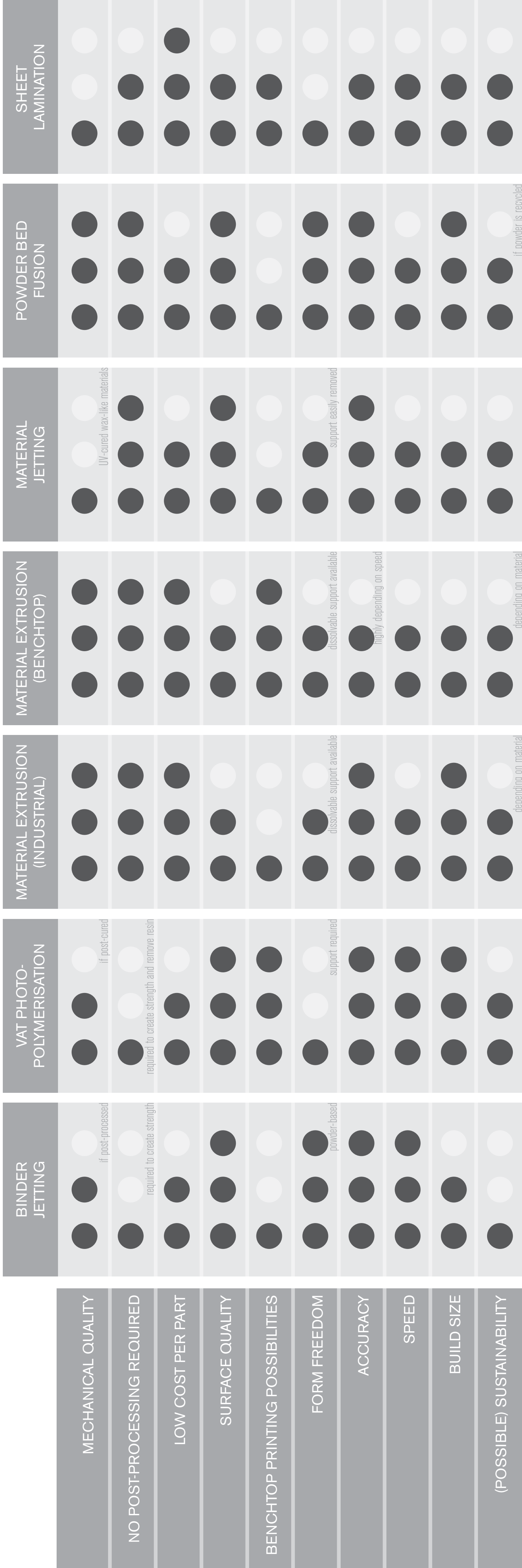
APPENDIX A - PROCESS SELECTION MATRIX



APPENDIX B - INSTRUMENT COST ESTIMATION

Please note that some numbers are based on estimations, as not all data on assembly time and material cost is accurately available.

MAN MINUTES FOR PRINTING THE RIGHT HAND SIDE

man hours required to build one instrument, considering a total production of 10 instruments

Part	Subpart/task	Man minutes required	Explanation
Body	Print Setup Body	15	*Preparing & cleaning the printer*
	Dissolving PVA Buttons	15	*Dissolving the support, refreshing the water, putting to dry*
	Placing body inserts	15	*12xM3 insert + rod for the straps. The inserts are placed by pulling them in with a bolt*
Mechanics R	Print Setup Mechanics	15	*Preparing & cleaning the printer*
	Dissolving PVA Mechanics	15	*Dissolving the support, refreshing the water, putting to dry*
	Placing Buttons	5	*Dissolving the support, refreshing the water, putting to dry*
	Cutting + placing felt	25	*vilt voor de kleppen, onder de button cover en in de body*
	Placing springs & arms	20	*veren op de armpjes, armpjes in de body*
Reeds	Placing ventiles on reeds	15	*Leather valves are glued onto reeds to prevent air leaks*
	Placing gasket & reeds	10	*Reeds & gasket are placed into the body*
	Securing reeds	10	*Using the printed reed holders. Currently 10 bolts.*
Bellow flange	Glueing onto bellow	5	*Applying glue + clamps*
	Placing gasket & securing to body	5	*Securing using two bolts*
Other	Print Setup Other	15	*Preparing & cleaning the printer - Bellow Connector, Buttons, Reed holders, Button cover & Grille*
	Dissolving PVA Other	15	*Dissolving the support, refreshing the water, putting to dry*
	Placing button cover & grille + gauze	15	*Grille gauze needs to be cut to fit*
	Producing gasket	10	*10 gaskets in a sheet = 100 minutes for ordering etc*
		3,8 **hours (print R)**	

