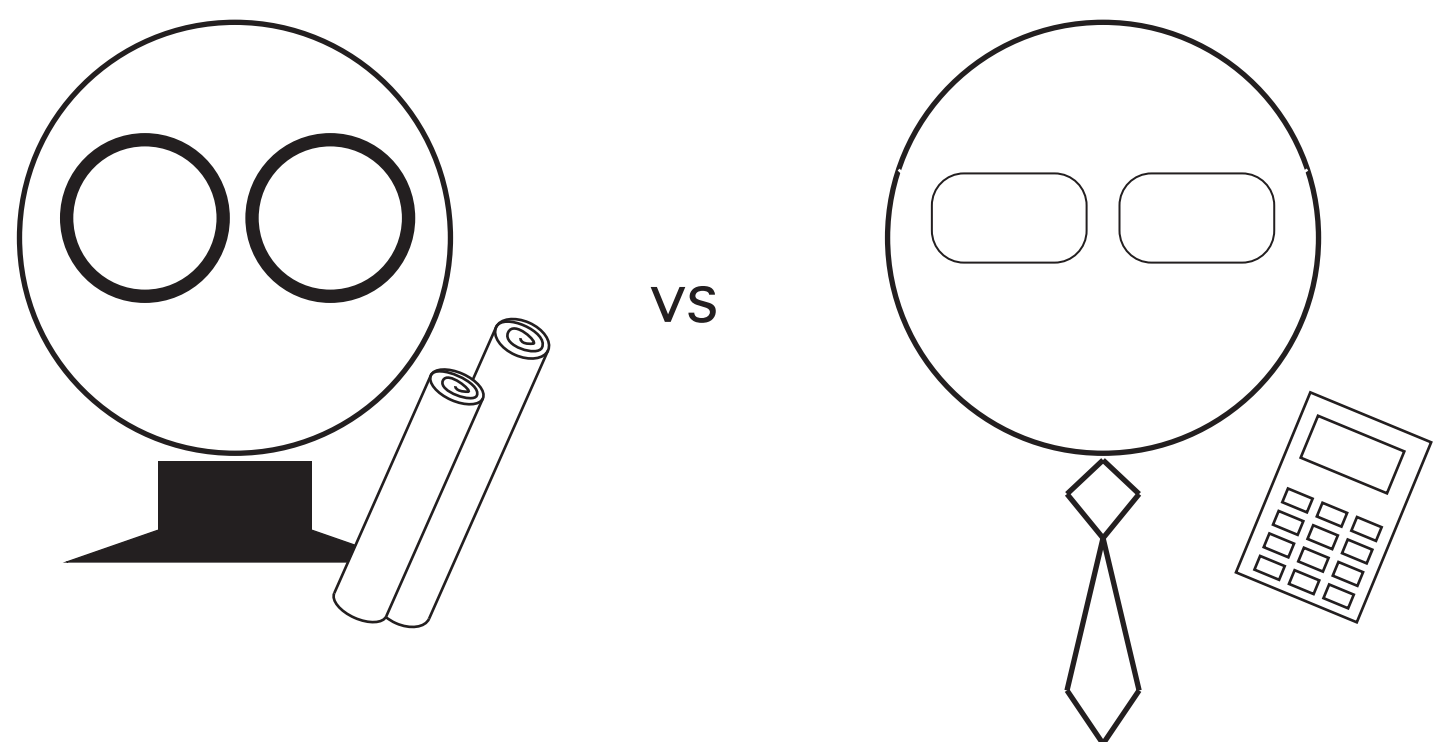


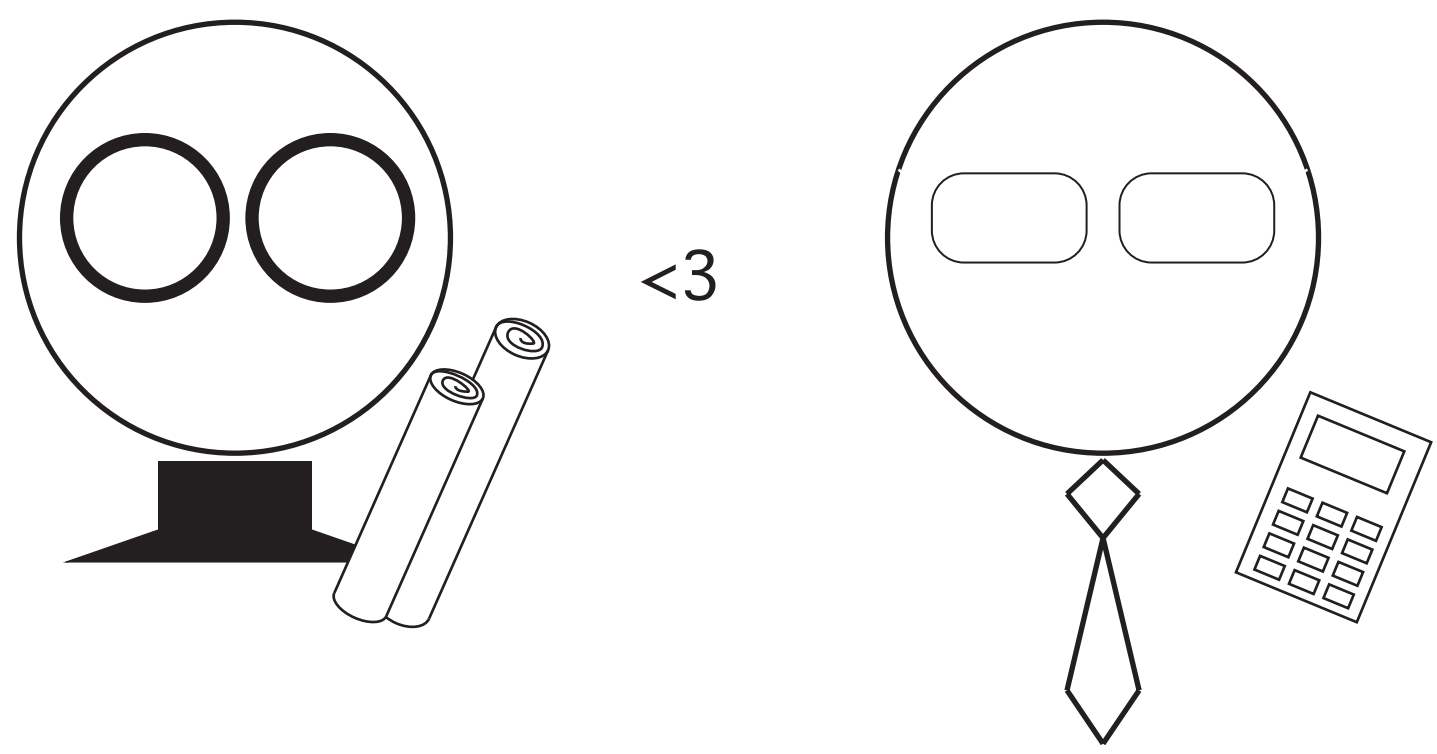
Glass connections

Veerle van Es
4160487

Why



Why



How



What



Main question

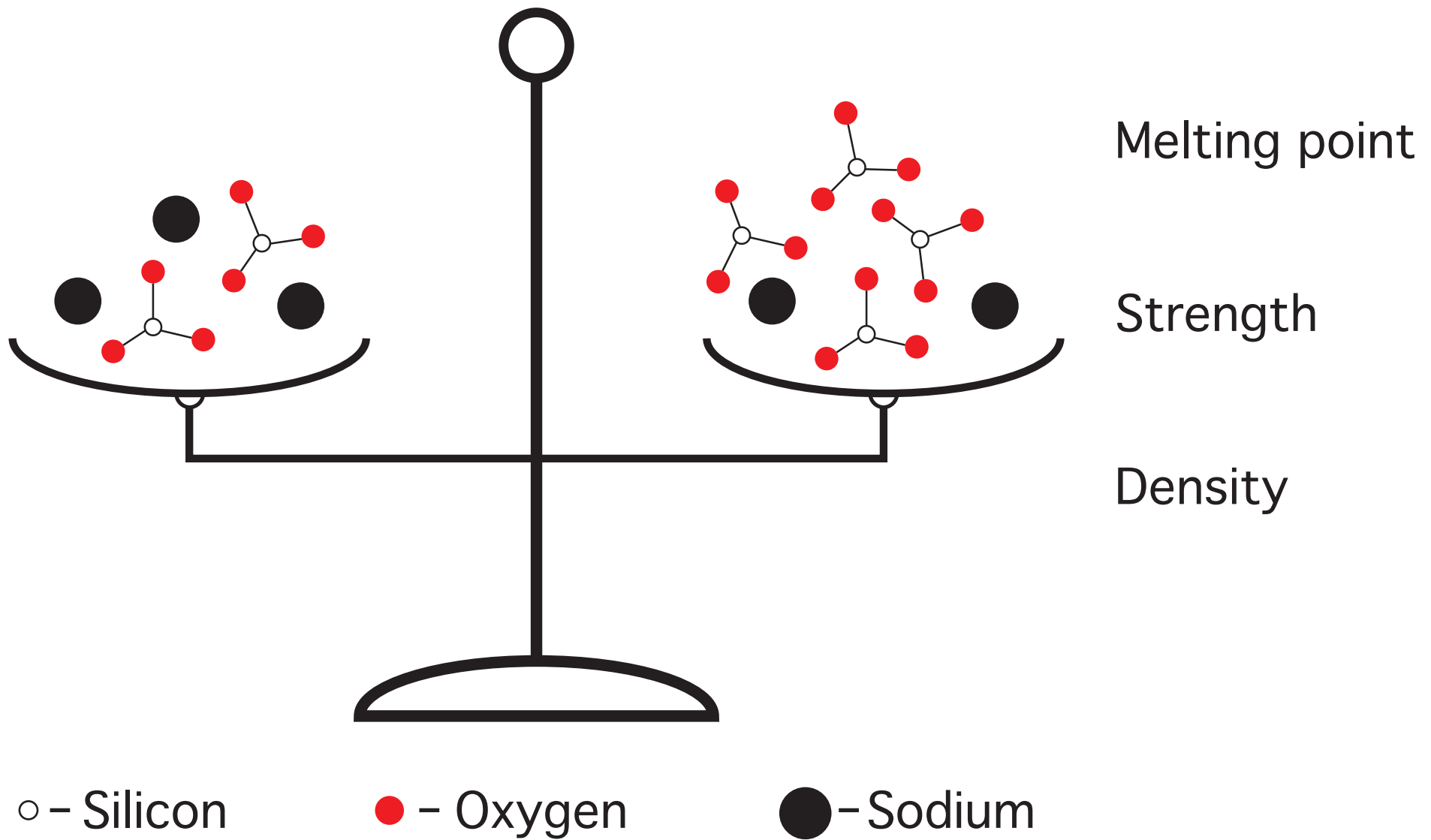
‘How is it possible to make an all glass construction?’

Methodology

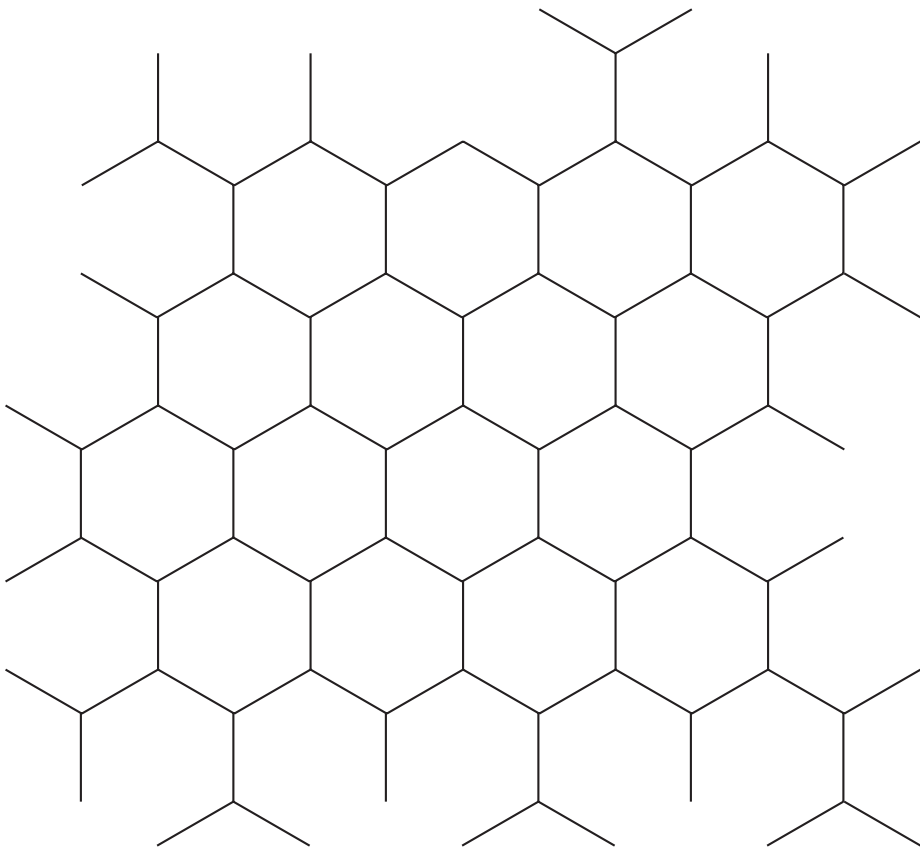
- Literature study
- Design research
- Final designs
- Experiments
 - Sanded design
 - Profiled design
- Feasibility
- Conclusions and recommendations

Literature study

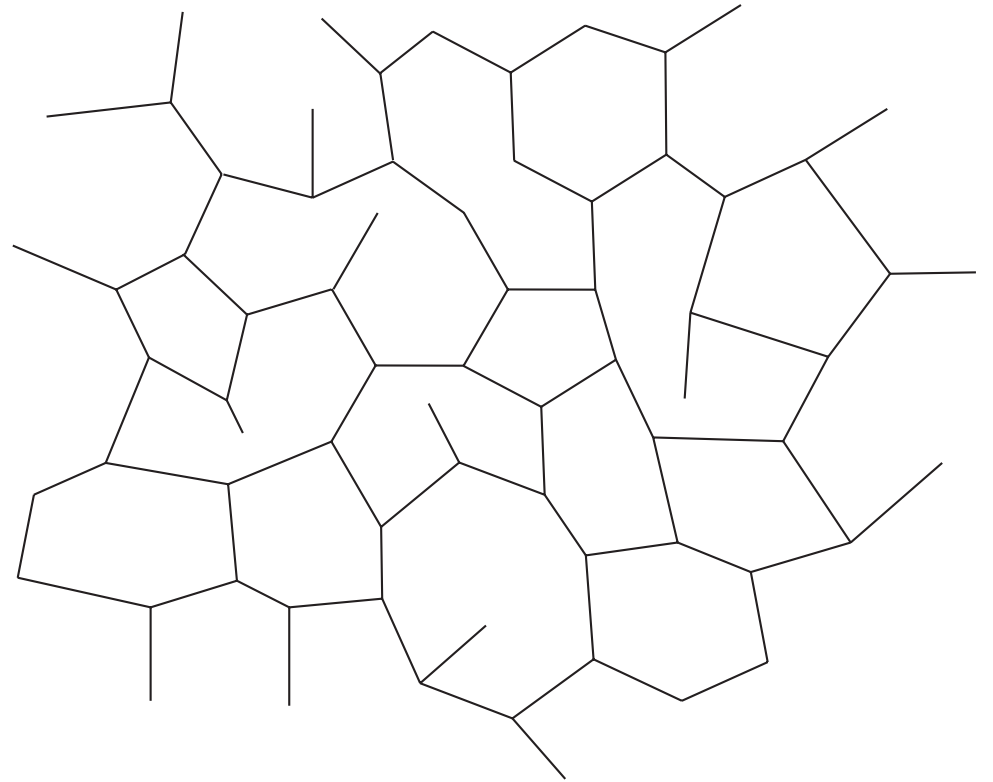
What is glass?



