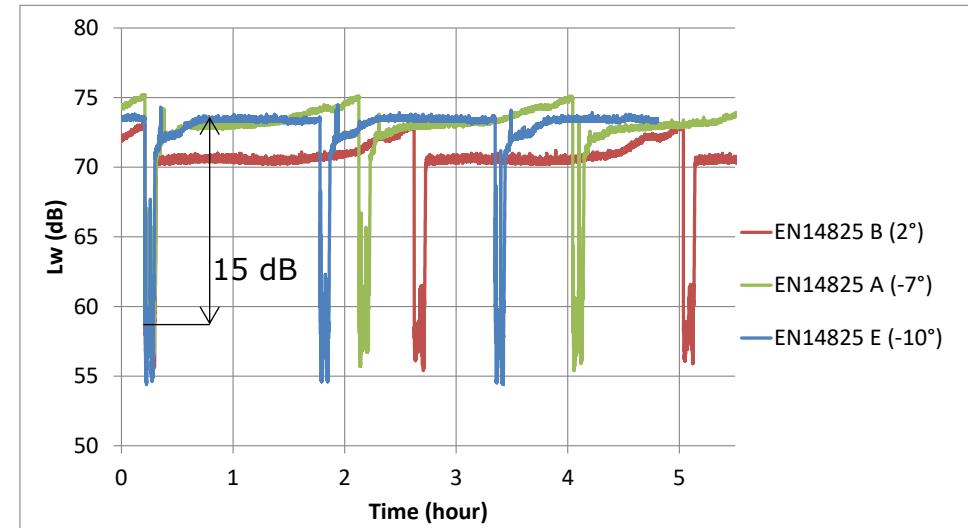
→ On average, it accounts 15 dB(A) less than the noise without frosting

- Duration:

- 5 to 6 minutes defrosting every 80 to 130 min
- Duration changes according to ambient temperature

- Assumption:

Temperature °C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3
Time % of defrosting	4%	4%	4%	4%	5%	5%	5%	5%	6%	6%	6%	7%	7%	8%



Intermittent work: cycling

- **Cycling:**

- At ambient air temperatures above 12 °C, the requested thermal load becomes lower
 - the heat pump works intermittently



- Assumption:

Temperature °C	12	13	14	15
Time % stopped	15%	22%	25%	50%

Improved calculation

- with:
 - **Lw when defrosting: ~ 55 dB(A)**
 - **Lw when stopped: 0 dB(A)**
- The resulting Seasonal Lw, taking into account the intermittent work, decreases by only 0.2 dB(A):
 - **The relative contribution of intermittent work is low**
 - **Accuracy of the assumptions on defrost and cycling durations is not critical**
- The strongest contribution to the weighted average remains around 2 °C ambient air temperature

Outdoor air temp. °C	Hours	Lw(A)	Normal operation	Special operation	Stop/defrost ratio time
Tj	h/j	dB(A)	Relative contribution		Defrost
-10	1	71.5	34.4	4.3	4%
-9	25	71.5	48.4	18.3	4%
-8	23	71.5	48.0	17.9	4%
-7	24	71.5	48.2	18.1	4%
-6	27	71.2	48.4	19.6	5%
-5	68	70.9	52.1	23.6	5%
-4	91	70.6	53.1	24.9	5%
-3	89	70.3	52.7	24.8	5%
-2	165	70.1	55.0	28.2	6%
-1	173	69.8	55.0	28.4	6%
0	240	69.5	56.1	29.9	6%
1	280	69.2	56.4	31.2	7%
2	320	68.9	56.7	31.8	7%
3	357	67.1	55.4	32.8	8%
4	356	65.4	54.0	Lw defrost	
5	303	63.6	51.5	55.2	
6	330	61.9	50.2	Lw Stopped	
7	326	60.1	48.4	0	
8	348	59.7	48.2	Time stopped	
9	335	59.3	47.7	15%	
10	315	58.9	47.0	22%	
11	215	58.5	44.9	35%	
12	169	58.1	42.7	-22.9	50%
13	151	58.1	41.9	-21.7	
14	105	58.1	39.5	-21.3	
15	74	58.1	36.8	-21.2	
Total hours	4910	66.0	66.0	39.1	
		dB(A)			

Which metric to describe HP sound levels?

- ▶ EN 14825 results from 4 laboratories
- ▶ calculation of Seasonal Sound Power Level
- ▶ EN 12102-1 acoustics
- ▶ standard condition EN 14511 A7(6)-W30/35

	Lab 1	Lab 2	Lab 3	Lab 4	Average
	Lw dB(A)				
EN 14825 point A (-7 °C)	71.5	68.2	68.0	70.2	69.5
EN 14825 point B (2 °C)	68.9	67.2	68.1	68.6	68.2
EN 14825 point C (7 °C)	60.1	57.0	57.5	58.7	58.3
EN 14825 point D (12 °C)	58.1	54.4	55.1	56.3	56.0
Seasonal Lw dB(A)	66.0	63.7	64.3	65.3	64.8
EN 12102-1 "acoustics"	60.3	57.2	57.6	58.7	58.4
<i>Difference</i>	-5.7	-6.4	-6.7	-6.6	-6.4
EN 14511 A7(6) W30/35	68.2	67.1	67.5	68.0	67.7
<i>Difference</i>	2.2	3.4	3.2	2.7	2.9
Difference	-0.6	-0.1	-0.6	-0.6	-0.5

- Noise measured from EN 12102-1 A.4 condition is far from the seasonal sound level (-6.4 dB)
 - Too low load of the unit: not really representative
 - Tricky to set

- Test at EN 14511 is seducing as it is
 - Close to Seasonal Lw (+2.9 dB)
 - Very close to EN 14825 pt B (-0.5 dB)
→ biggest contribution to the seasonal Lw
 - Very easy to implement
 - ... *but not declared in EU regulation*

→ Conclusions to be confirmed by tests on other units

Thank you for your attention

More at
<https://heatpumpingtechnologies.org/annex51>