MAN HOURS FOR PRODUCTING A CONVENTIONAL INSTRUMENT

		Production in NL	Production in Italy
Right hand side	Body R	4	2
	Mechanics, felt, buttons R	4	2
	Reed waxing R	2	1
	Applying Reed ventiles R	0,25	0,25
Left hand side	Body L	4	2
	Mechanics, felt, buttons etc L	6	4
	Reed Waxing L	2	1
	Applying Reed ventiles L	0,25	0,25
	Tuning L + R	2	2
Bellow	Bellow	8	2
Overall	Finishing	3	2
		35,5 **hours (NL)**	**18,5** **hours (IT)**

MAN HOURS FOR PRODUCING THE PRINTED(R)-CONVENTIONAL(L) INSTRUMENT

		Production in NL
Right hand side	Body, reeds, mechanics R	3,8
	Applying reed ventiles L	0,25
Left hand side	Body L	4
	Mechanics, felt, buttons etc L	6
	Reed Waxing L	2
	Applying reed ventiles L	0,25
	Tuning L + R	2
Bellow	Bellow	8
Overall	Finishing	2
		28,3 **hours (print-conv.)**

35,5-28,3=7,3 ***Man hours saved compared to completely conventional***

TOTAL COST PRICE		
	Conventional	**Printed(R)-Conventional(L)**
Man hours	35,5	28,3
Materials (€)	385	363
Hourly rate (€/h)	17,5	17,5
Cost (€)	**1006**	**858**
	100%	85%

MATERIAL COST FOR A CONVENTIONAL INSTRUMENT		
		Price (€)
Wood	*estimation*	30
Felt		10
Leather		5
Mechanics R	*estimation*	25
Mechanics L	*estimation*	25
Buttons	*estimation*	20
Springs	*estimation*	5
Reeds		110
Bellow		120
Celluloid	*estimation*	30
Wax	*estimation*	5
		385

MATERIAL COST FOR A PRINTED(R)-CONVENTIONAL(L) INSTRUMENT			
Material Costs print + conventional left	**quantity**	**price/qty**	**Price (€)**
Printing 120W average*	205	€0,22/kWh	5,41
Print material body	0,348	€40/kg	13,92
Support material body	0,178	€89/kg	15,84
Print material Mechanics	0,079	€40/kg	3,16
Support material mechanics	0,083	€89/kg	7,39
Print material other	0,151	€40/kg	6,04
Support material other	0,092	€89/kg	8,19
Gasket	0,02m^2	€19/m2	0,38
Lasercutting gasket**	1/63 sheet	€15 + €1/min	0,57
Springs	19	€100/100	1,90
Bolts	14	€26,4/1000	0,37
Inserts	14	€0,86/100	0,12
Felt			5
Leather			5
Reeds			110
Bellow			120
Wood L	*estimation*		15
Mechanics L	*estimation*		25
Celluloid L	*estimation*		15
Wax L	*estimation*		2,5
Springs L	*estimation*		2,5
			363

** community.ultimaker.com/topic/16590-ultimaker-3-power-consumption/*

*** 20s per gasket set, 63 gasket sets/sheet (laserbeest.nl)*

APPENDIX C - ADDITIONAL INSIGHTS PIGINI FACTORY

These are the main questions that were answered during the visit to Pigini in Italy. They focus on the design requirements for a Pigini accordion, as well as its construction. Most of the information has been integrated into the text on accordion production, except for these questions.

How are the dimensions of a Pigini accordion established?

They are defined by the components inside the instrument: all the reeds have to fit in, and need to be connected to all their controls.

Are there guidelines for the pressure of the buttons on the instrument?

It has to feel good. We use standard springs, and that works well.

How does Pigini design a new instrument?

Massimo Pigini is responsible for everything regarding production and design. Together with specialists, he shapes the different components of a new instrument. It is all done in-house, except for components like the grille design, that is sometimes outsourced.

Does Pigini produce on an order basis only?

Larger instruments are built upon order, while there is a desire to keep smaller instruments in stock.

Does the process change often?

No, the process as a whole does not change that much over time. Of course, every instrument is different, but the basic steps remain the same. A significant change in the past years is a robot arm that welds some parts of the mechanic together. More robots for small process steps like this may be introduced in the future.

What materials does Pigini use for the body, and why?

Up to seven types of wood, including pine, mahogany, oak and pine. This is done in order to enhance sound quality, while keeping the cost low (the outer body can be made of pine). The arrangement has come about through trial and error over many years.

Which properties influence the sound of the instrument the most?

The reed itself, in combination with the whole instrument that resonates and the way of the airflow through it. For instance, the casotto, a separate sound chamber, makes the instrument sound totally different. The wood has a certain sound, and each sound chamber has its own acoustics.

How has the reed design developed over the years?

The basic design has been like this for centuries; it is quite simple, a steel part (with weight) on an aluminium block.

Do bellows come in standard sizes?

No, the bellows are constructed from cardboard pieces that are cut to any desired size . Therefore, every accordion builder can easily order custom bellows.