Amorph structure

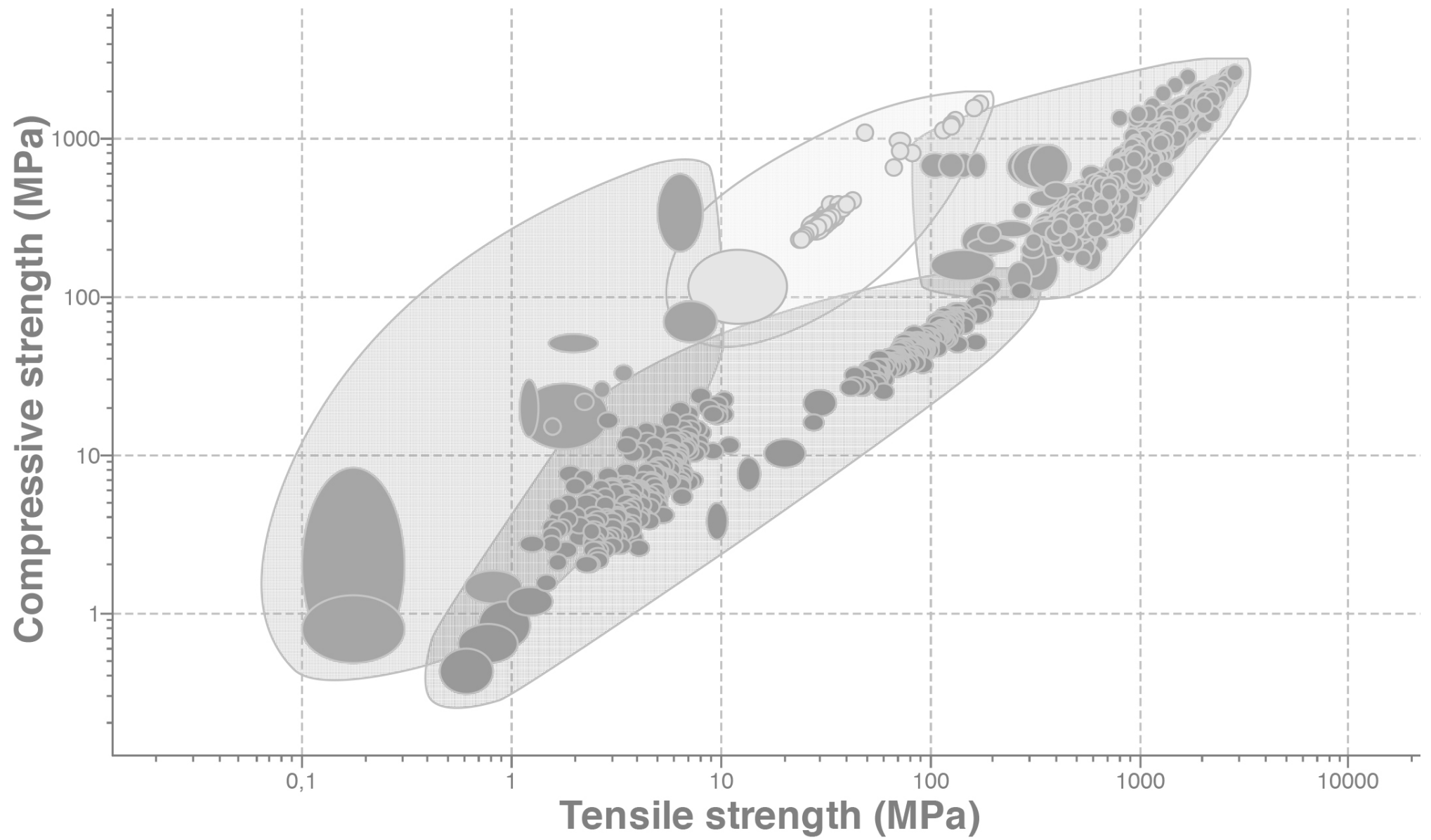


Crystals

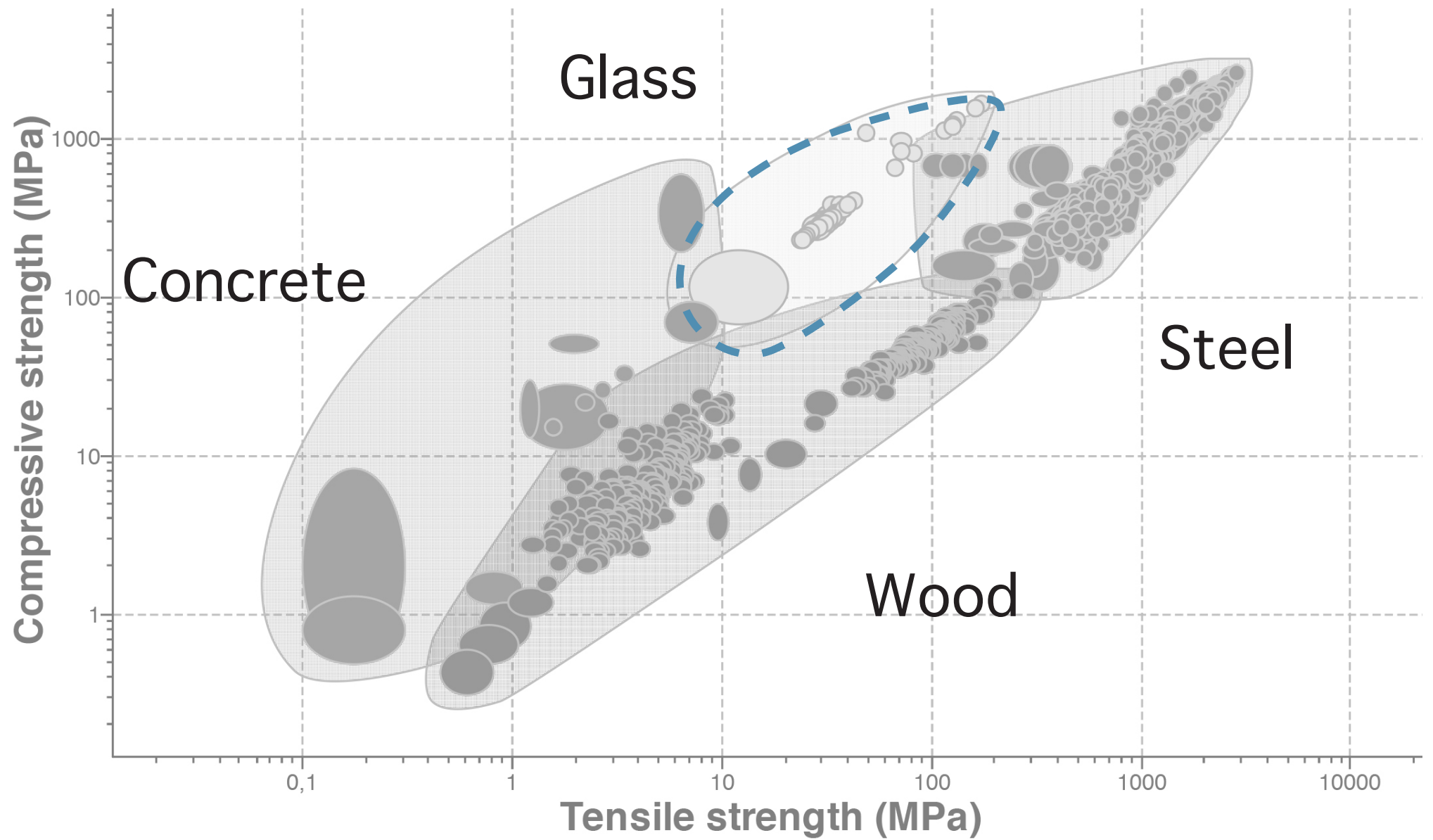


Glass

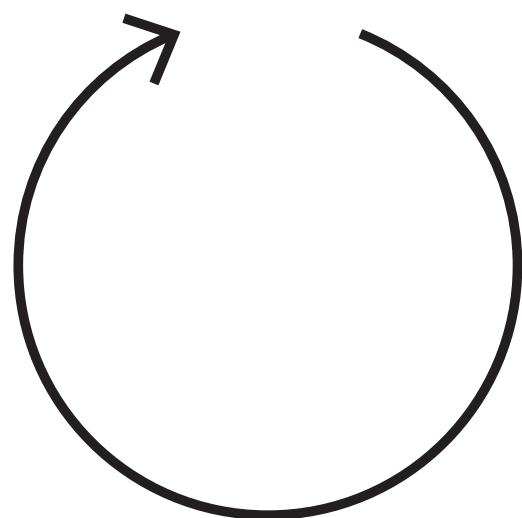
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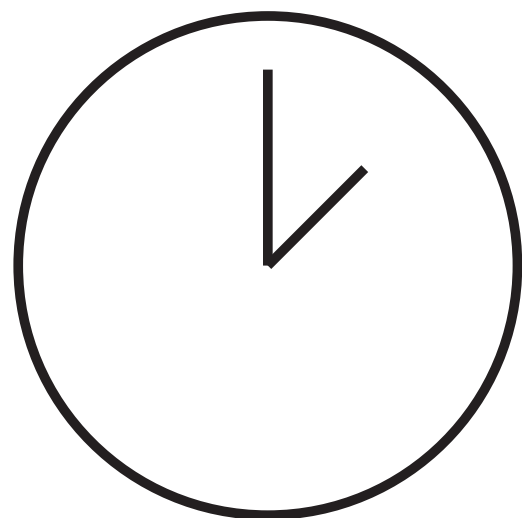
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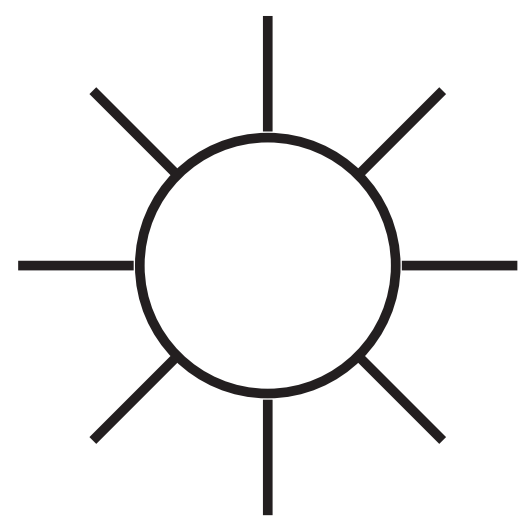
Durability



Recycle



Strong



Natural lighting

What has been done



MVDRV

Crystal house

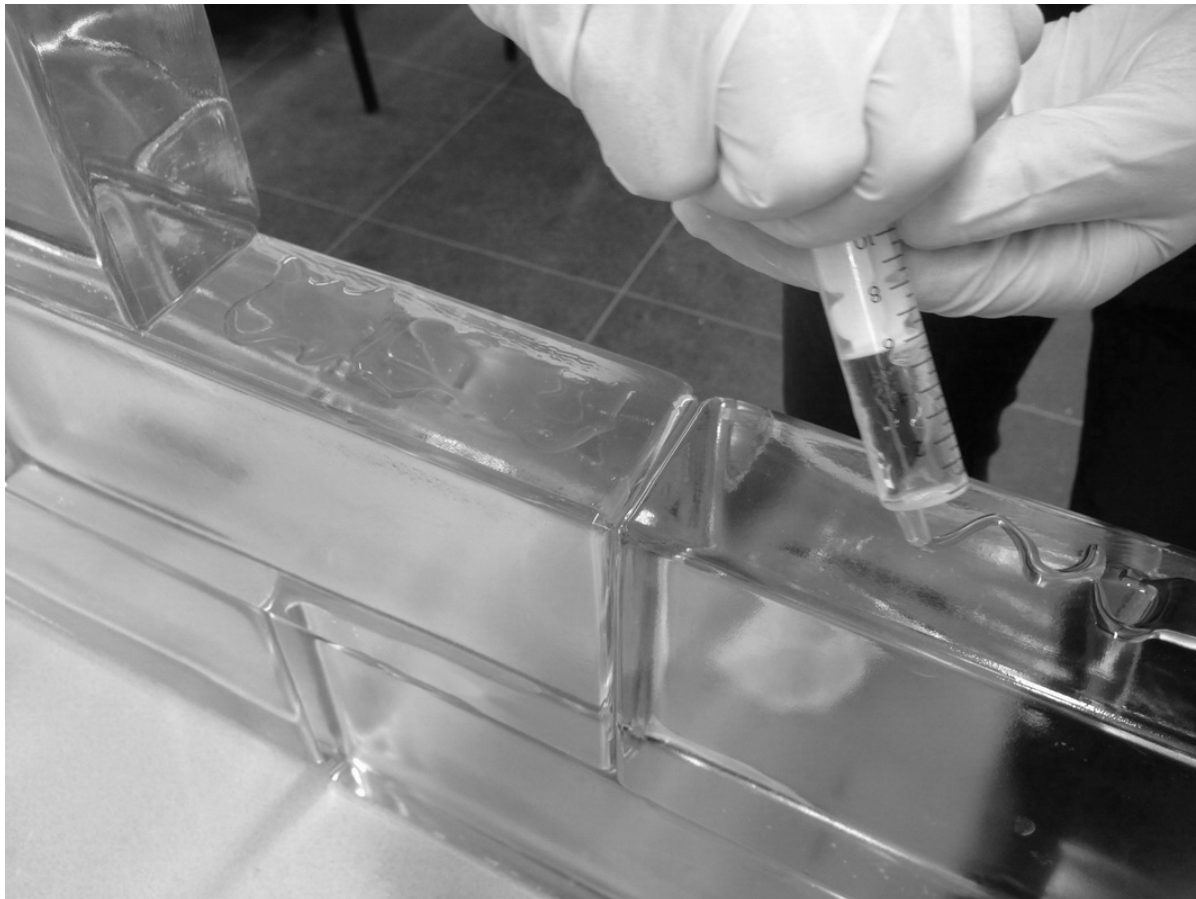
Renovation

10 meters

Small 8 hours

Big 36 hours

Acrylic
adhesive



What has been done

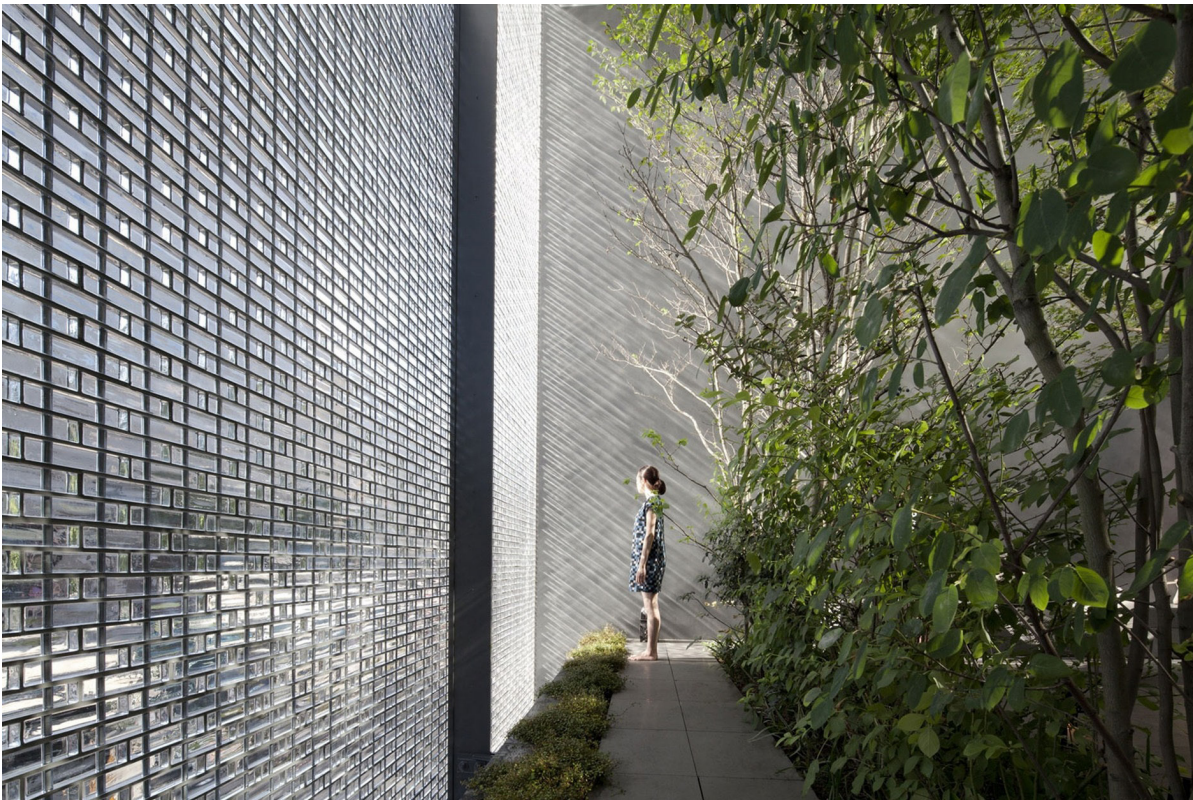


Nakamura

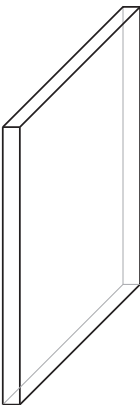
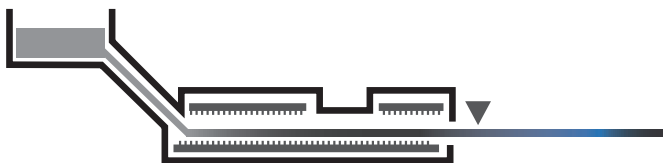
Optical house

8,5 meter

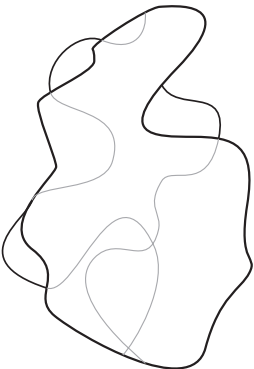
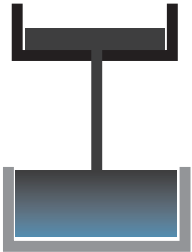
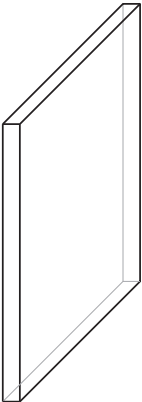
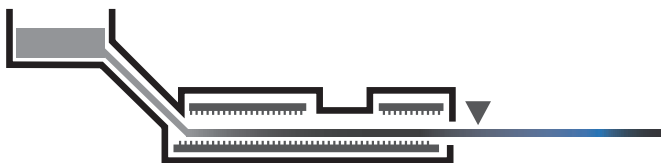
Steel cables



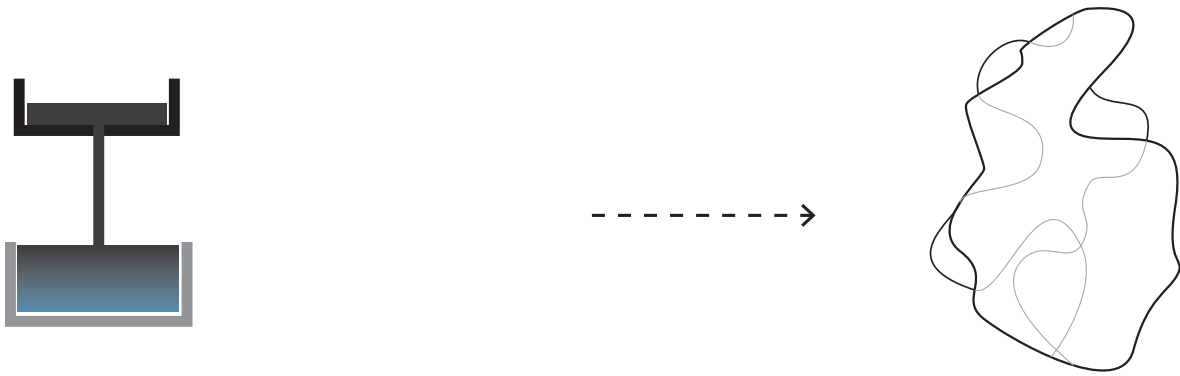
Shapes



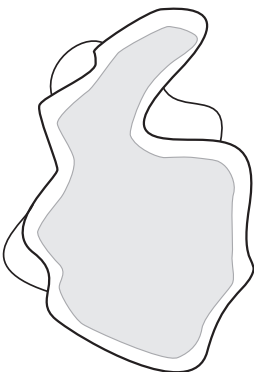
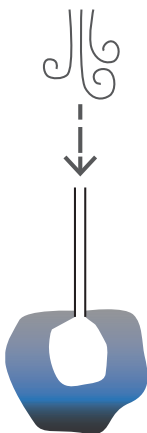
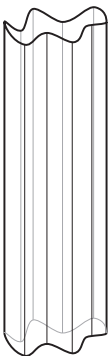
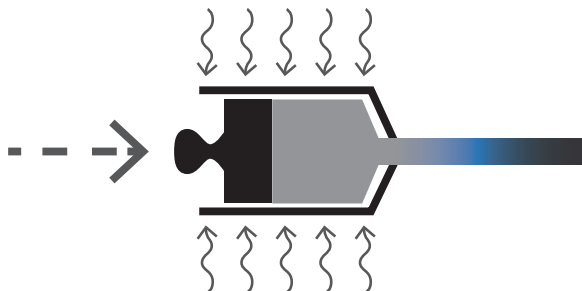
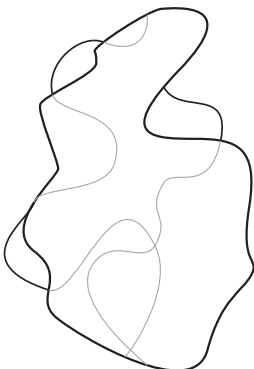
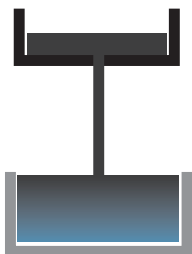
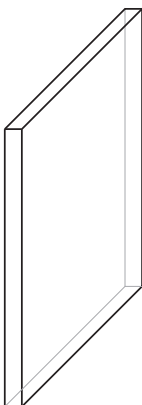
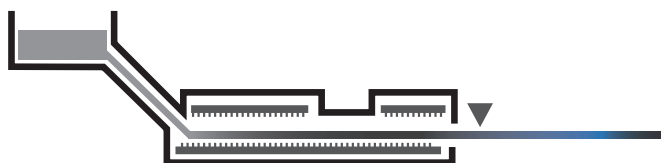
Shapes



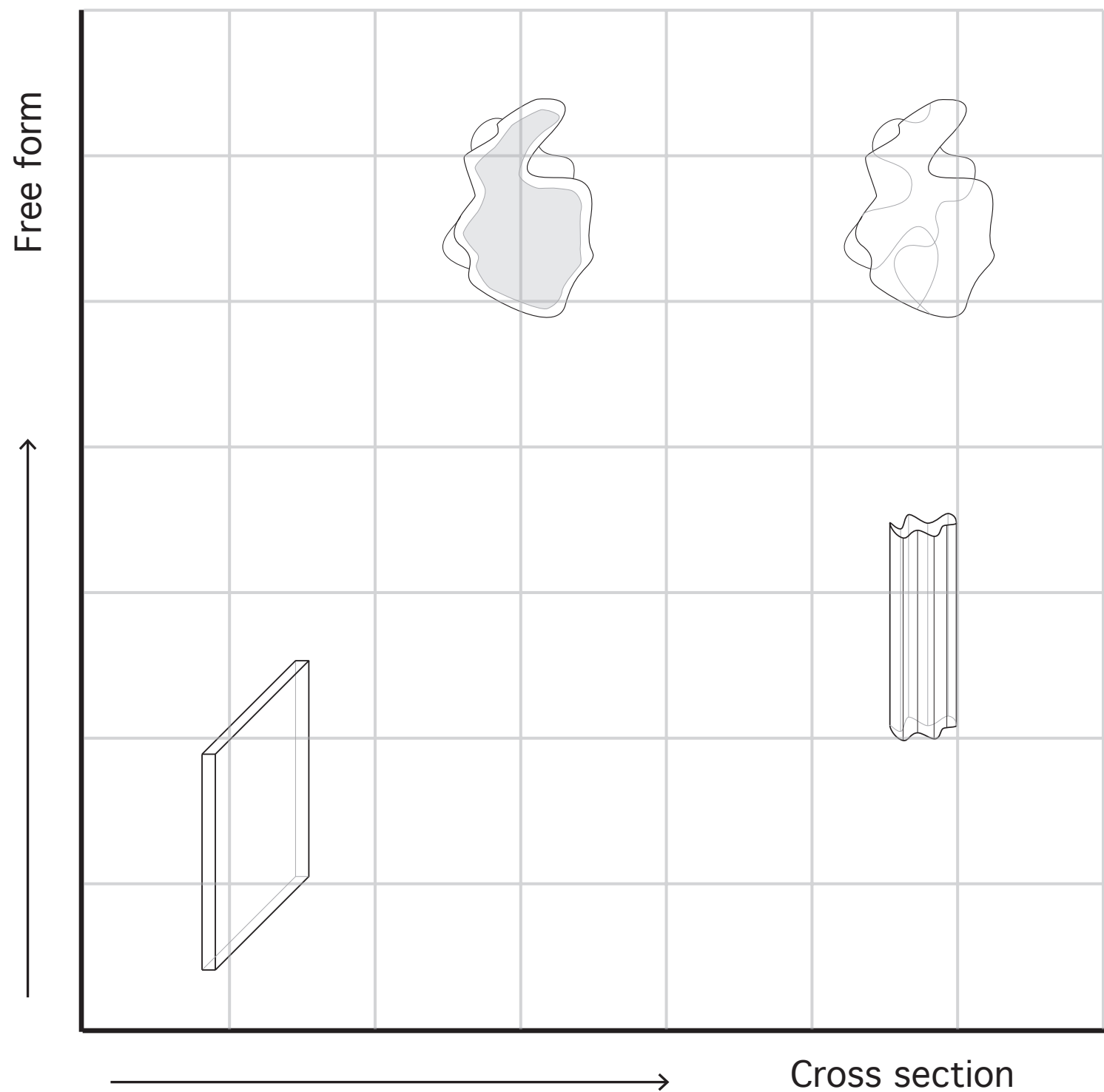
Shapes



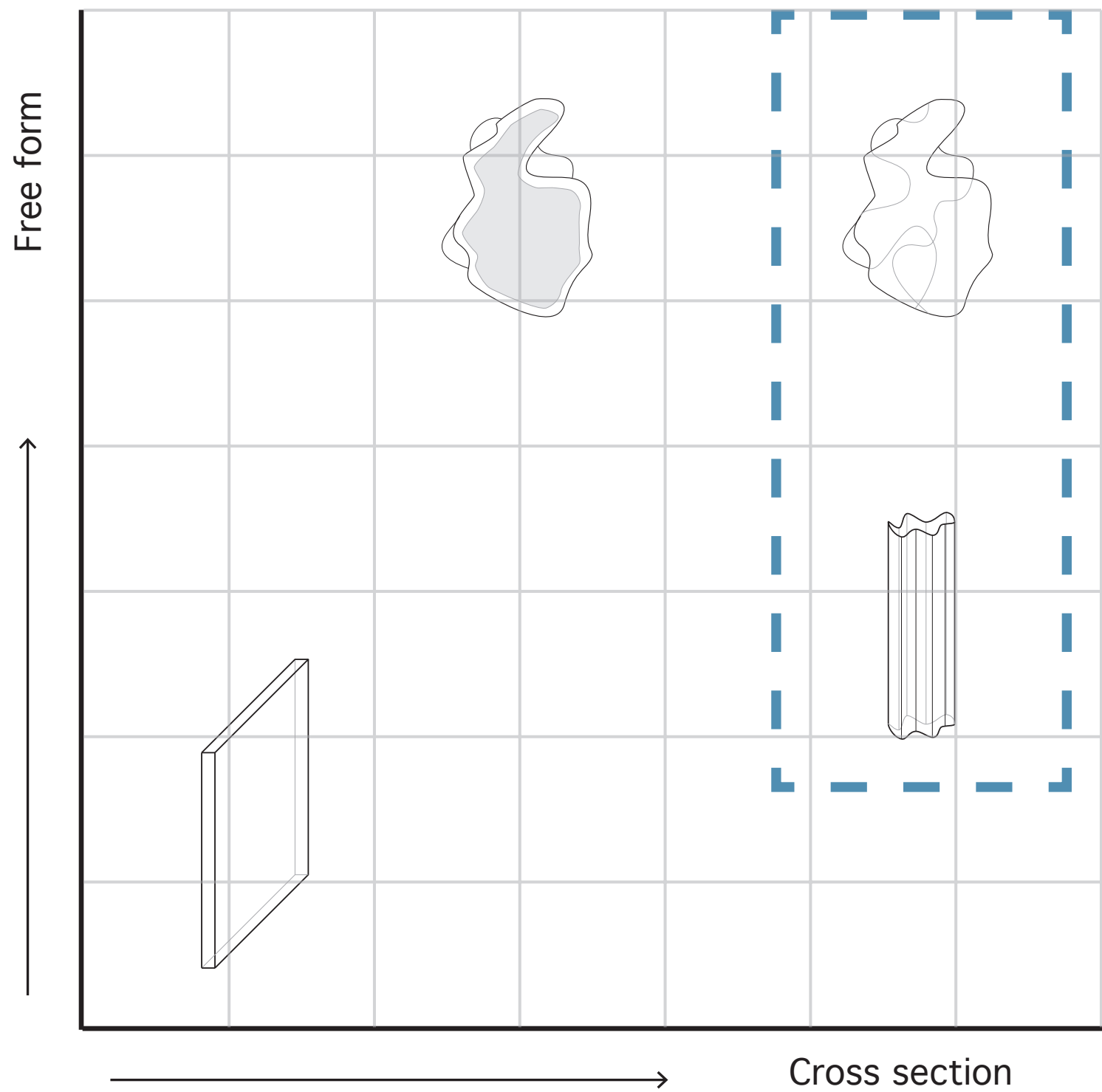
Shapes



Cross section

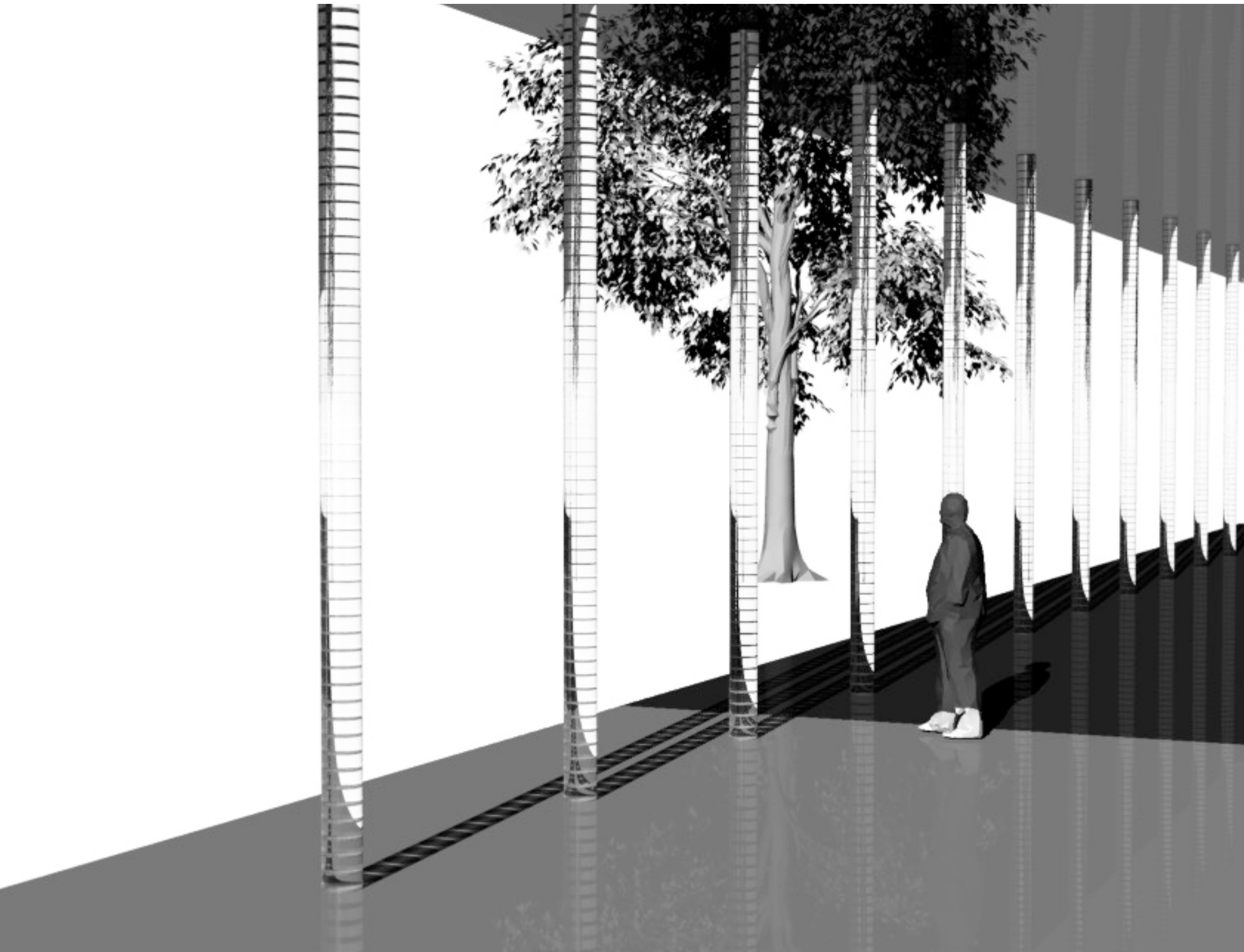


Cross section



Design research

Topic



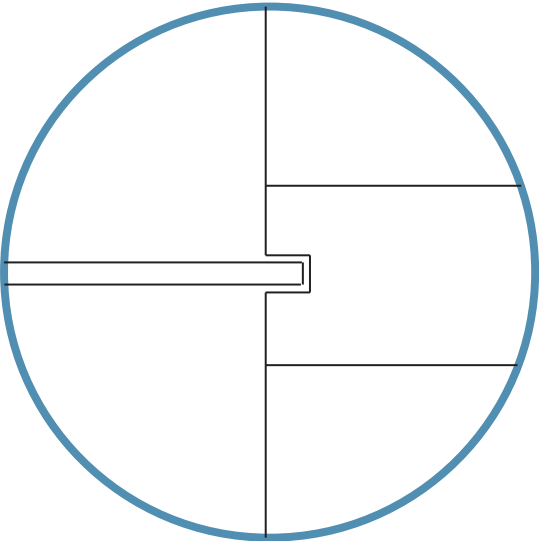
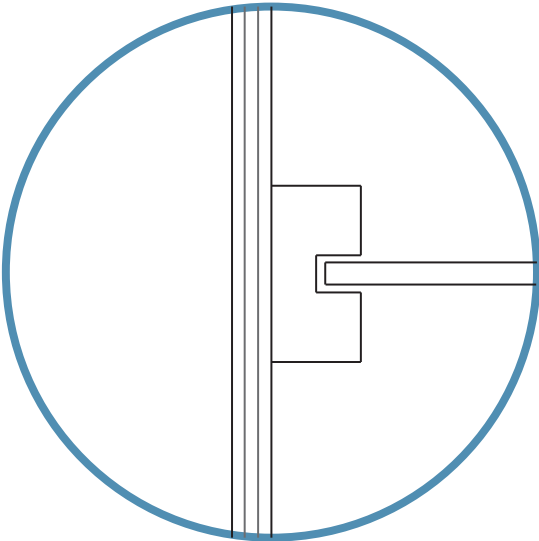
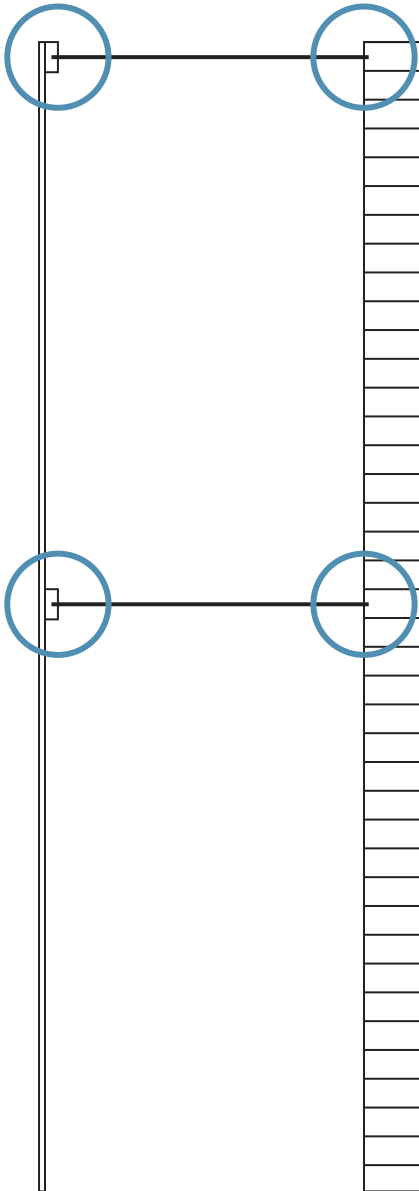
Topic



Topic

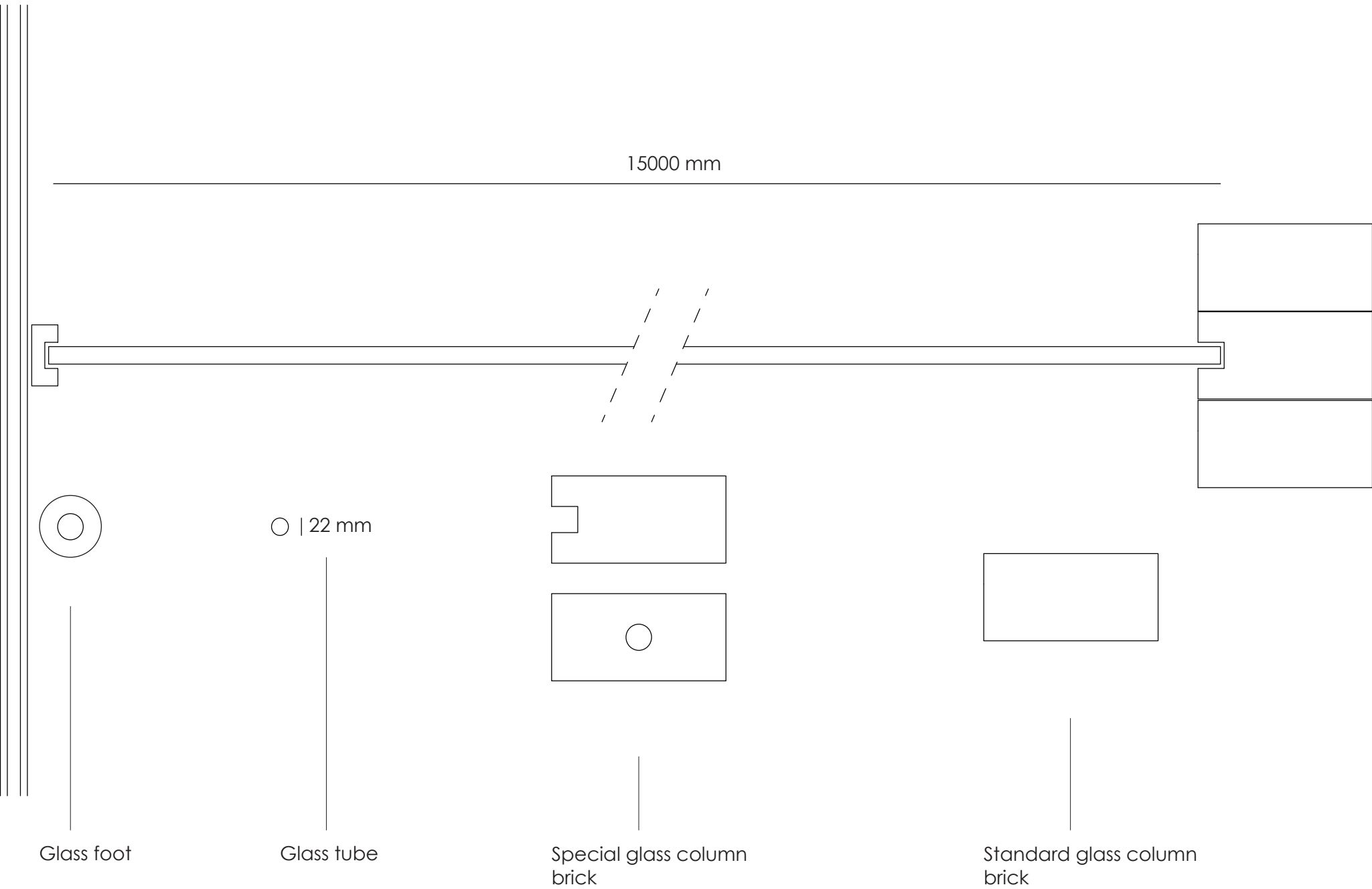


Problem area

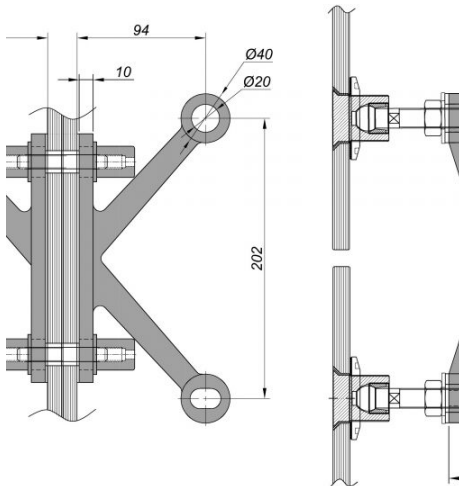
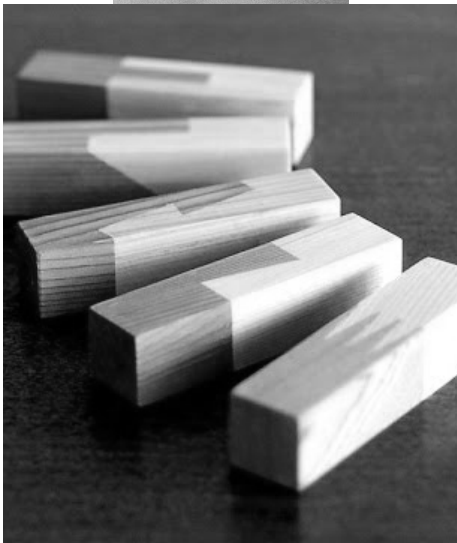
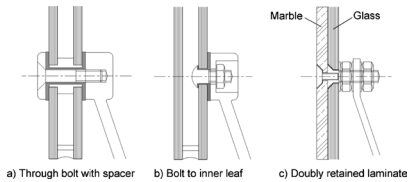
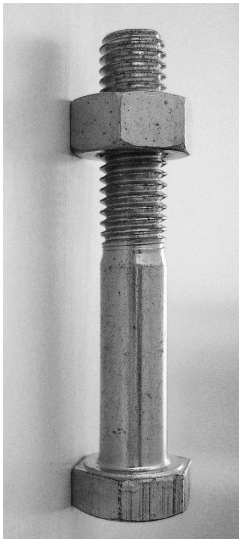


Problem area

8 | 15 | 8 mm

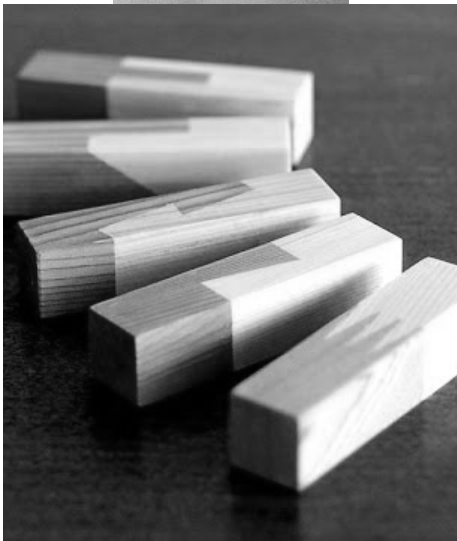
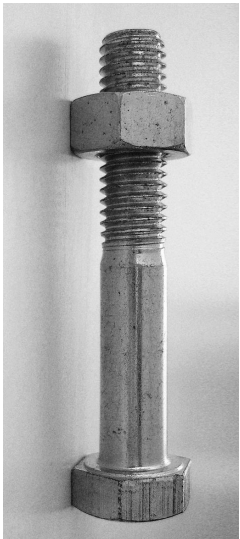


Connections



Connections

Profile



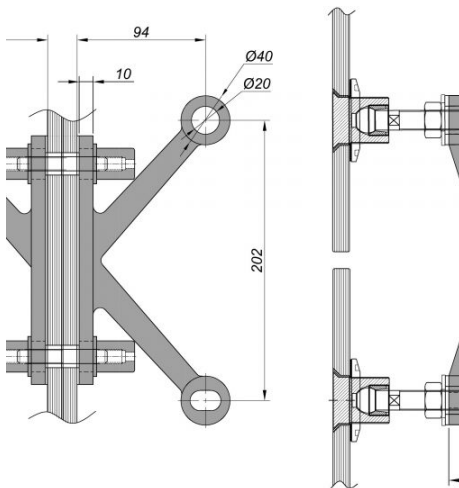
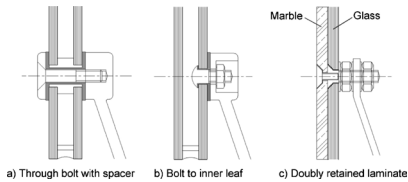
Sanded