What makes Pigini unique?

Its high quality and the dedication of the craftsmen. Some competitors are very much alike, but that is healthy competition.

How does Pigini guarantee quality?

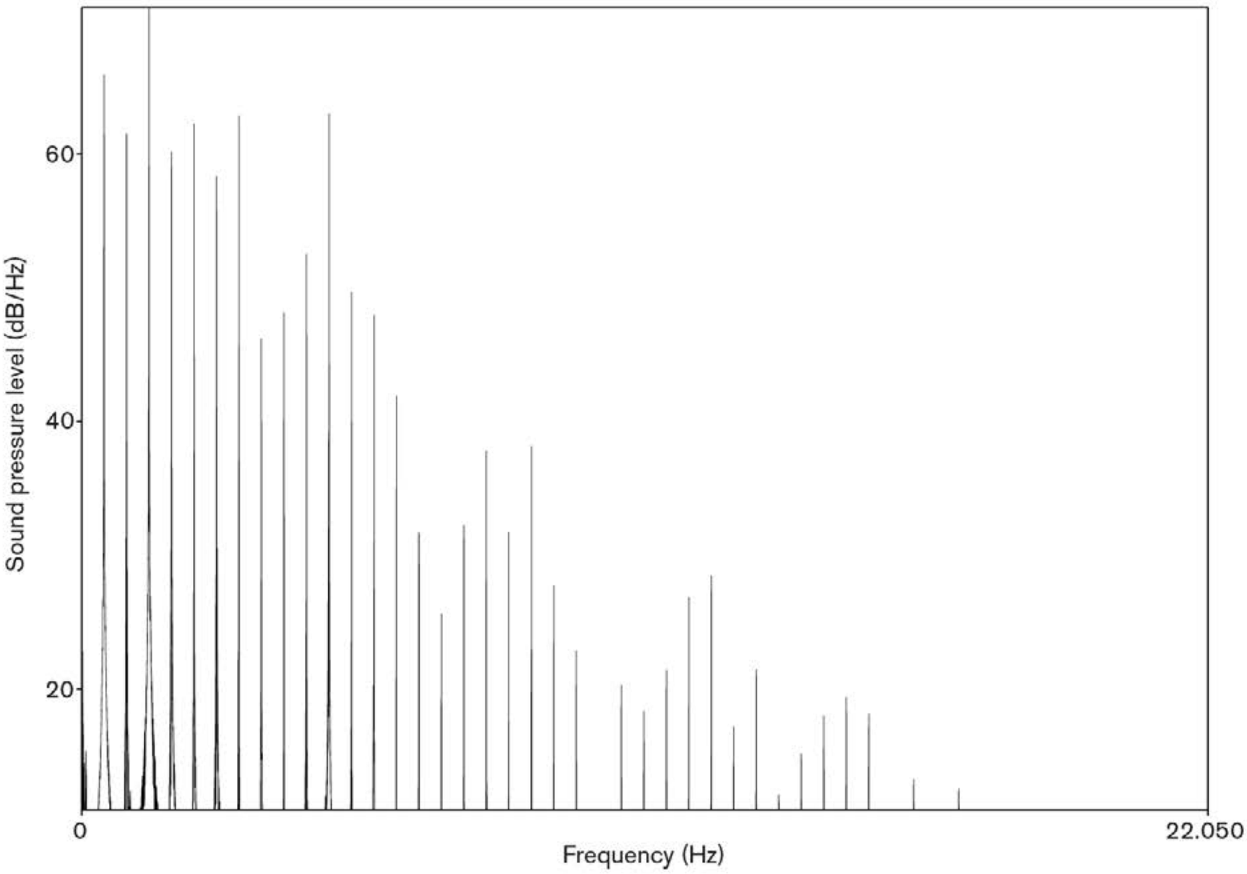
Through various checks during and after production. Every instrument goes through many hands, and the quality control is very strict. No instrument leaves the factory without being played in order to test it.

How long does Pigini guarantee quality?

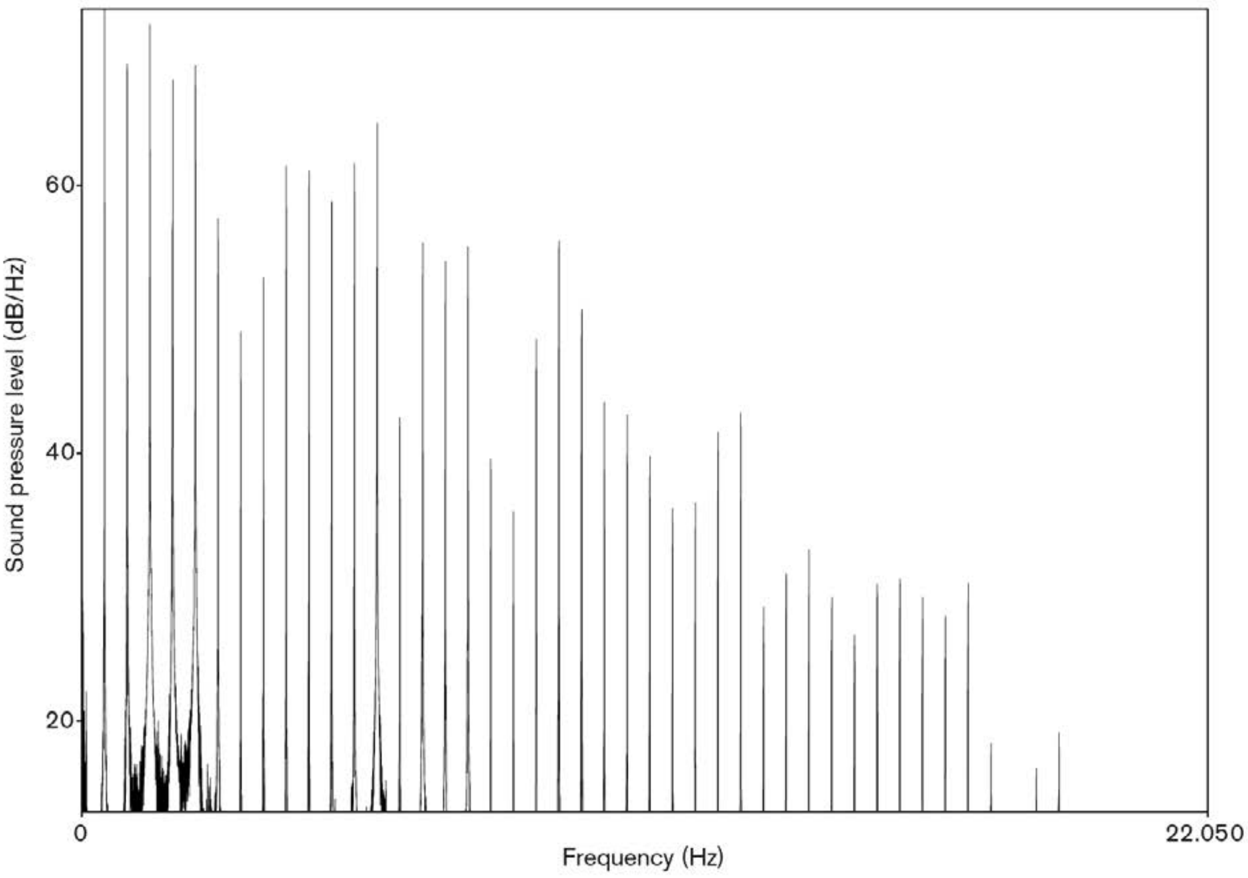
The instruments are expected both by Pigini and customers to last many years: 10 years up to a lifetime.