Adhesive

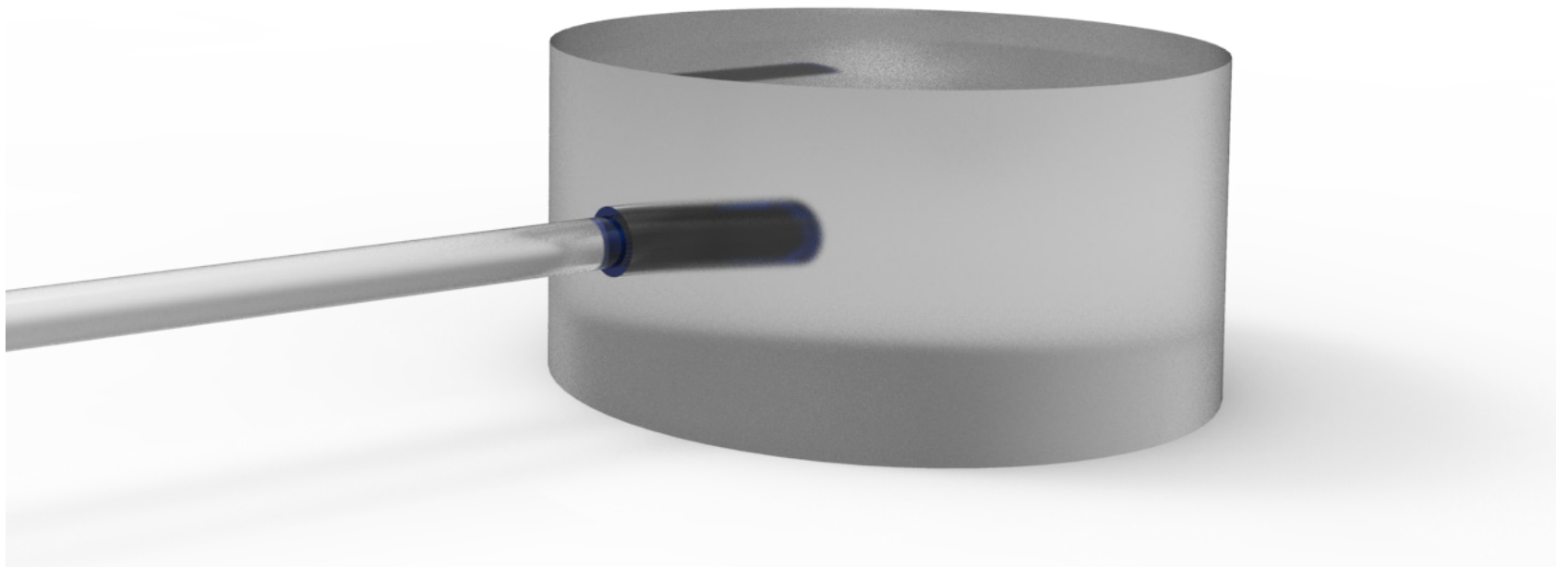


Plate



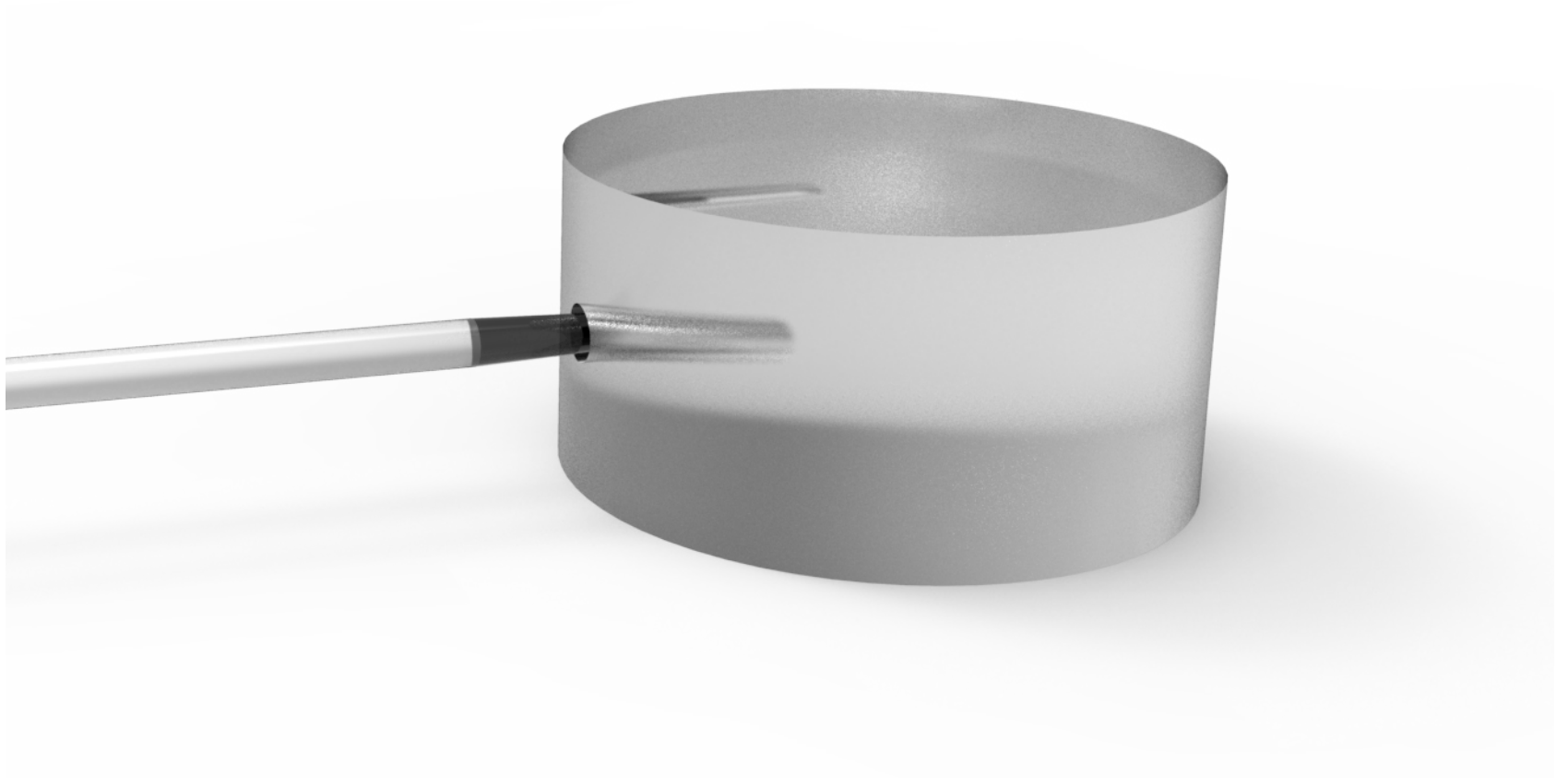
Connection 1

Adhesive



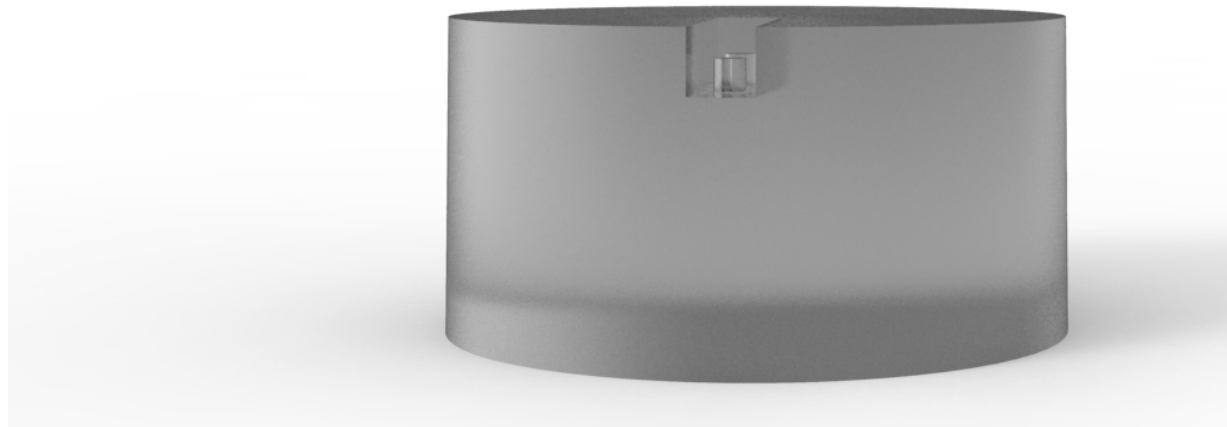
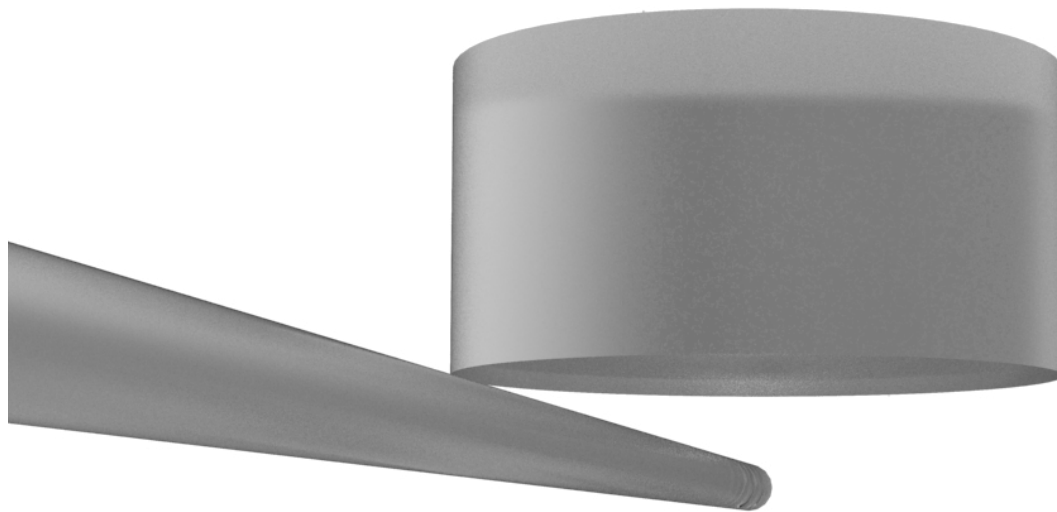
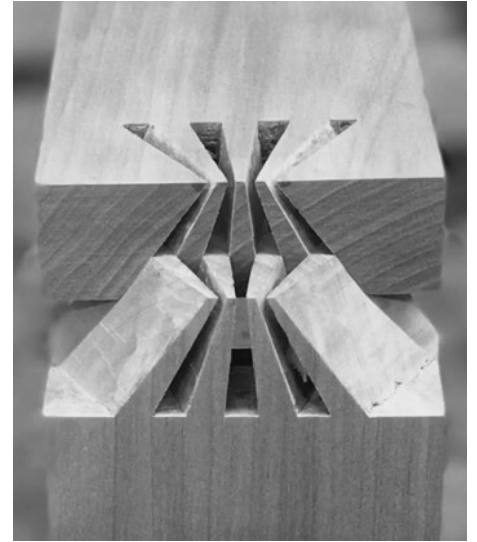
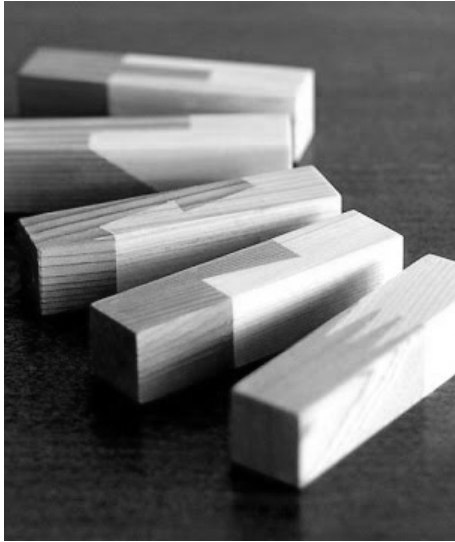
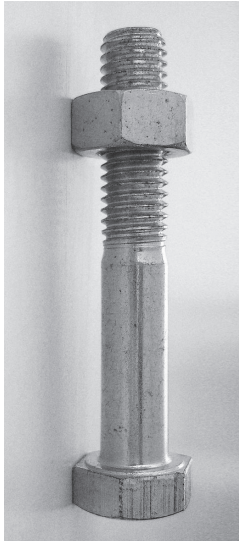
Connection 2

Sanded

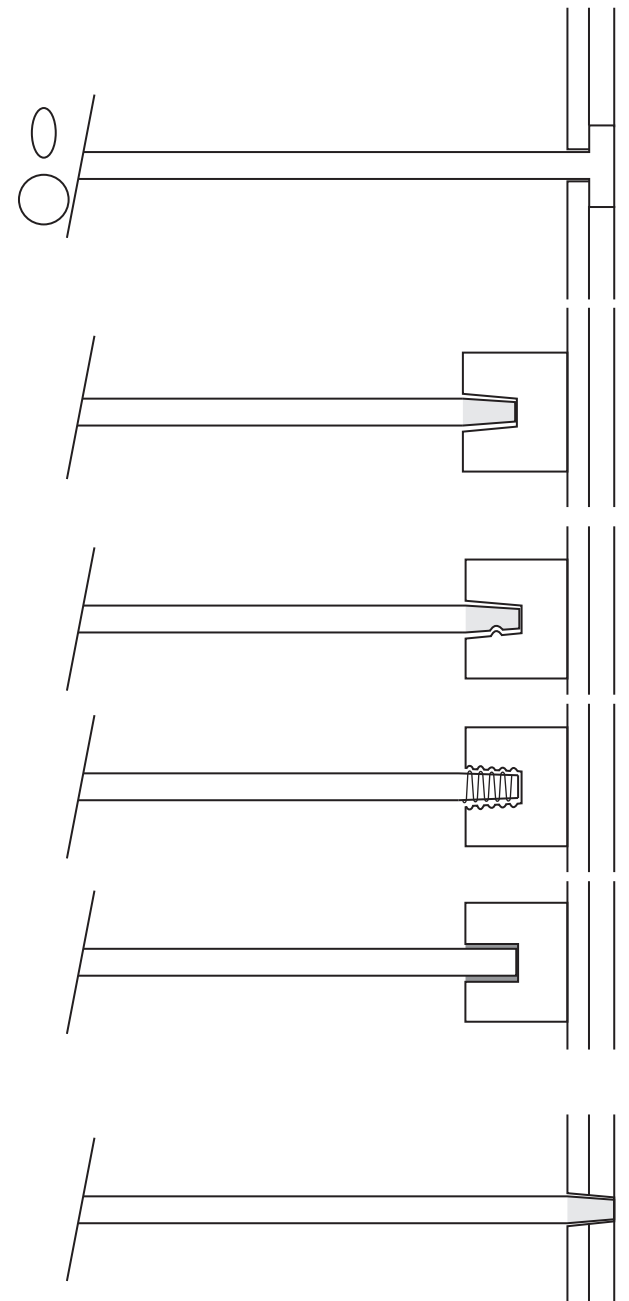
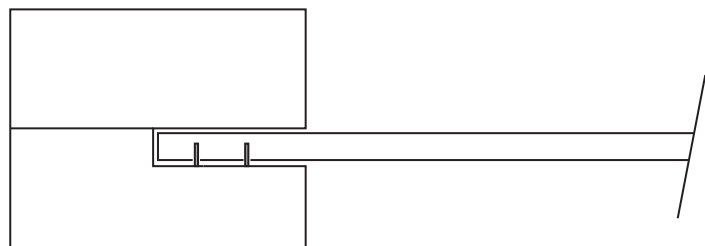
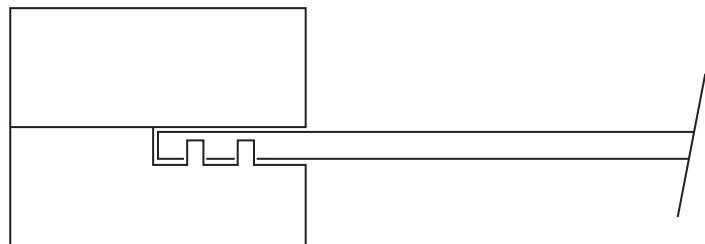
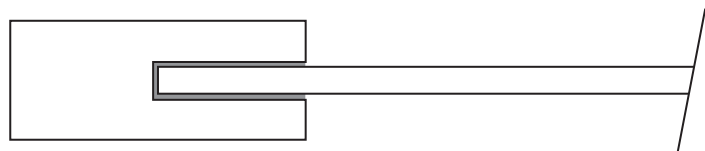
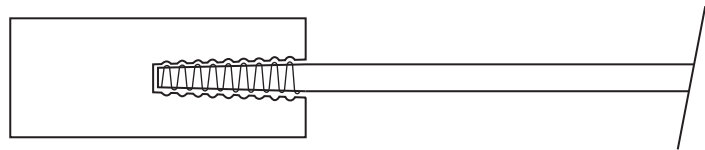
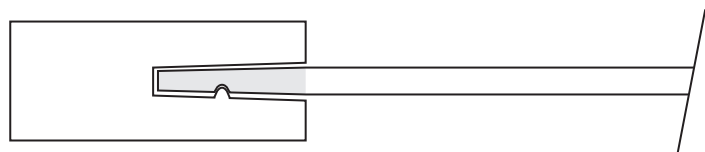
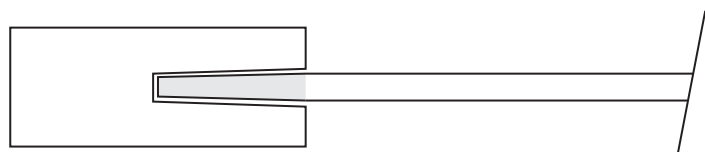
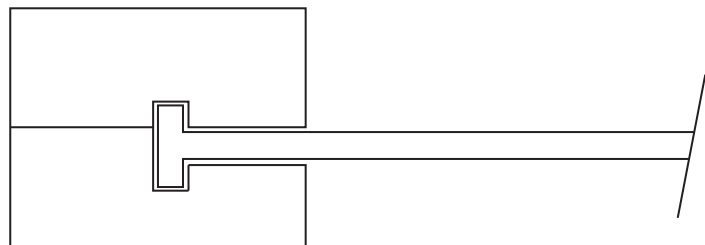