APPENDIX D - AUDIO SPECTRA

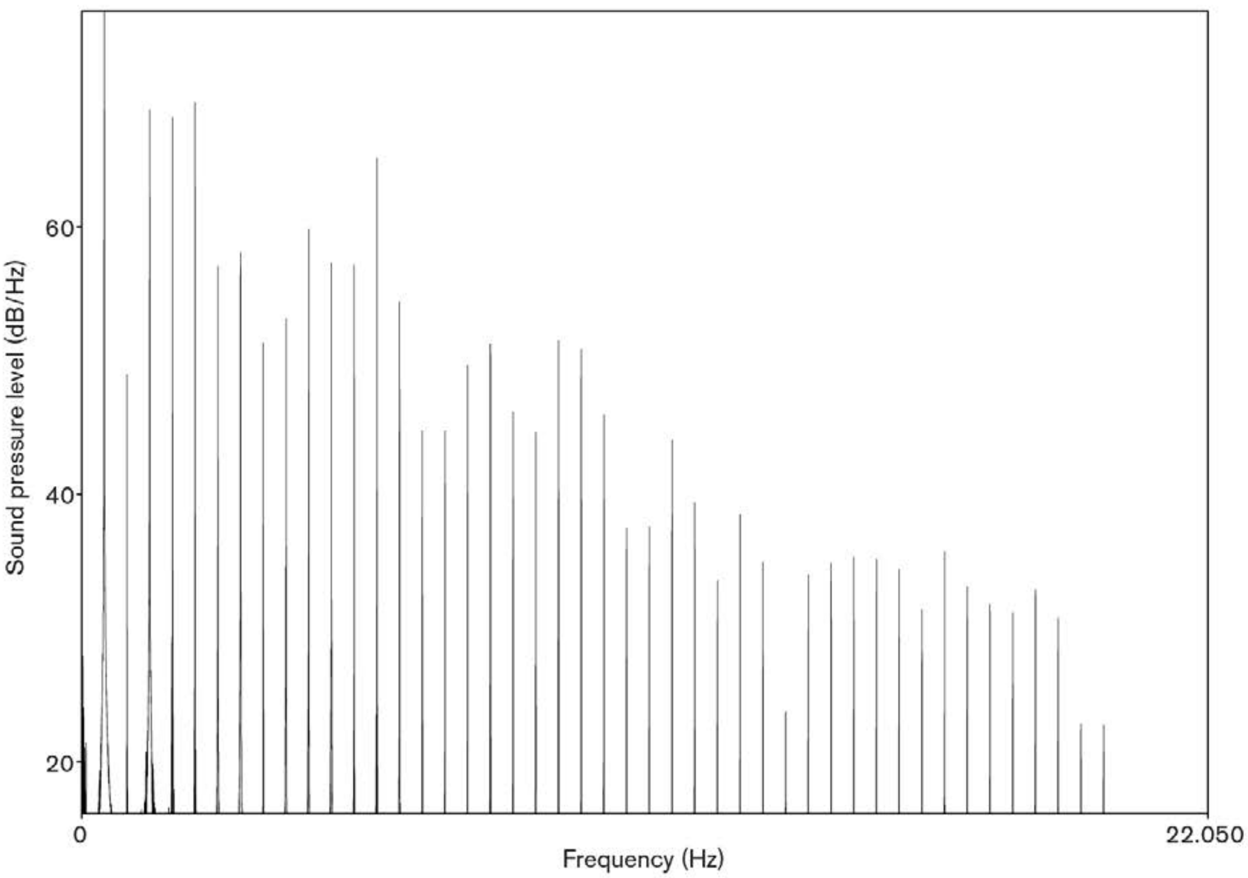
These are the larger versions of the audio spectrum graphs as discussed in the report.