Connection 3

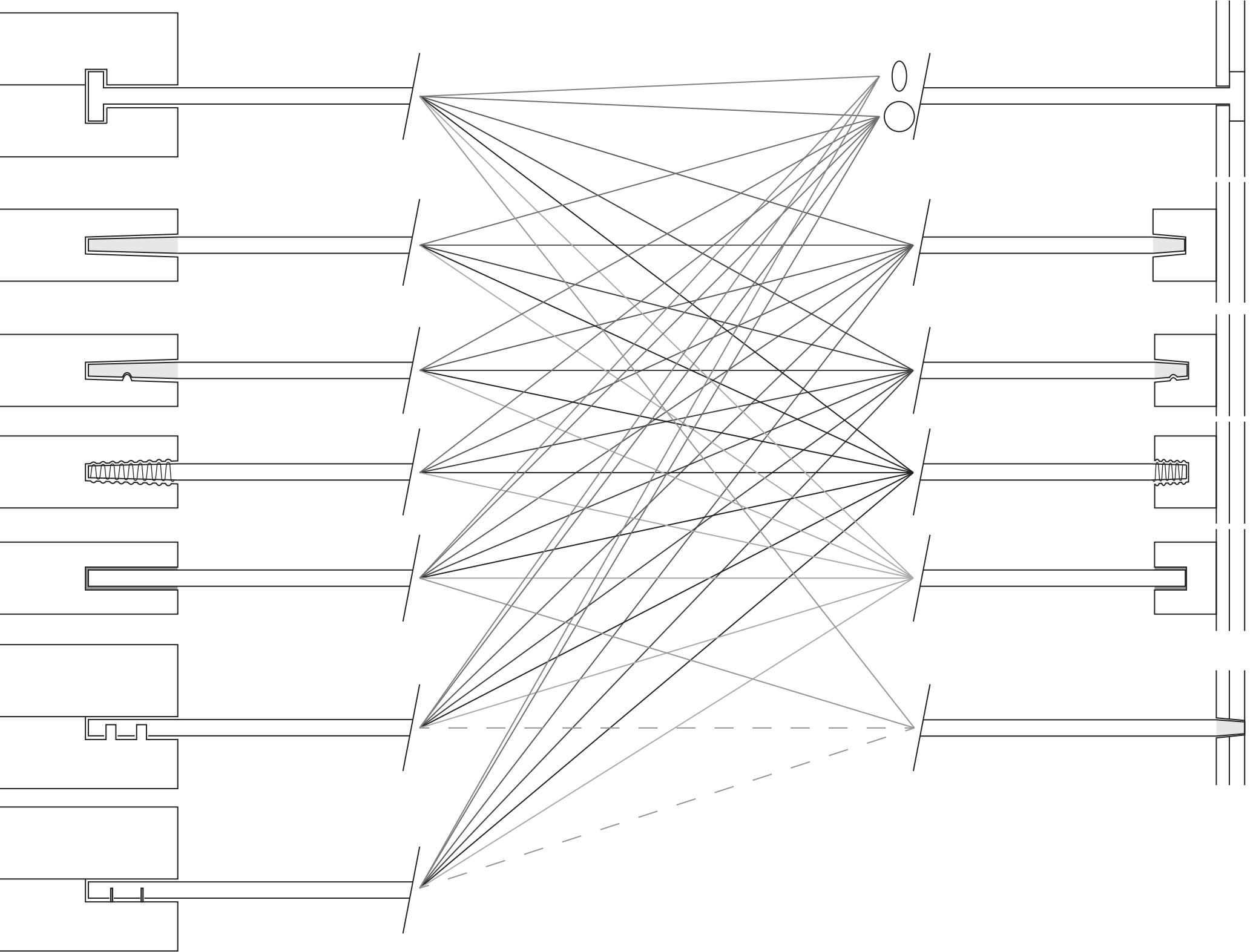
Profiled



Designed connections

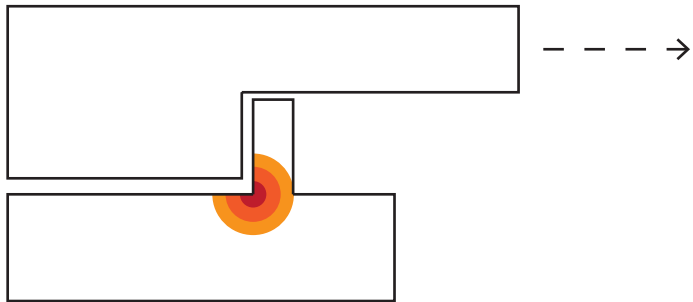


Designed connections



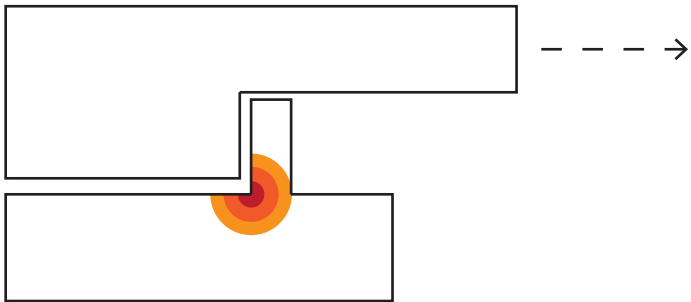
Criteria

Stress concentrations

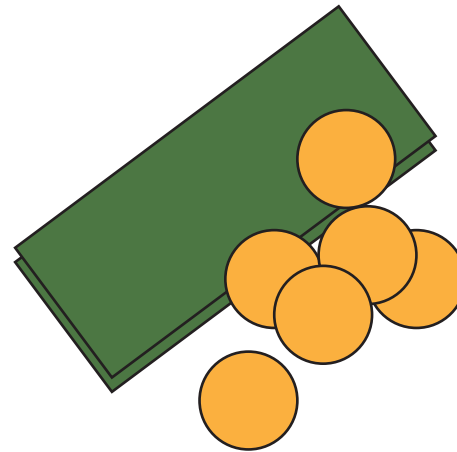


Criteria

Stress concentrations

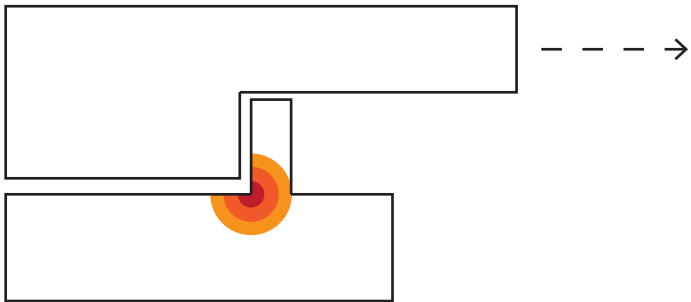


Manufacturing ease and costs

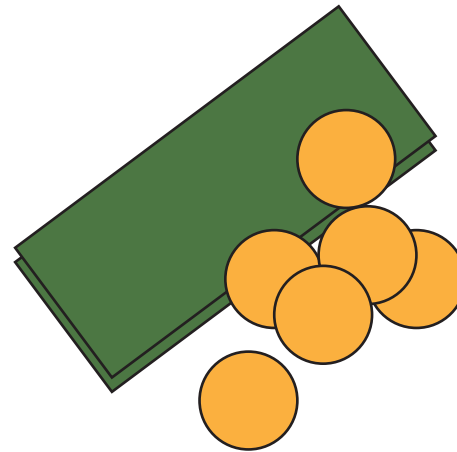


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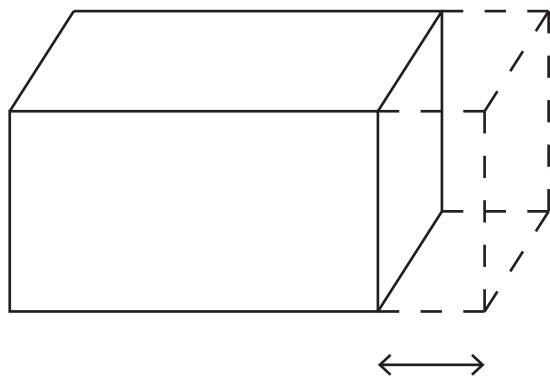
Stress concentrations



Manufacturing ease and costs

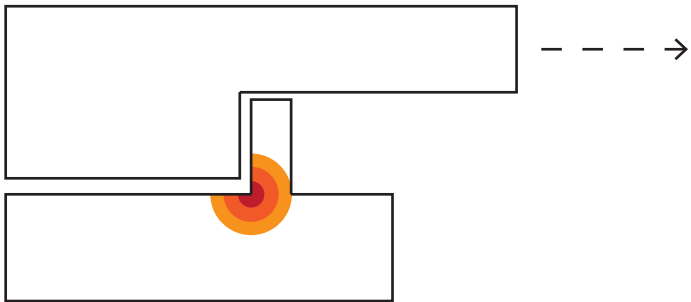


Tolerances

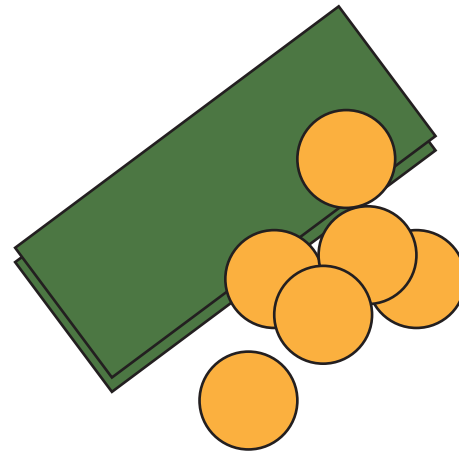


Criteria

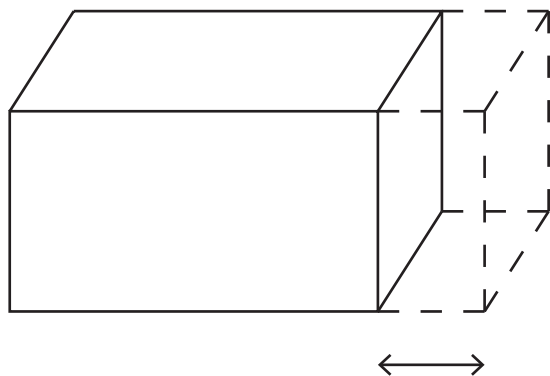
Stress concentrations



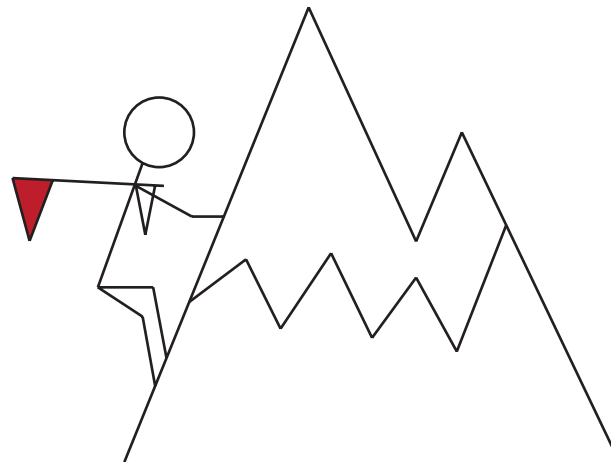
Manufacturing ease and costs



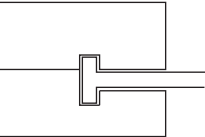
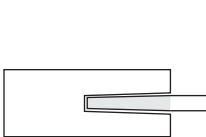
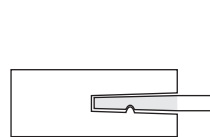
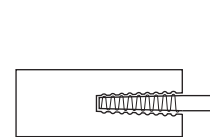
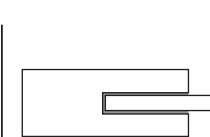
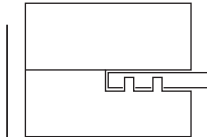
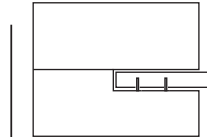
Tolerances



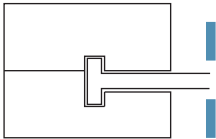
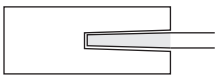
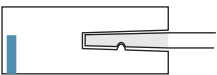
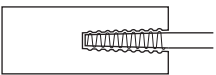
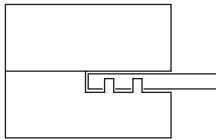
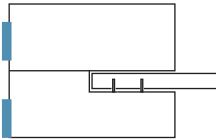
Challenging



Choose connections

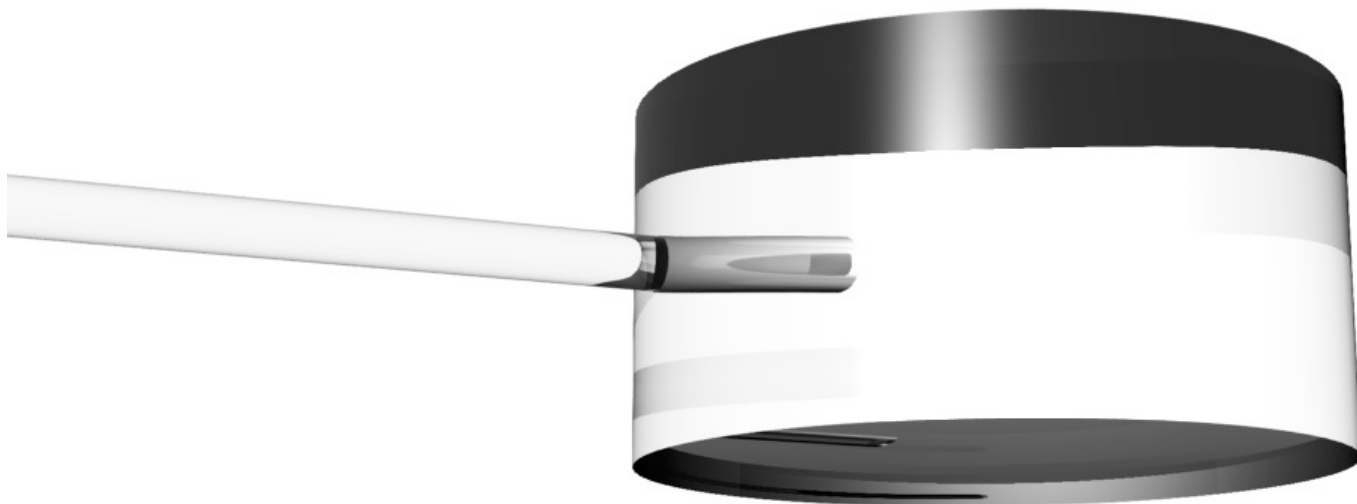
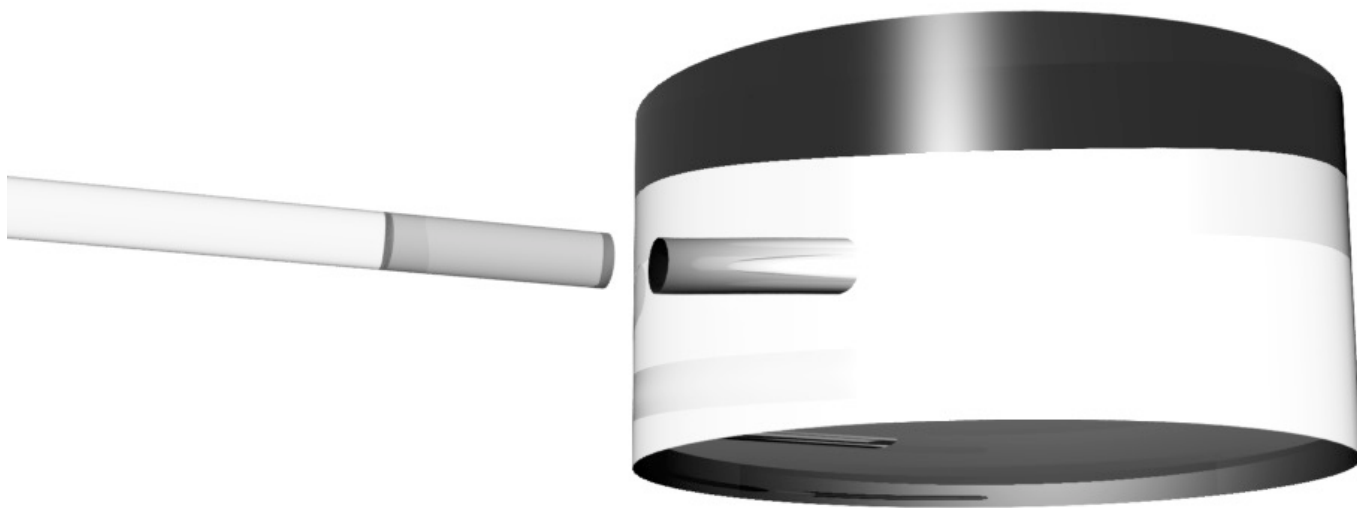
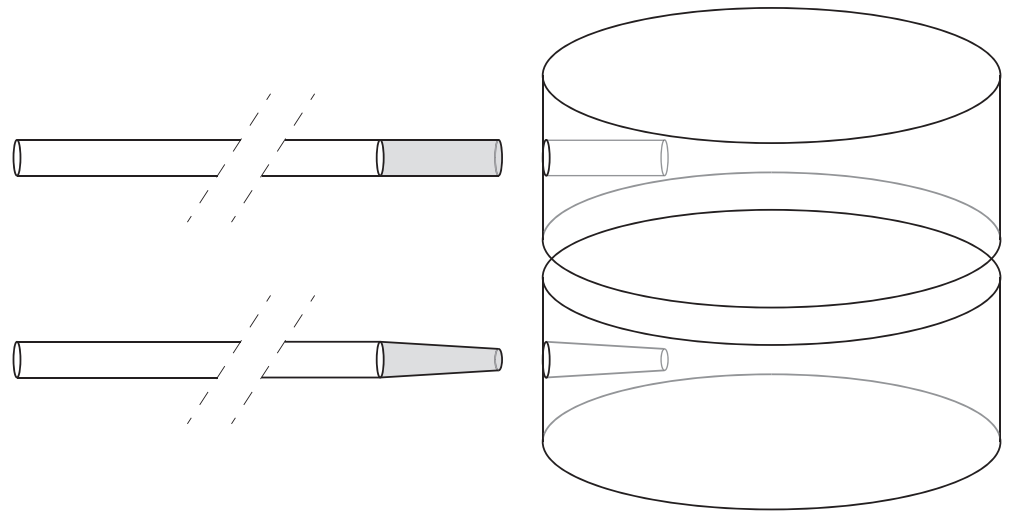
							
Stress concentrations	● ● ● ○ ○	● ● ● ● ○	● ● ○ ○ ○	● ○ ○ ○ ○	● ● ● ● ○	● ○ ○ ○ ○	● ○ ○ ○ ○
Manufacturing ease / cost	● ○ ○ ○ ○	● ● ● ● ●	● ● ● ○ ○	● ○ ○ ○ ○	● ● ● ● ●	● ● ● ● ●	● ● ● ○ ○
Tolerances	● ● ● ● ●	● ○ ○ ○ ○	● ○ ○ ○ ○	● ○ ○ ○ ○	● ● ● ○ ○	● ● ● ● ●	● ● ● ● ●
Challenging	● ● ● ● ○	● ● ● ● ●	● ● ● ● ●	● ● ● ● ●	● ○ ○ ○ ○	● ● ● ● ●	● ○ ○ ○ ○

Choose connections

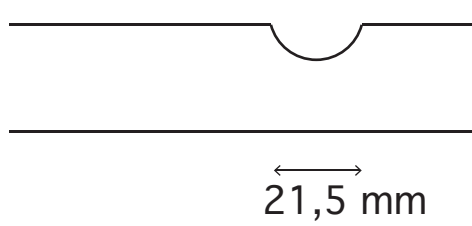
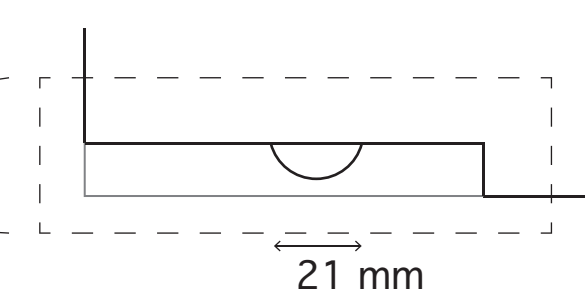
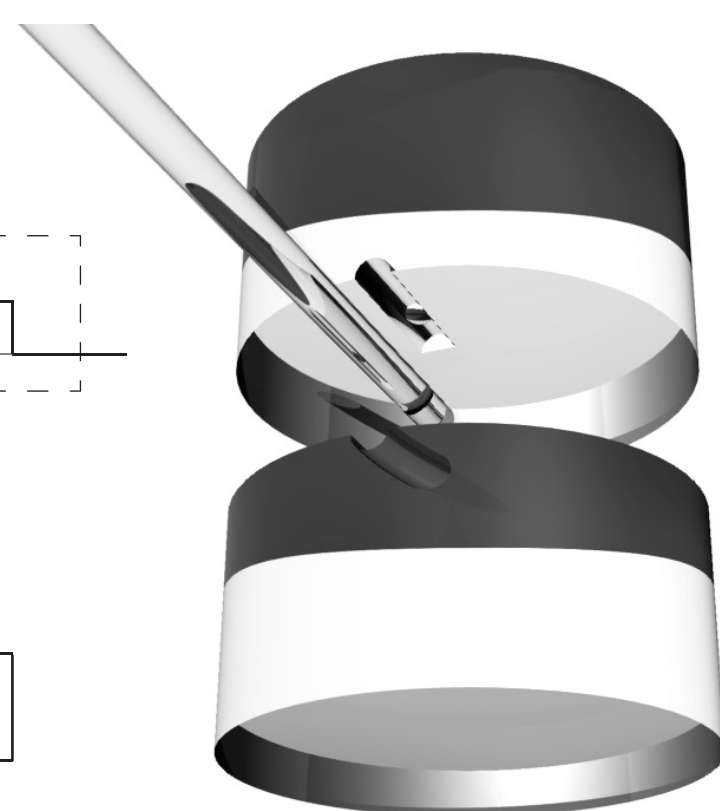
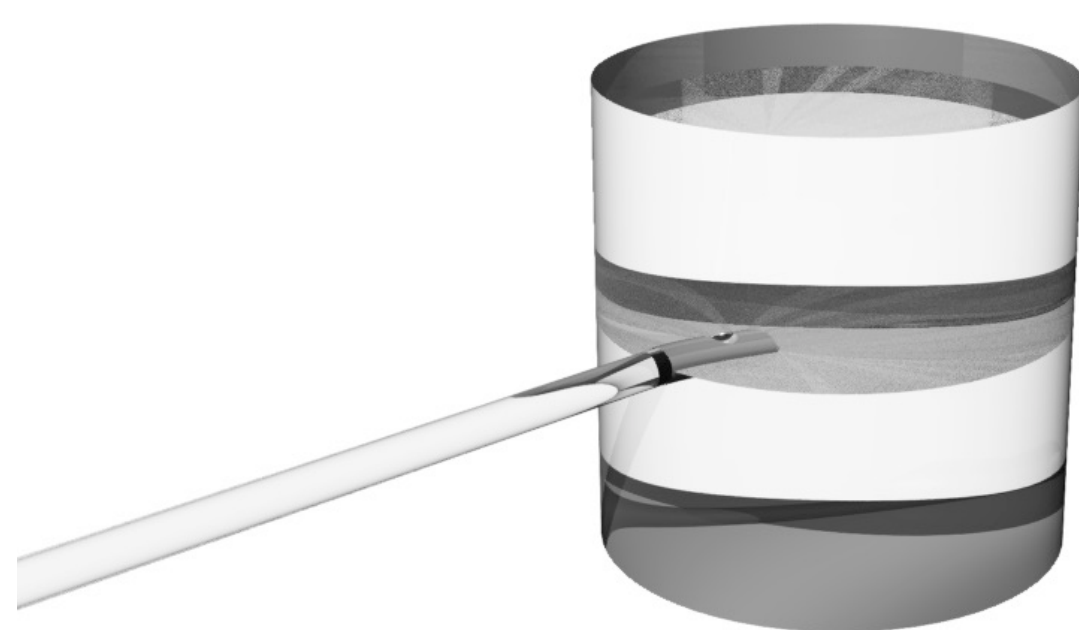
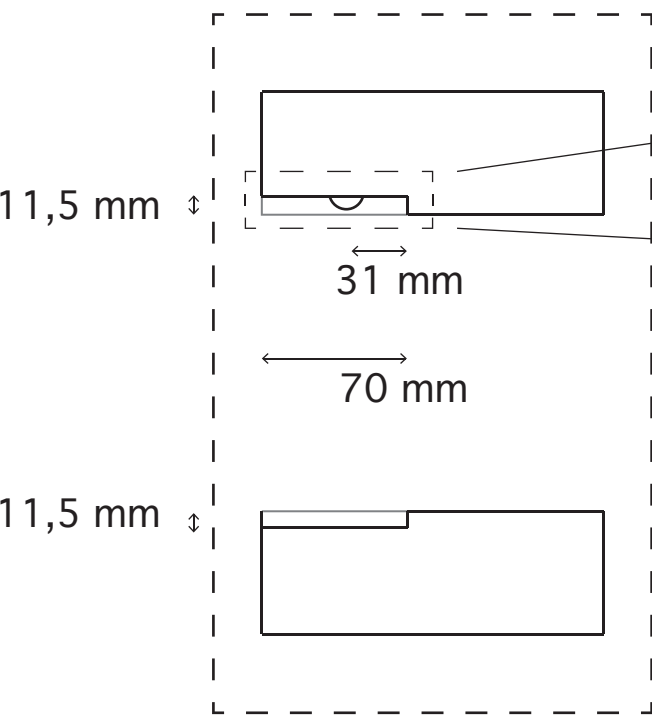
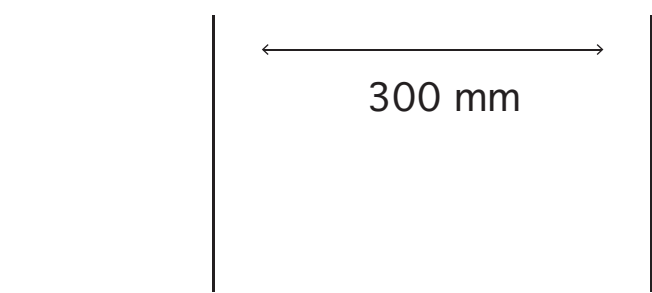
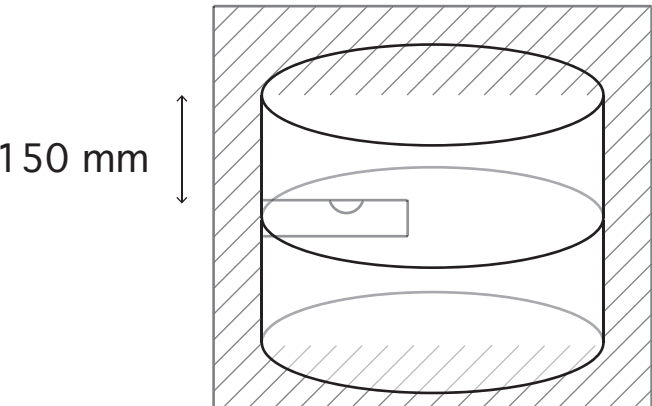
							
Stress concentrations							
Manufacturing ease / cost							
Tolerances							
Challenging							

Final designs

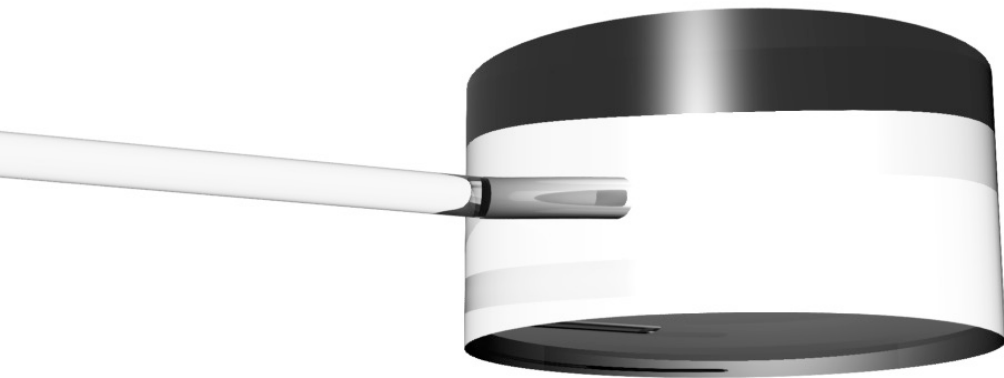
Sanded design



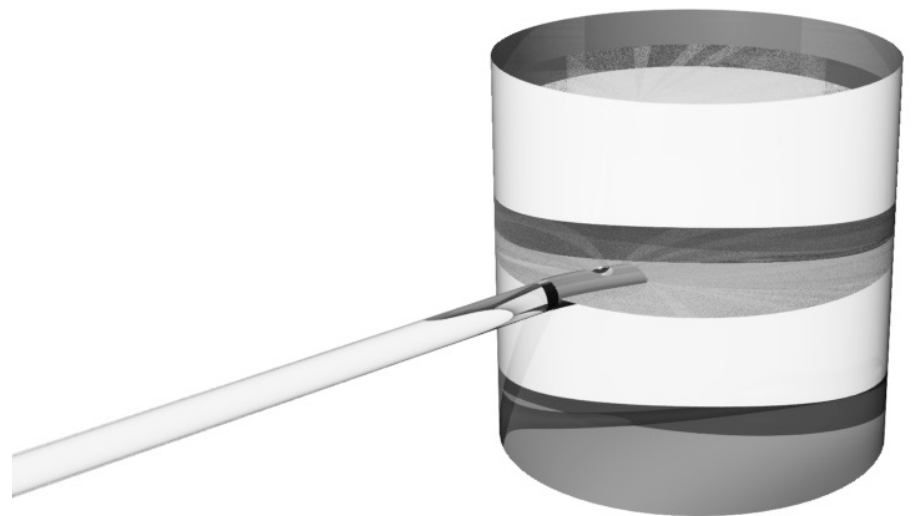
Profiled design



Comparing



- Full accuracy
- Unsure mechanical connection
- + Homogenous stress distribution
- + Production ease



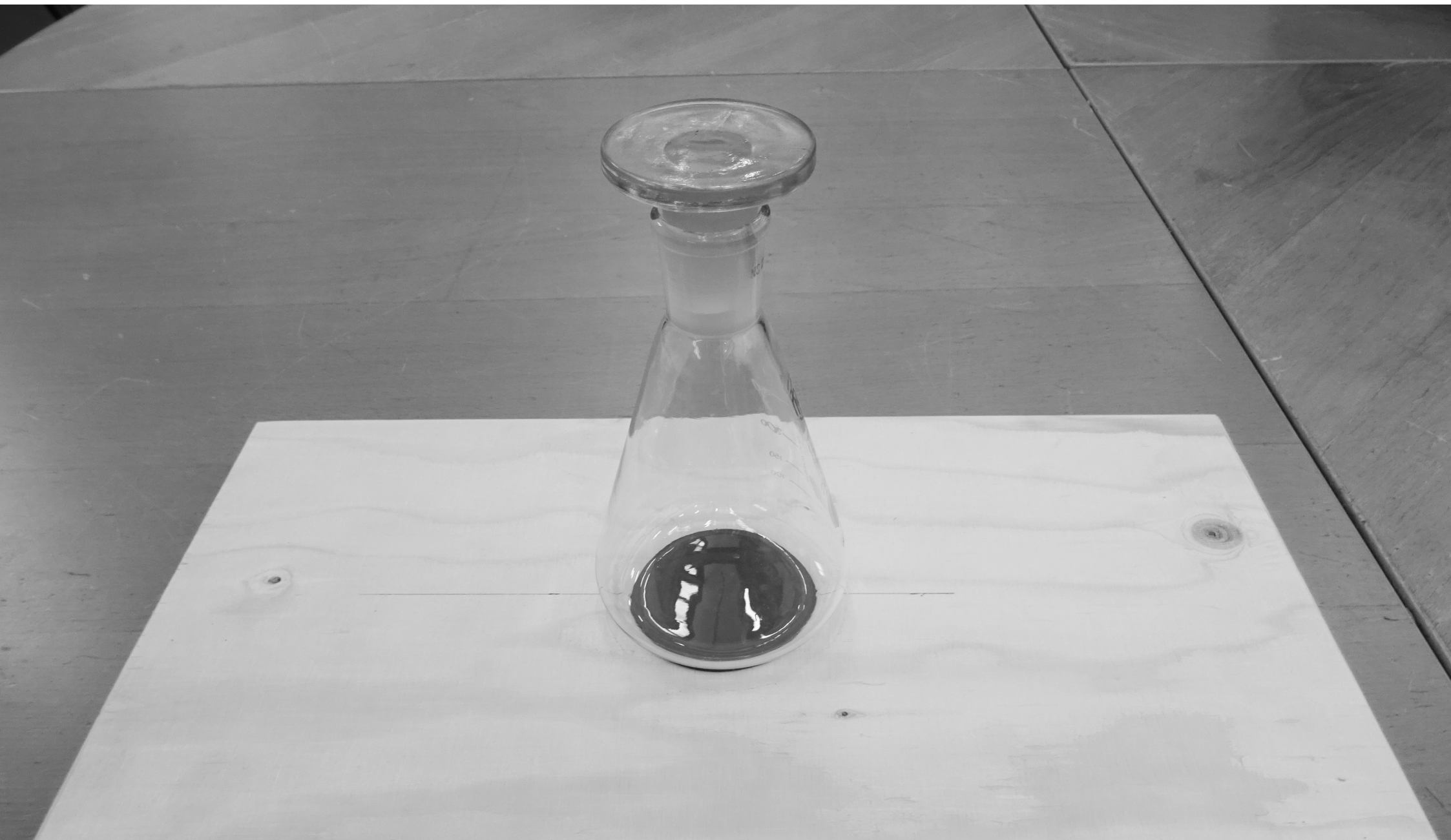
- + More tolerances
- + Connecting capacity
- Peak stresses
- Less production ease

Experiments

Experiments

Sanded design

Test set up



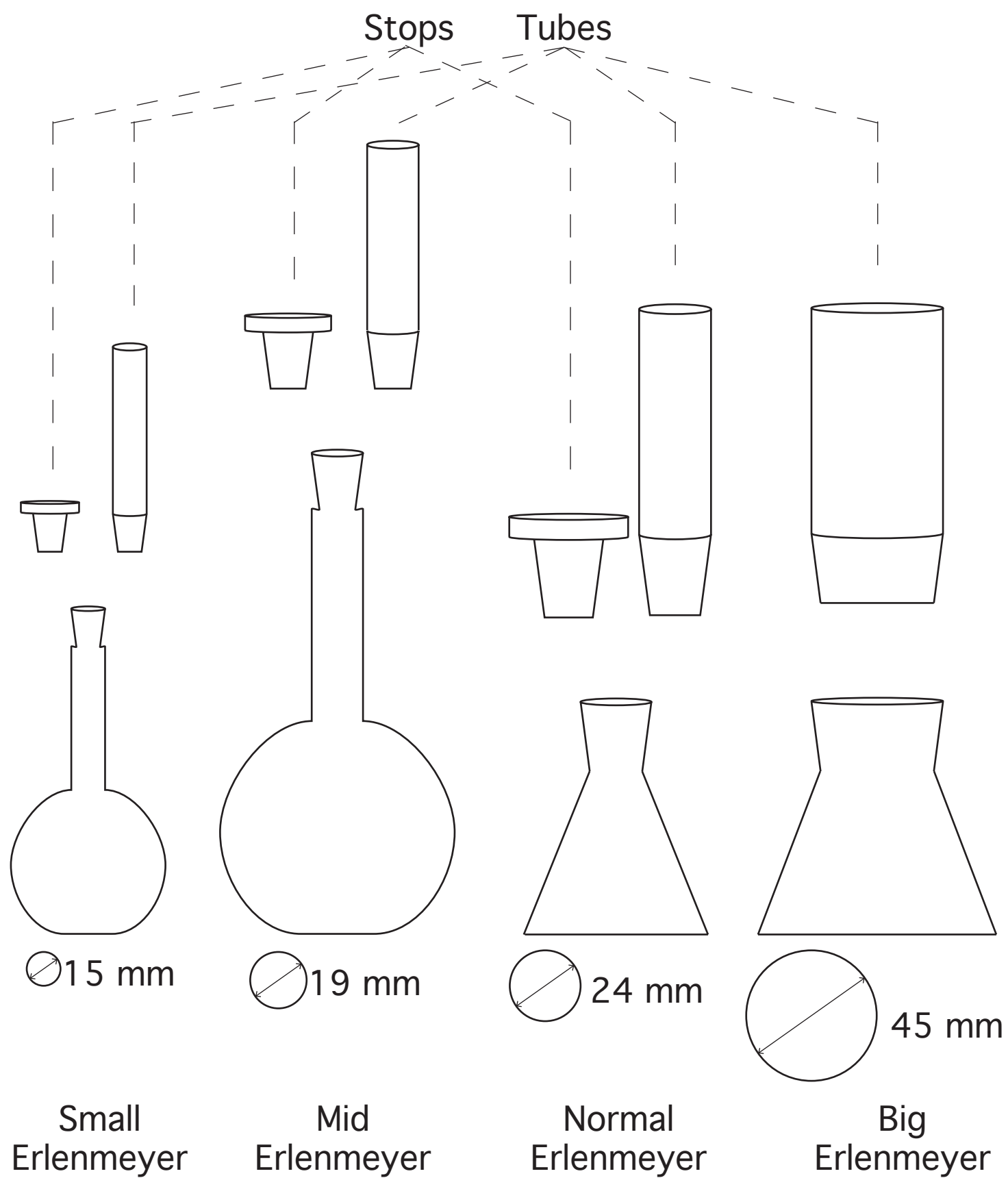
Test set up



Test set up



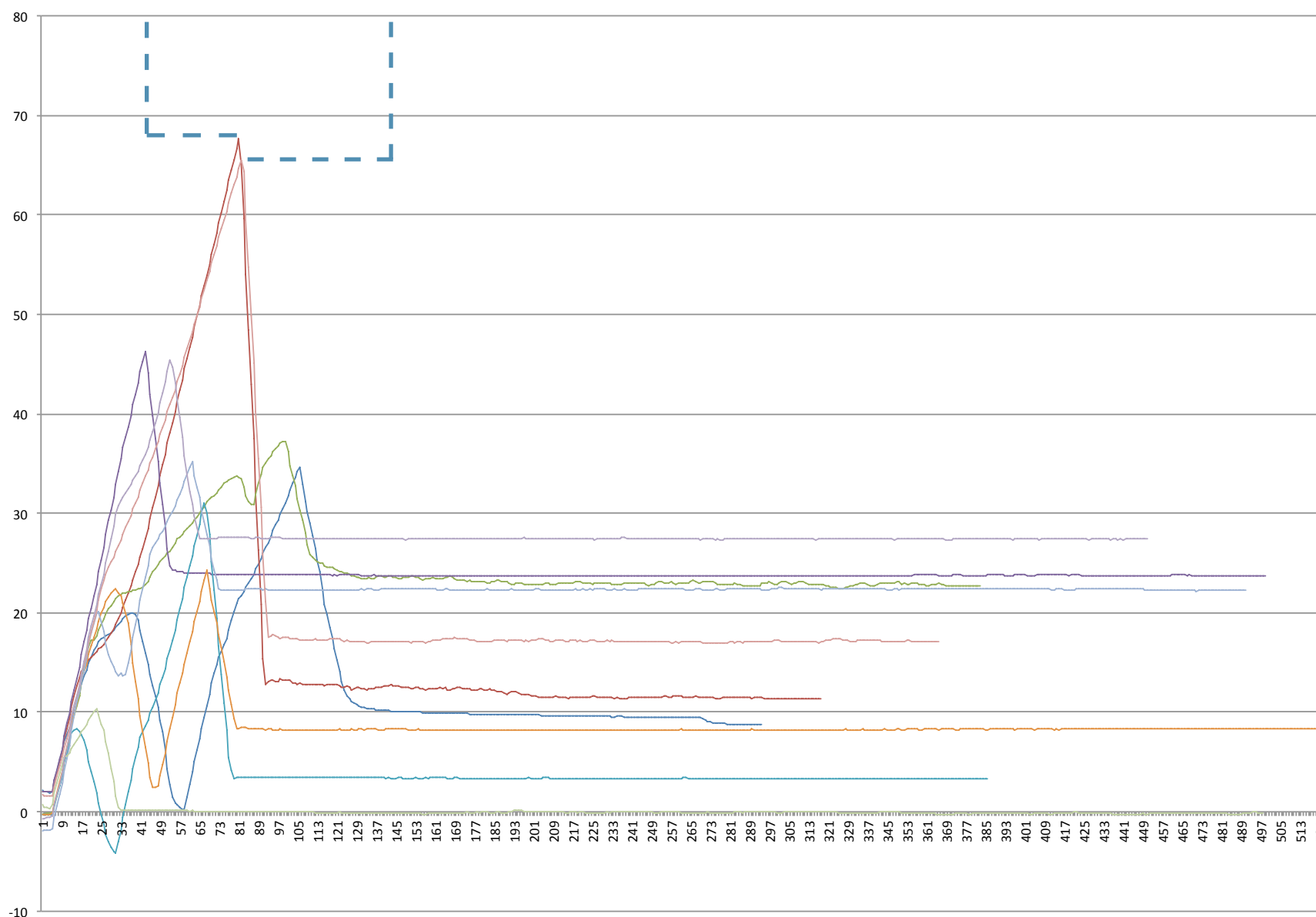
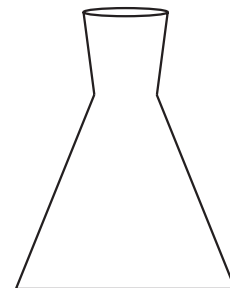
Test set up



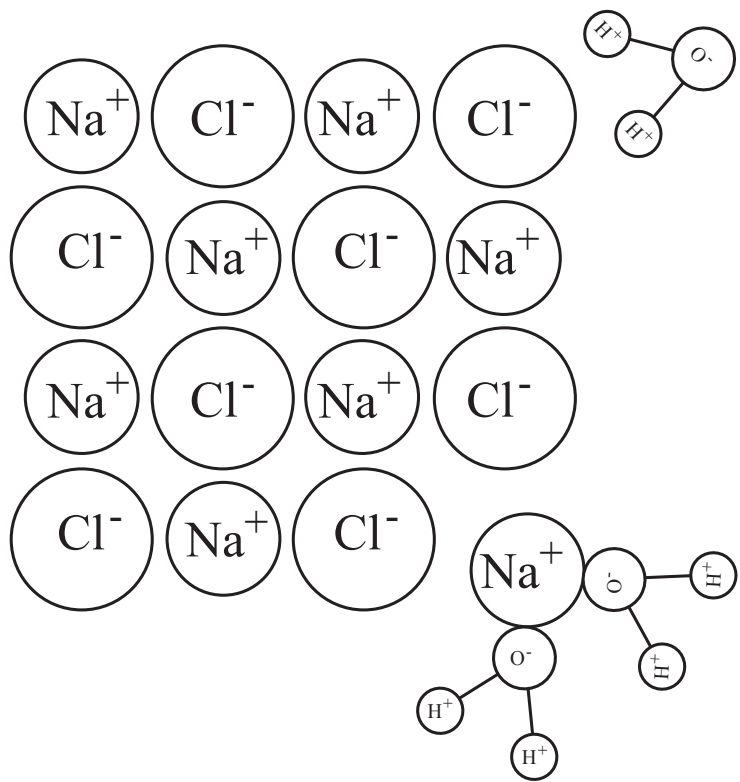
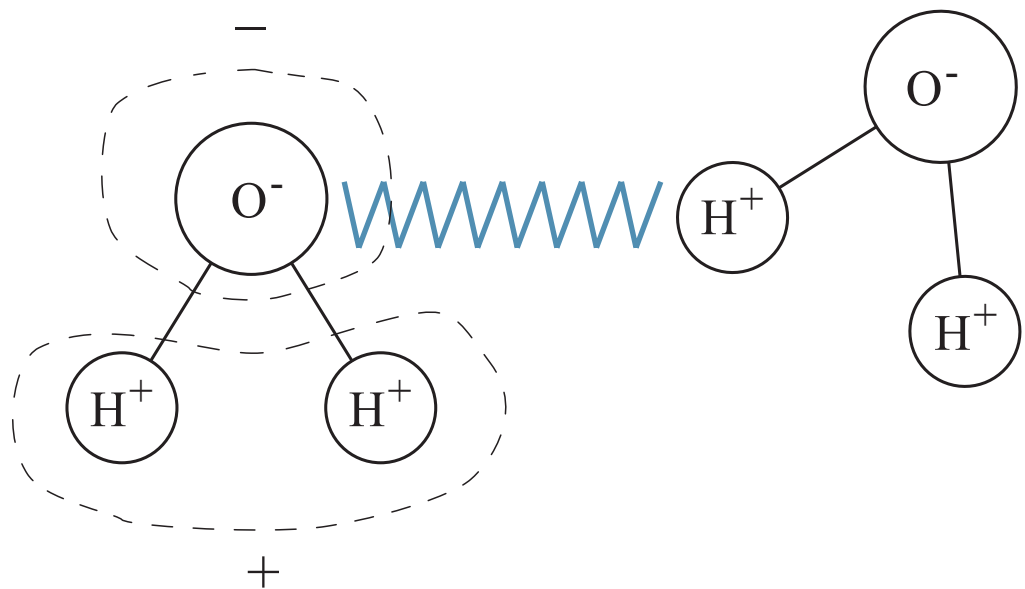
First test