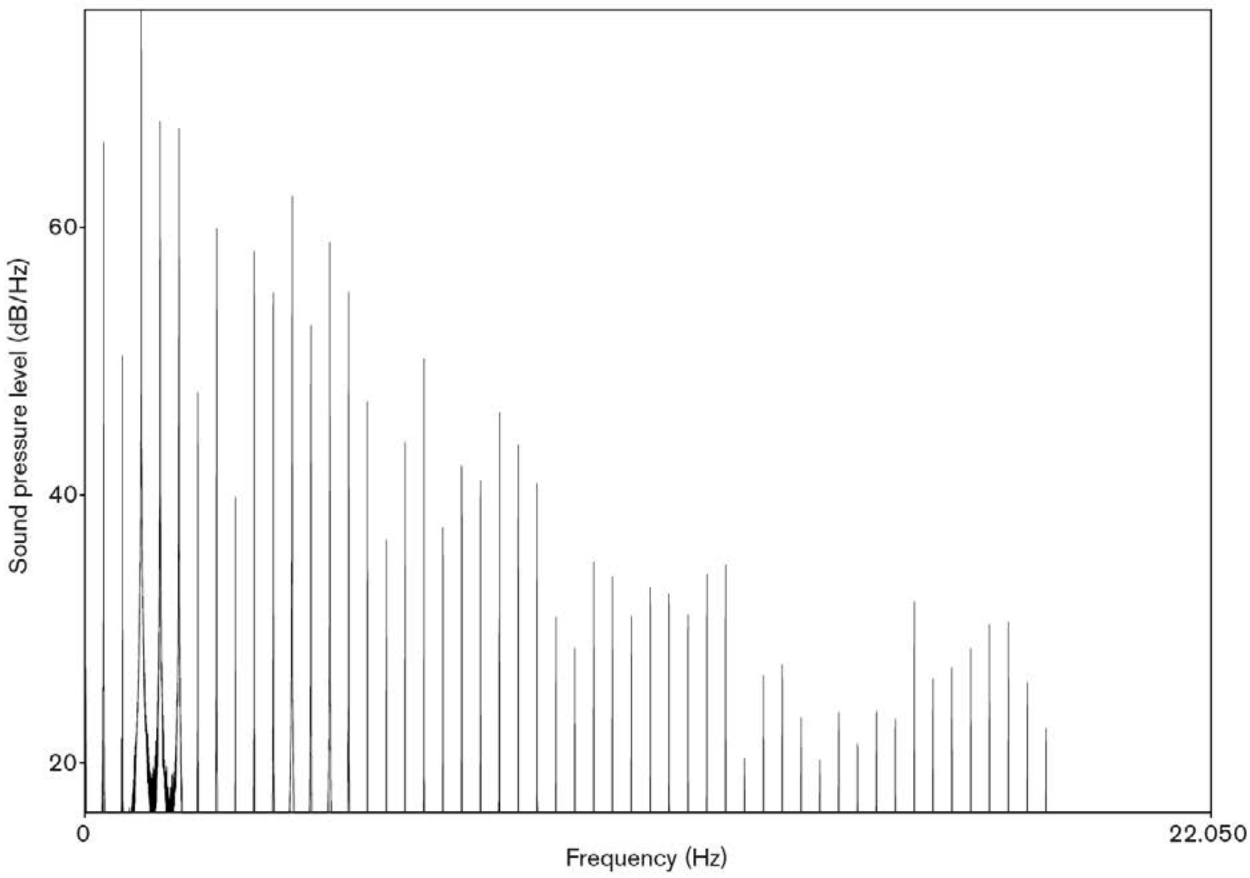
Spectrum of the A4 reference sample



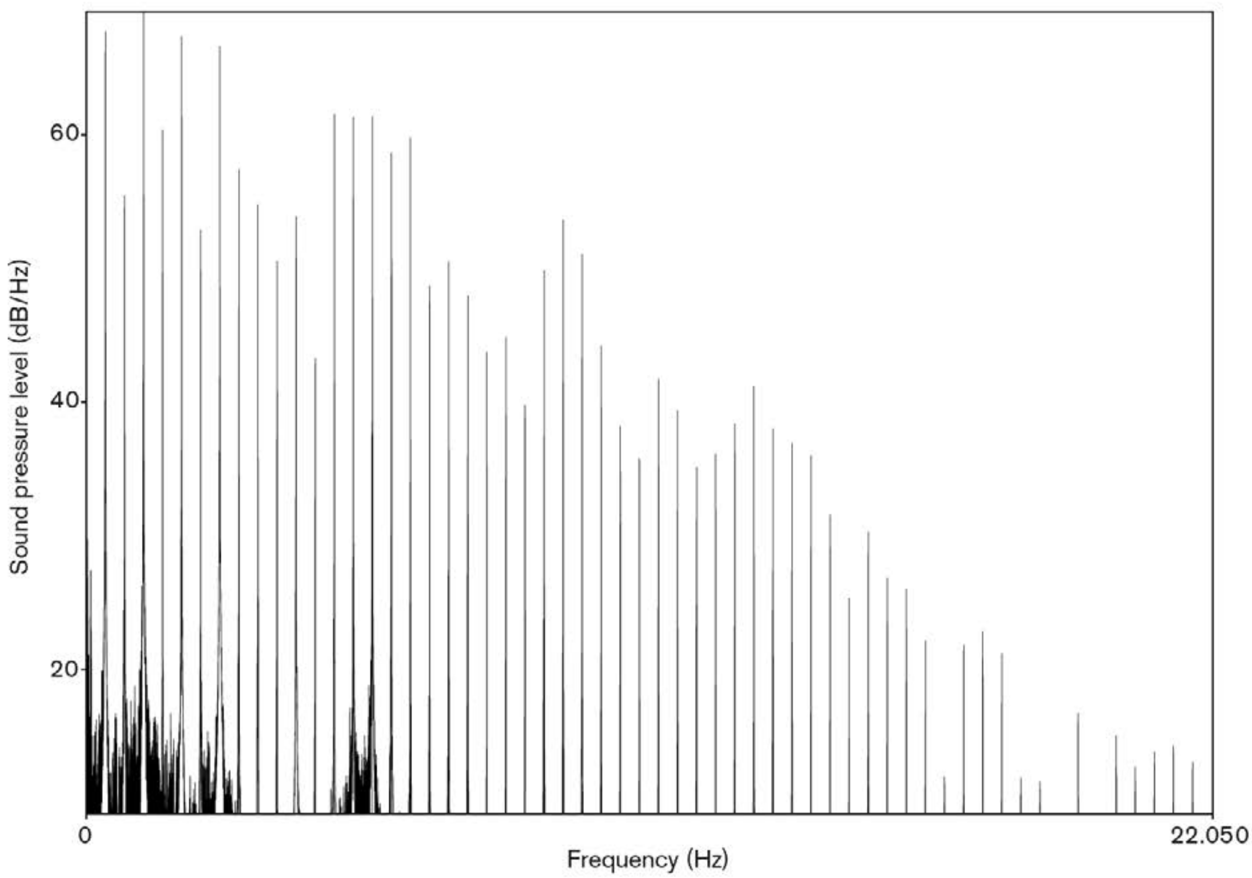
Spectrum of the A4 least preferred sample (chamber 1)



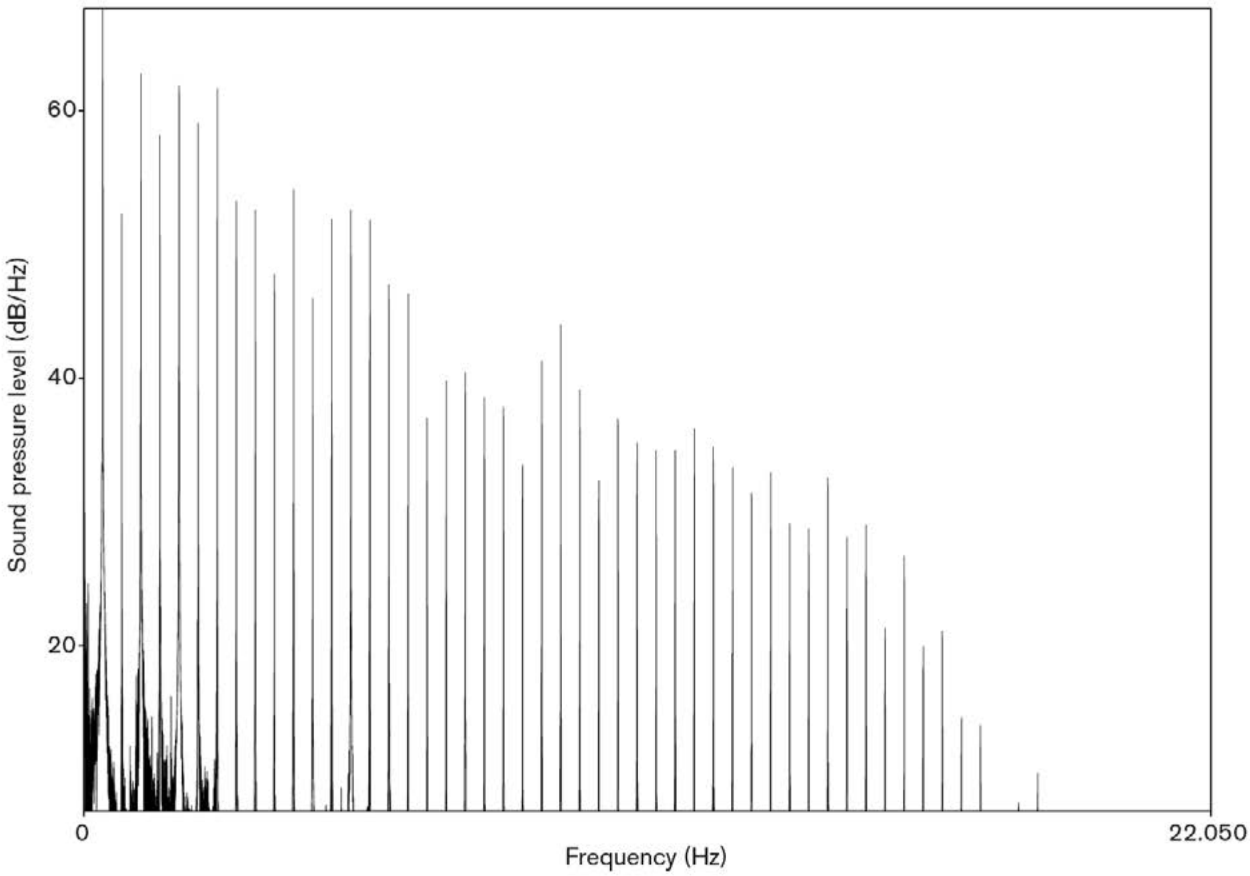
Spectrum of the A4 most preferred sample (chamber 7)