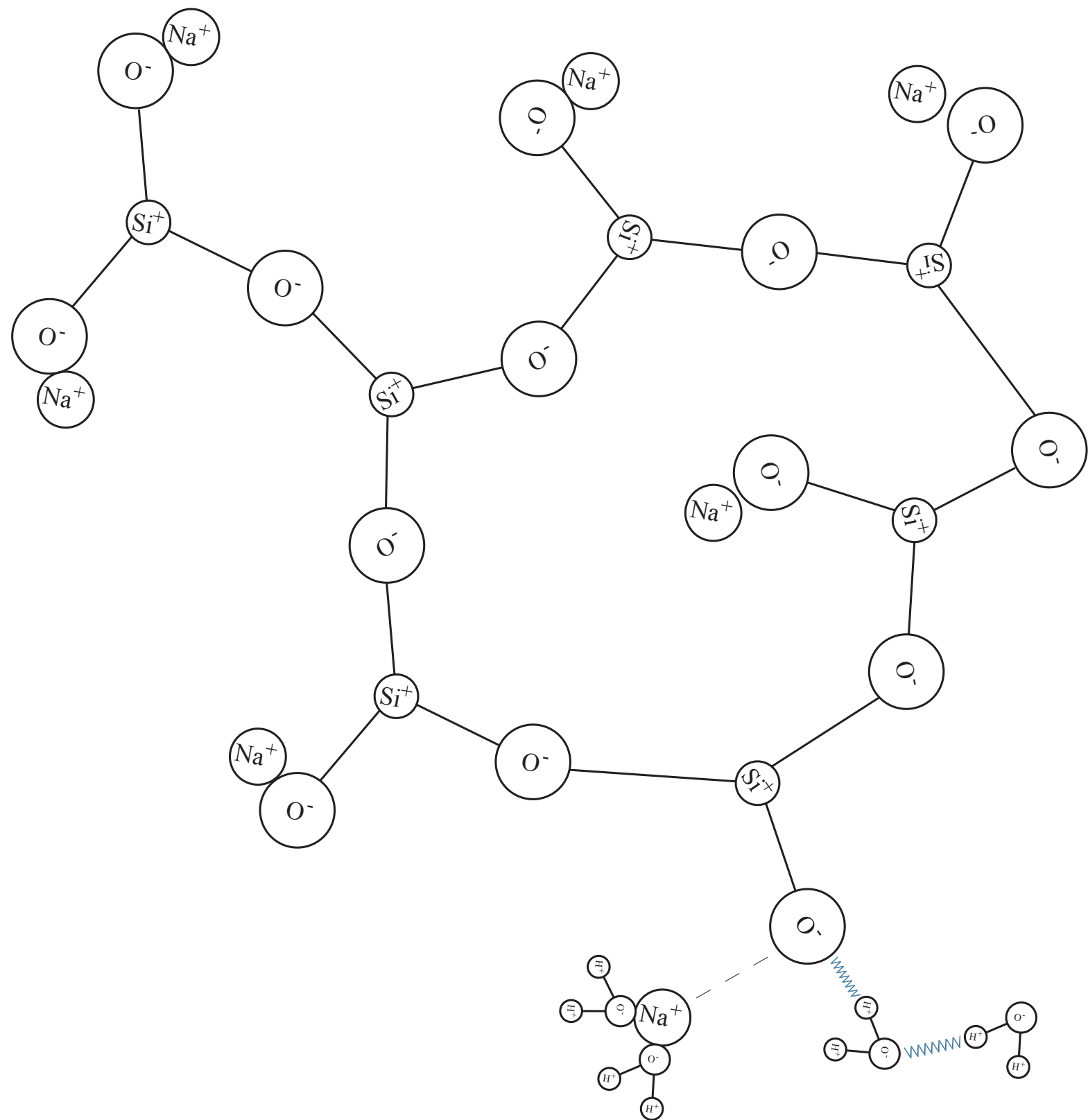
First test



Water study



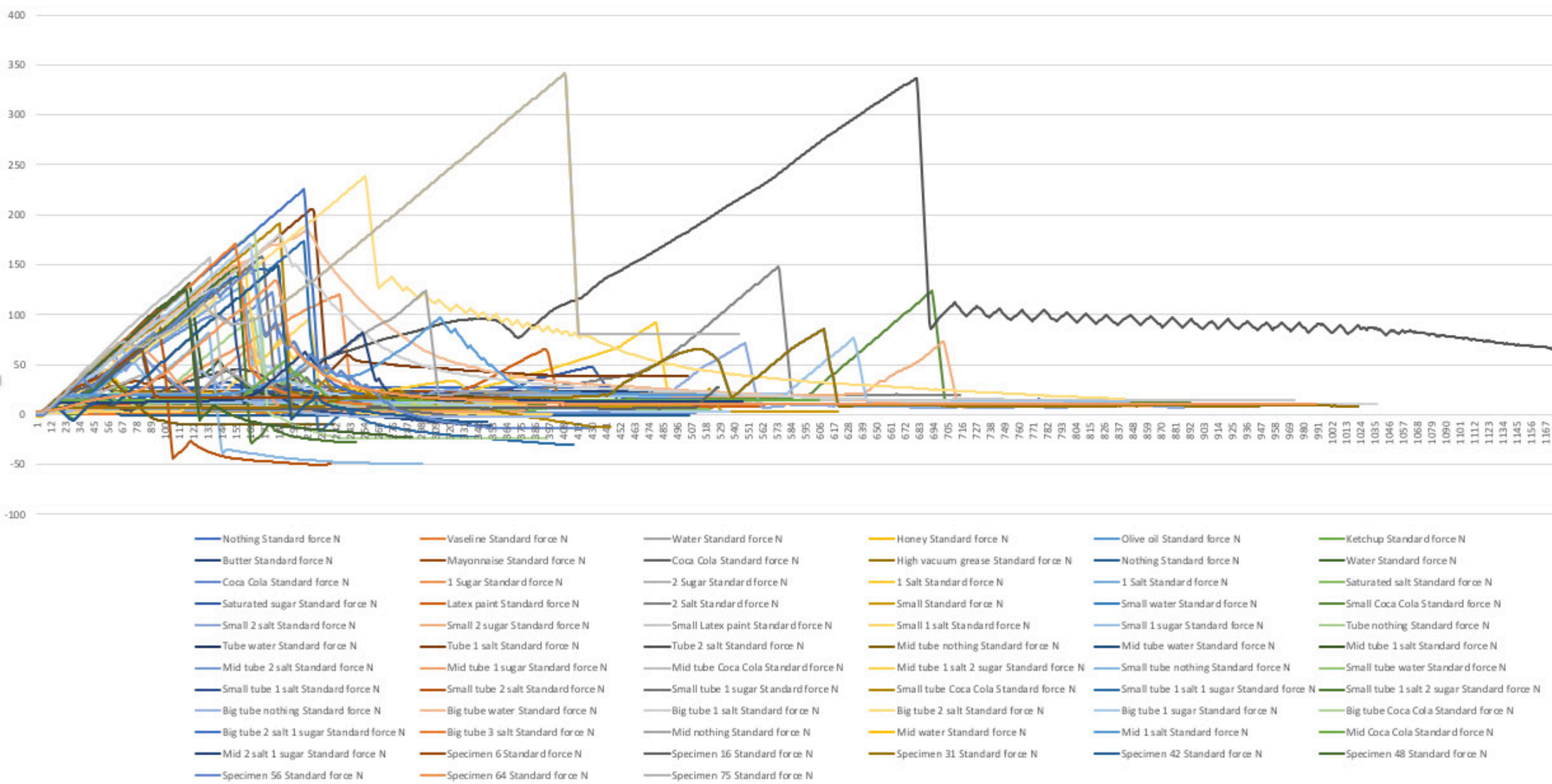
Water study



List of all used liquids

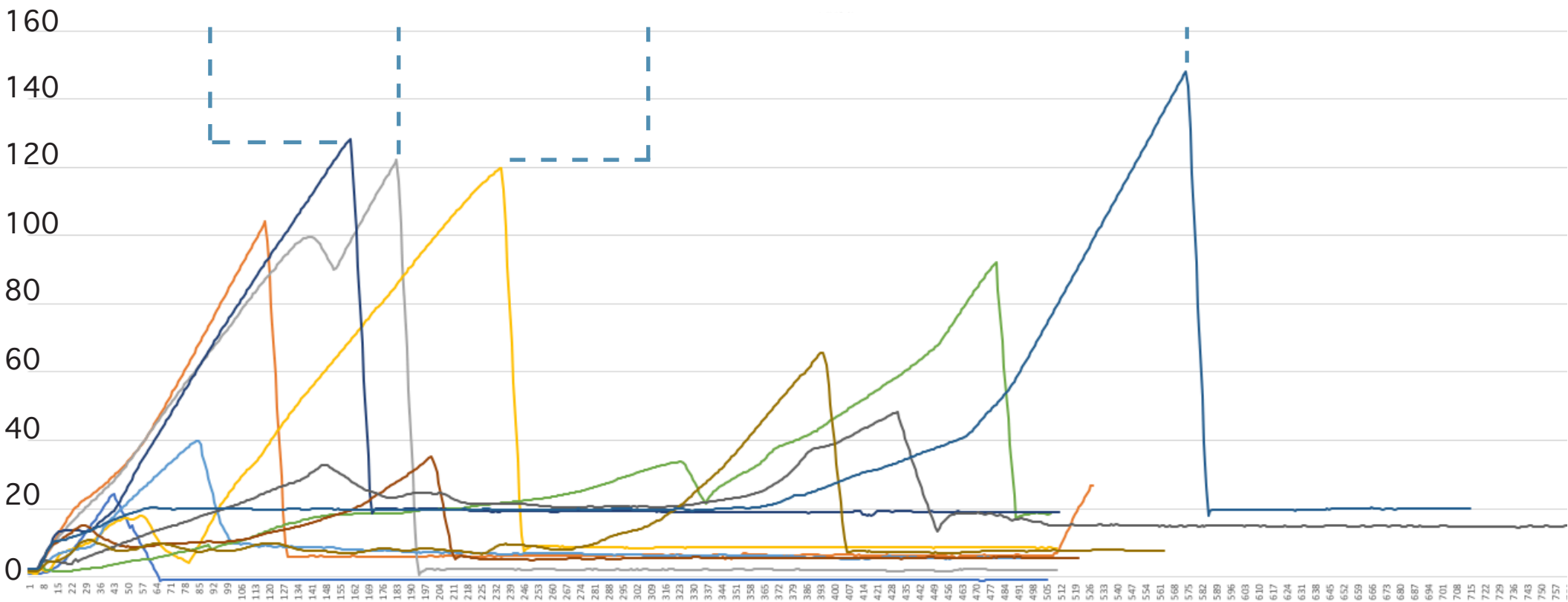
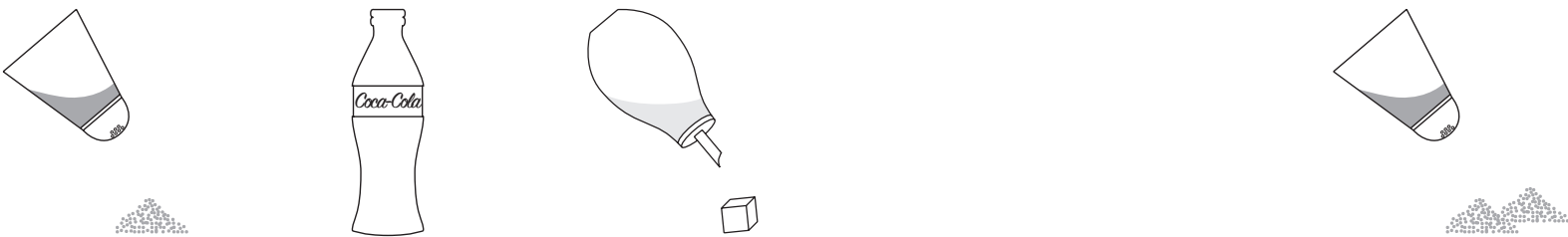
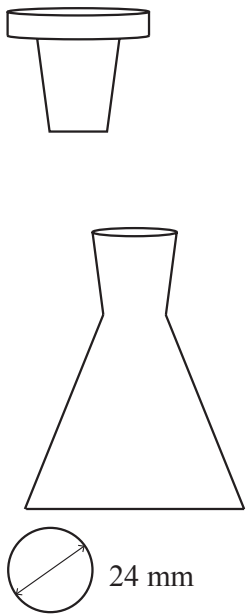
- | | | |
|-------------------------------------|-----------------------------------|----------------------------|
| 01 - | 31 Small one water | 60 Mid tube 1 sugar |
| 02 - | 32 Small one Coca Cola | 61 Mid tube Coca Cola |
| 03 Nothing | 33 Small one 2 salt | 62 Mid tube 1 salt 2 sugar |
| 04 - | 34 Small one 2 sugar | |
| 05 Vaseline | 35 Small one Latex paint | 63 Big tube nothing |
| 06 Water | 36 “ | 64 Big tube water |
| 07 Honey | | 65 “ |
| 08 Olive oil | 37 2 Salt | 66 Big tube 1 salt |
| 09 Ketchup | 38 Small one 1 salt | 67 “ |
| 10 Butter | 39 Small one 1 sugar | 68 Big tube 2 salt– |
| 11 Mayonnaise | 40 Small one Coca Cola | 69 Big tube 1 sugar |
| 12 Coca Cola | 41 Tube nothing | 70 “ |
| 13 High vacuum grease–e | 42 Tube water | 71 Big tube Coca Cola |
| 14 “ | 43 Tube 1 salt | 72 Big tube 1 salt 2 sugar |
| | 44 Tube 2 salt | 73 Big tube 3 salt |
| 15 Nothing | 45 “ | 74 Mid one nothing |
| 16 Water | 46 “ | 75 Mid one water |
| 17 Coca Cola | | 76 Mid one 1 salt |
| 18 “ | 47 Small tube nothing | 77 “ |
| 19 1 sugar | 48 Small tube water | 78 Mid one Coca Cola |
| 20 2 sugar | 49 Small tube 1 salt | 79 Mid one 1 salt 2 sugar |
| 21 “ | 50 Small tube 2 salt | 80 - |
| 22 1 salt | 51 Small tube 1 sugar | 81 Mid one water |
| 23 2 salt | 52 Small tube Coca Cola | |
| 24 “ | 53 Small tube 1 salt 1 su-
gar | |
| 25 Saturated sugar | 54 Small tube 1 salt 2 su-
gar | |
| 26 Saturated sugar se-
cond pull | 55 Mid tube nothing | |
| | 56 Mid tube water | |
| 27 Saturated salt | 57 Mid tube 1 salt | |
| 28 Saturated sugar | 58 “ | |
| 29 Latex paint | 59 Mid tube 2 salt | |
| 30 Small one | | |

All tests



Relevant tests

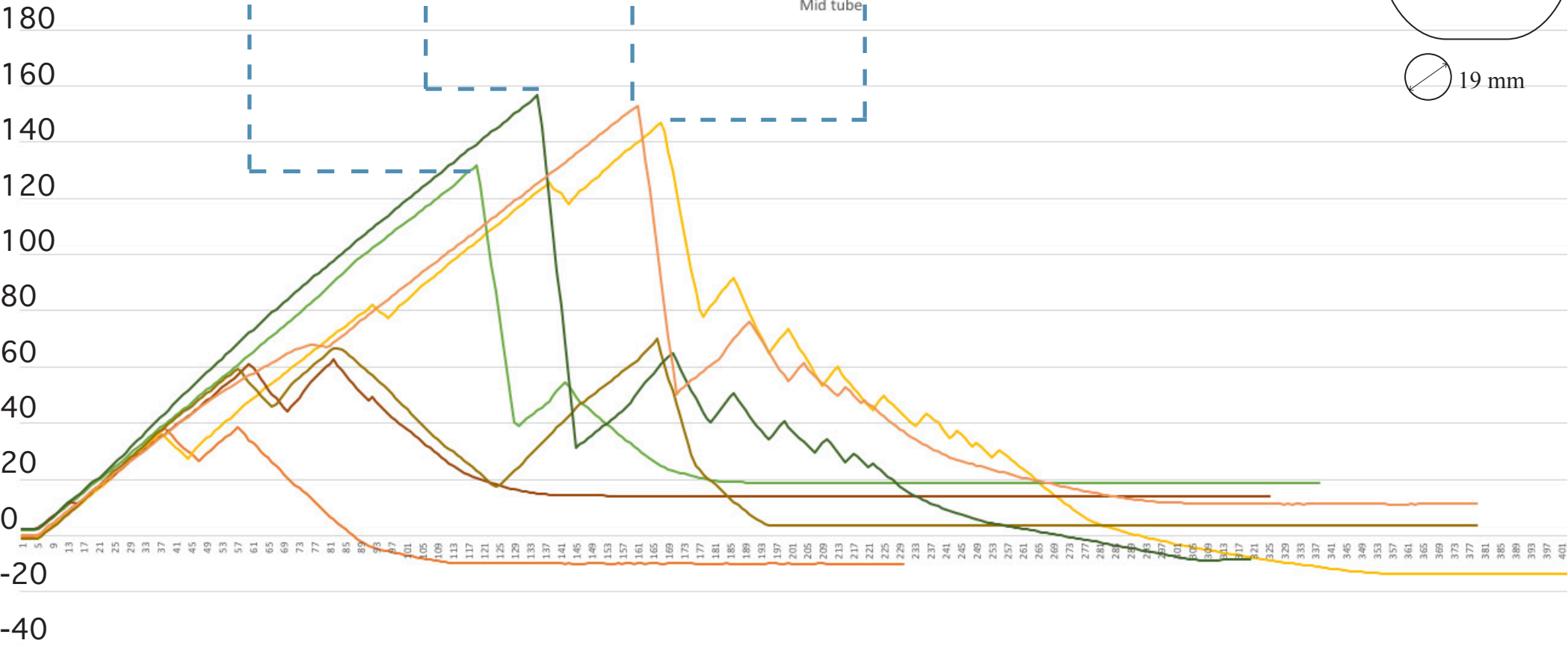
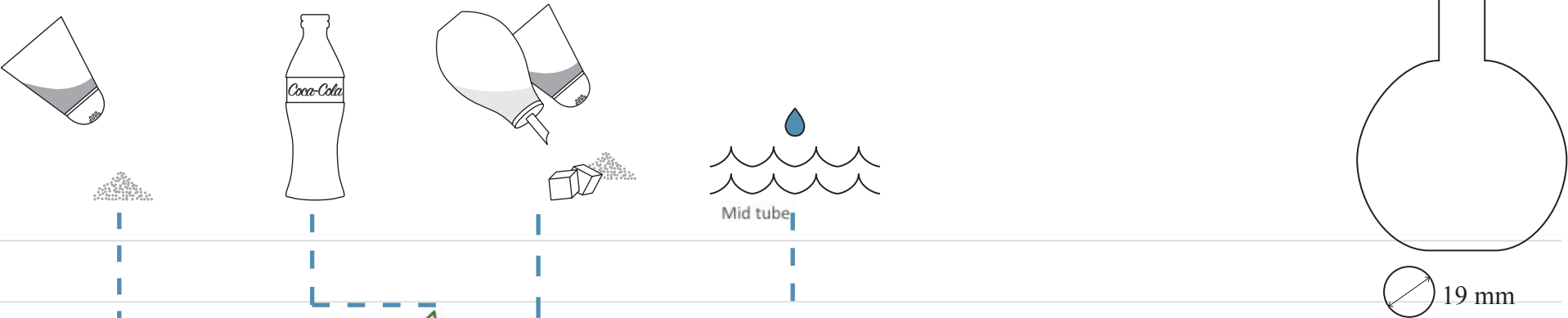
Normal fixed



- Nothing Standard force N
- 2 Sugar Standard force N
- Saturated sugar Standard force N
- Water Standard force N
- 1 Salt Standard force N
- Latex paint Standard force N
- Coca Cola Standard force N
- 1 Salt Standard force N
- 2 Salt Standard force N
- 1 Sugar Standard force N
- Saturated salt Standard force N

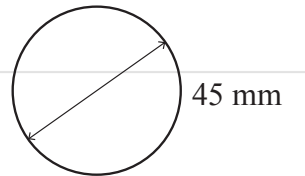
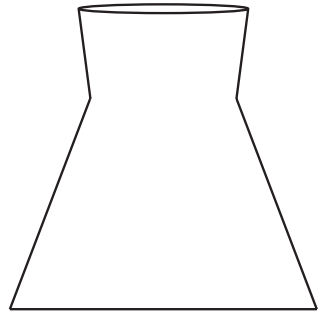
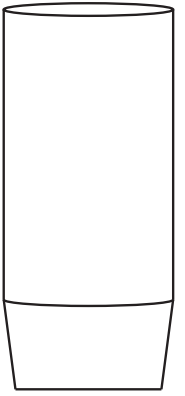
Relevant tests