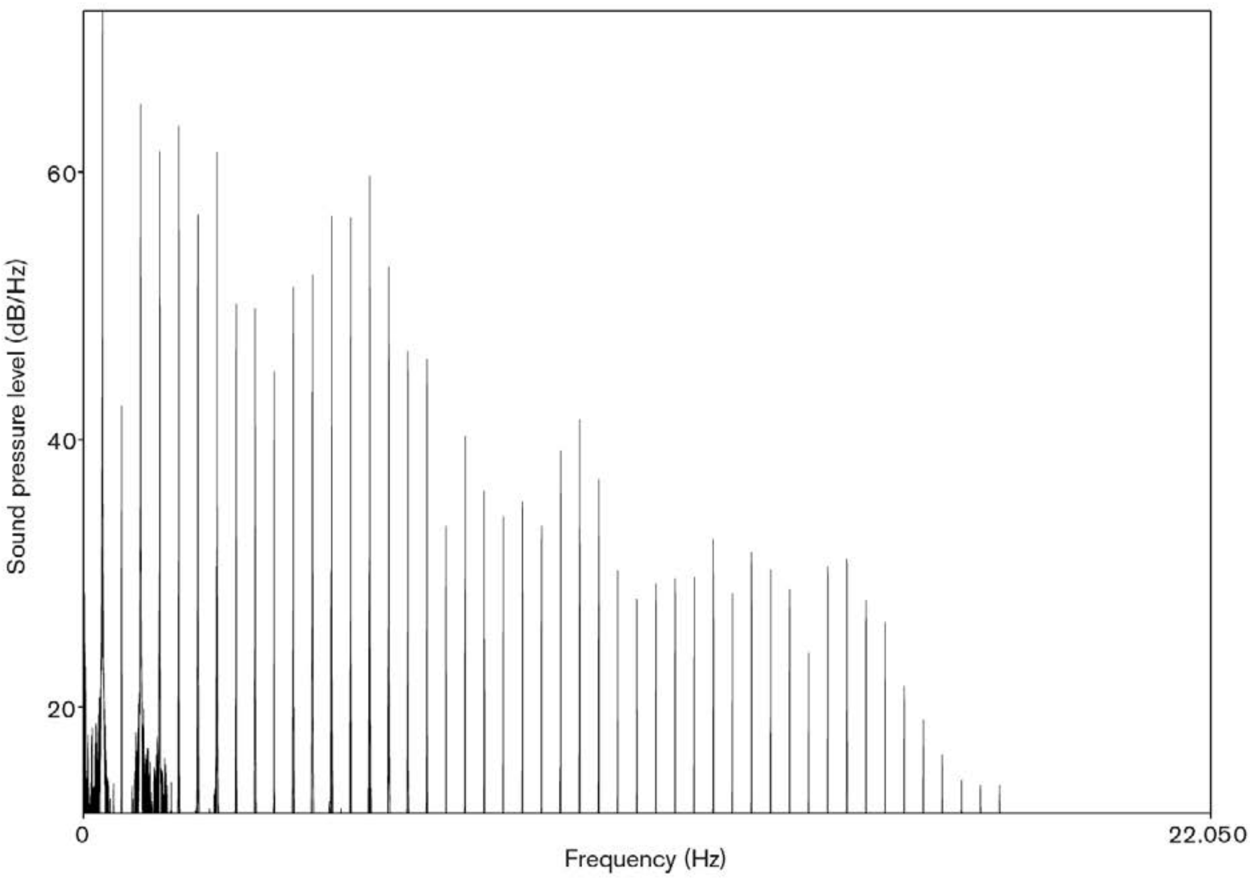
Spectrum of the F#4 reference sample



Spectrum of the F#4 least preferred sample (chamber 3)



Spectrum of the F#4 second most preferred sample (chamber 5)



Spectrum of the F#4 most preferred sample (chamber 6)

APPENDIX E - SOUND CHAMBER DEPTH CALCULATION

The sound chamber depths in this sheet have been calculated using the formulas provided by Tonon (2009). Using these outcomes, the model for the sound research is printed.

https://en.wikipedia.org/wiki/Piano_key_frequencies											
c		342	m/s	Speed of sound							
k		0,6		Factor - distance of aperture							
		Frequency (Hz)	Wavelength (m)	substracted reed volume (m3)	orthogonal cavity width (m)	orthogonal cavity length (m)	aperture with (m)	aperture length (m)	aperture area (m^2)	aperture length (m)	V required for helmholtz (m^3)
Toon	**Partial**	**v**	**λ**	**Vadj**	**W**	**L**	**d1**	**d2**	**A**	**t**	**Vhelm**
A4	1	440	0,7780565	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00016236
	2	880	0,3890282	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00004059
	3	1320	0,2593522	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00001804
	4	1760	0,1945141	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00001015
	5	2200	0,1556113	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00000649
	6	2640	0,1296761	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00000451
F#4	1	370	0,9252564	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00022961
	2	740	0,4626282	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00005740
	3	1110	0,3084188	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00002551
	4	1480	0,2313141	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00001435
	5	1850	0,1850513	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00000918
	6	2220	0,1542094	0	0,0145	0,0395	0,009	0,01	0,00009	0,0025	0,00000638

Required depth for helmholtz resonation (mm)	0,15*λ is the max size of any component for helmholtz to remain accurate (mm)	cavity height used for quarter wave calculation (m)	effective length of the air cavity (m)	cavity length for quarter-wave model (mm)		
H res. (mm)	**Smax (mm)**	**H fixed**	**Leff**	**L-QW (mm)**	**tGasket (mm)**	**Depth of print (mm)**
282,6	116,7	0,015	0,195	198,0	0,9	281,7
70,0	58,4	0,015	0,097	100,8	0,9	69,1
30,6	38,9	0,015	0,065	68,3	0,9	29,7
16,9	29,2	0,015	0,049	52,1	0,9	16,0
10,5	23,3	0,015	0,039	42,4	0,9	9,6
7,0	19,5	0,015	0,032	35,9	0,9	6,1
400,0	138,8	0,015	0,231	234,8	0,9	399,1
99,4	69,4	0,015	0,116	119,2	0,9	98,5
43,7	46,3	0,015	0,077	80,6	0,9	42,8
24,2	34,7	0,015	0,058	61,3	0,9	23,3
15,2	27,8	0,015	0,046	49,8	0,9	14,3
10,3	23,1	0,015	0,039	42,1	0,9	9,4