Mid tube



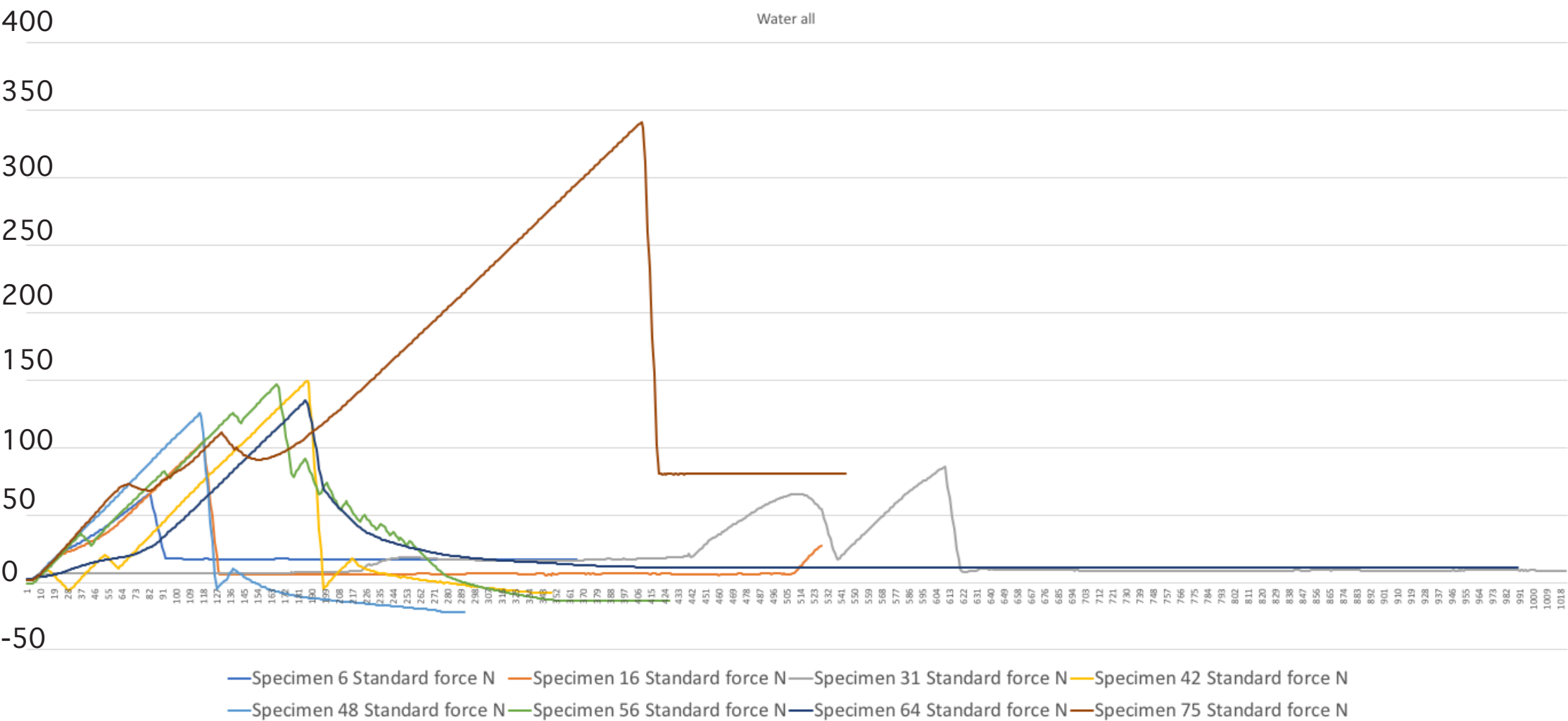
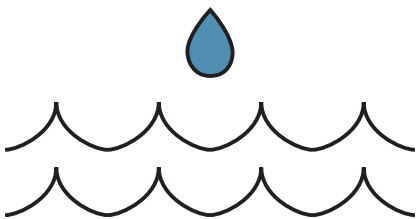
- Mid tube nothing Standard force N Mid tube water Standard force N Mid tube 1 salt Standard force N Mid tube 2 salt Standard force N
- Mid tube 1 sugar Standard force N Mid tube Coca Cola Standard force N Mid tube 1 salt 2 sugar Standard force N

Big tube



Relevant tests

Water



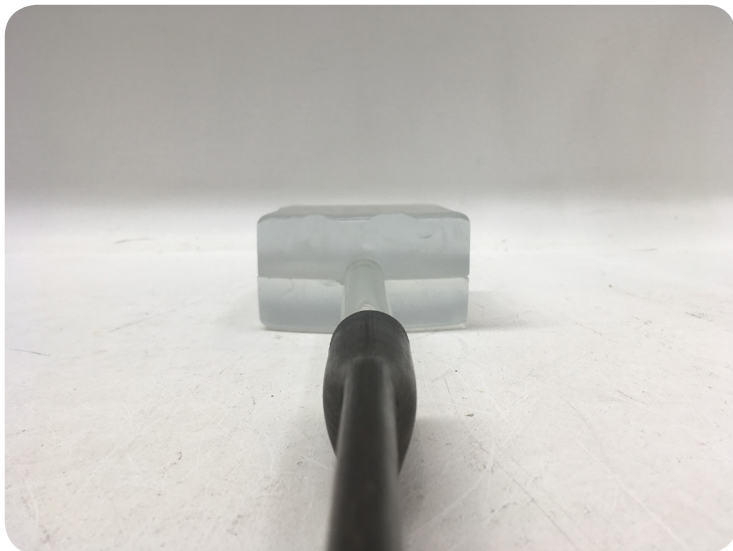
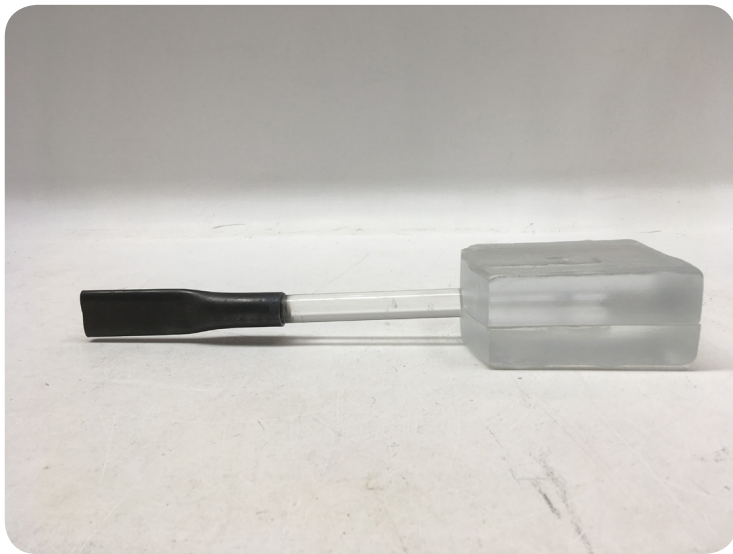
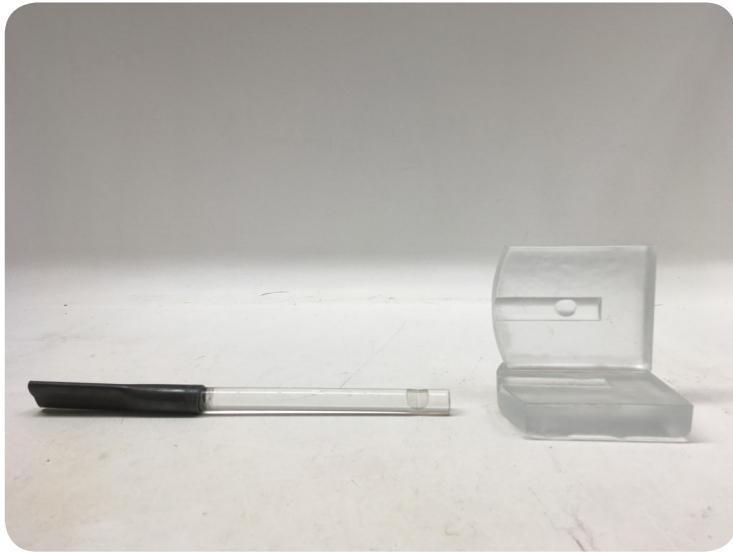
Conclusion



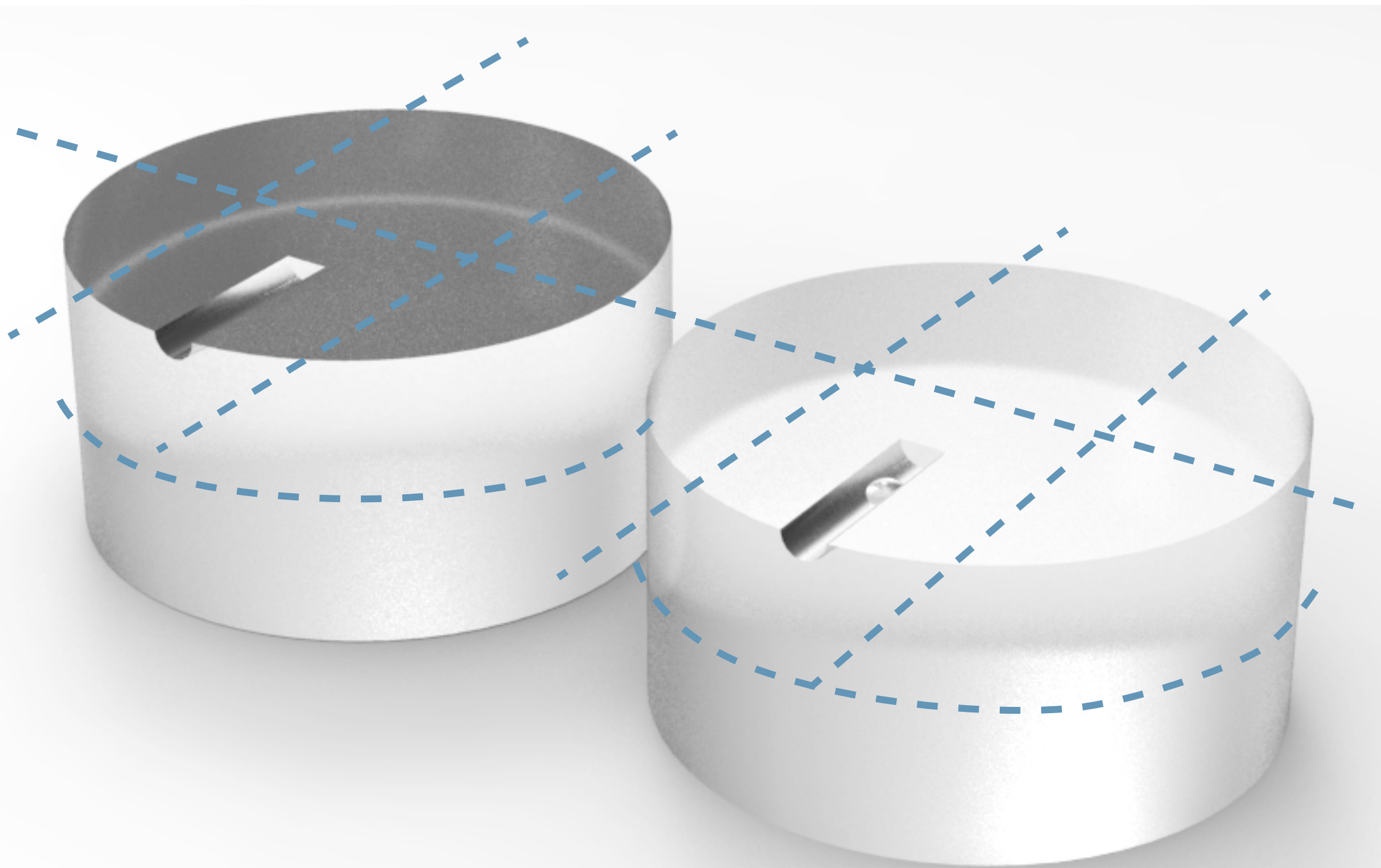
Experiments

Profiled design

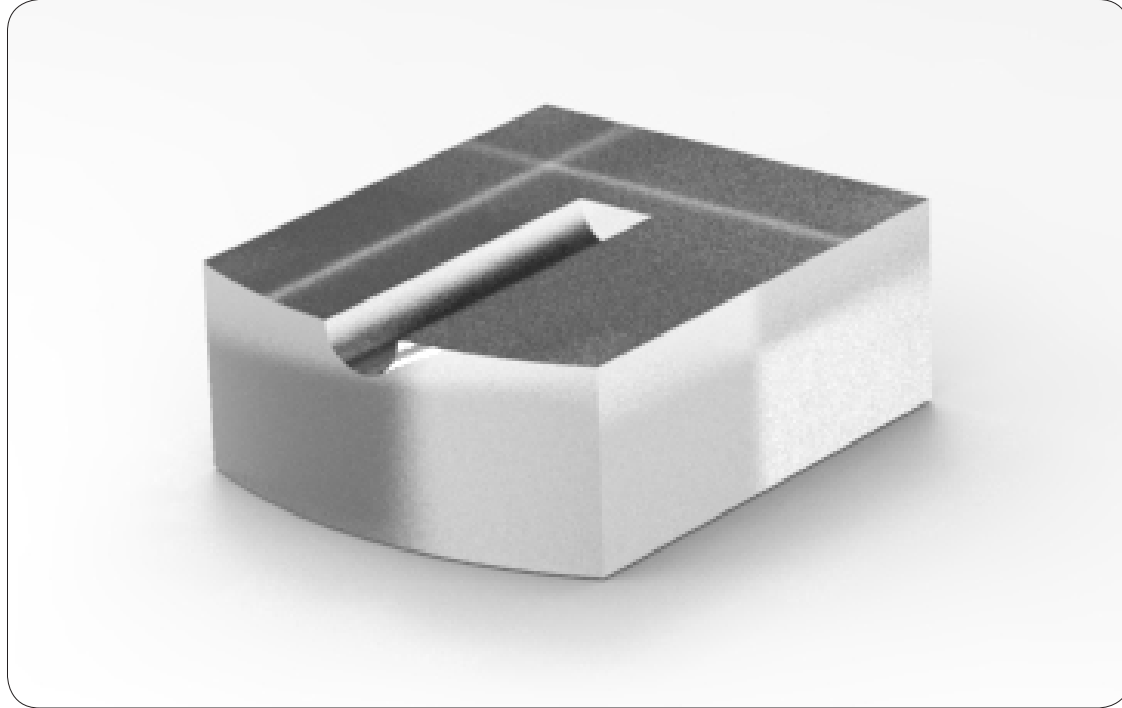
Test set up



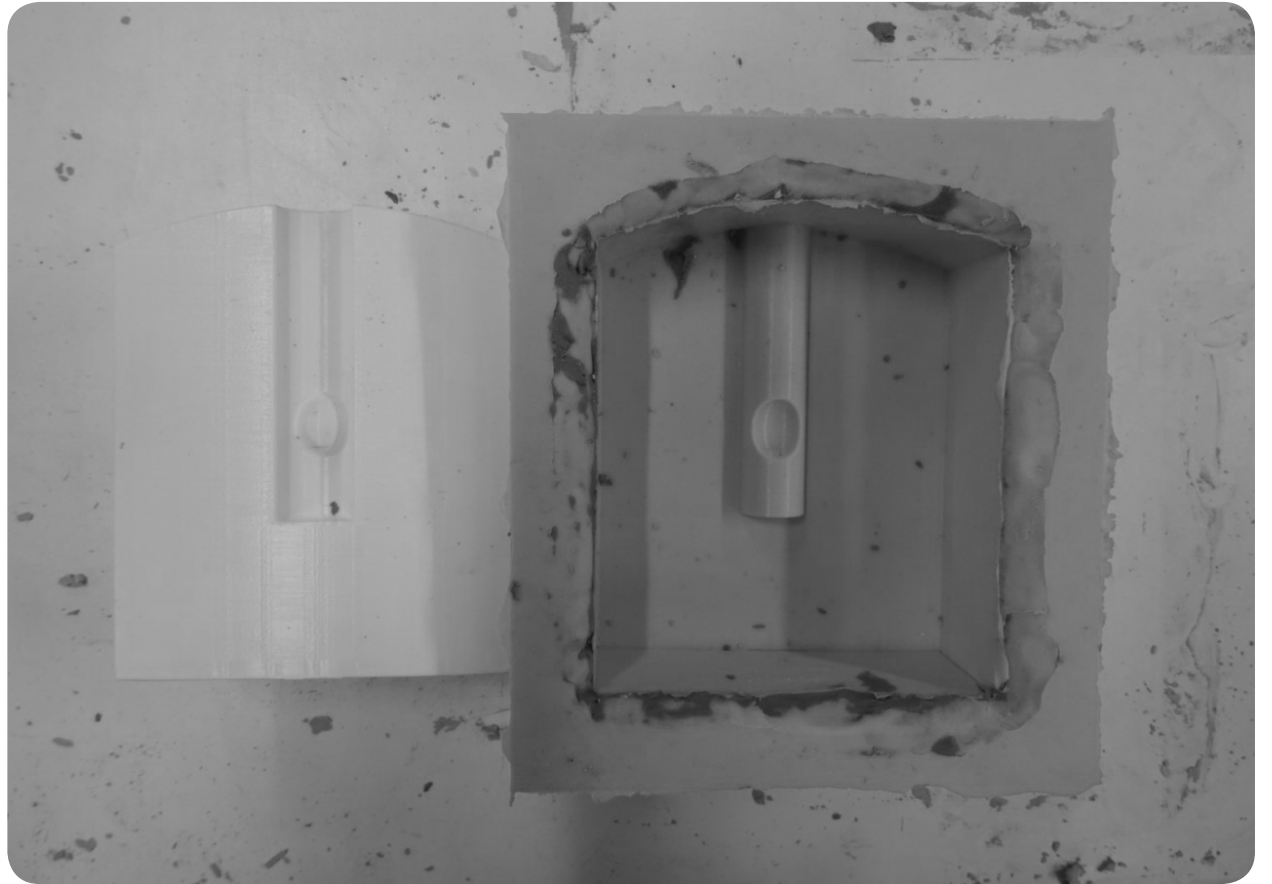
My glass



My glass



My glass



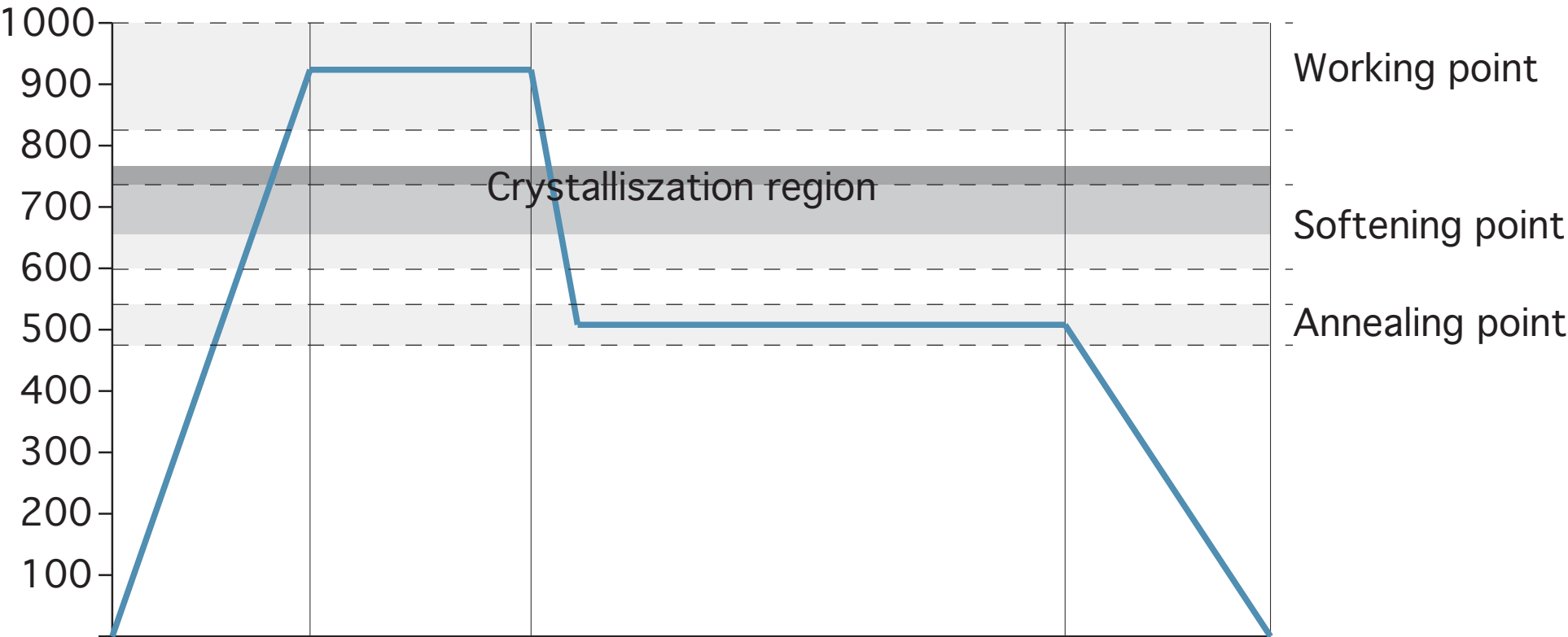
My glass



My glass



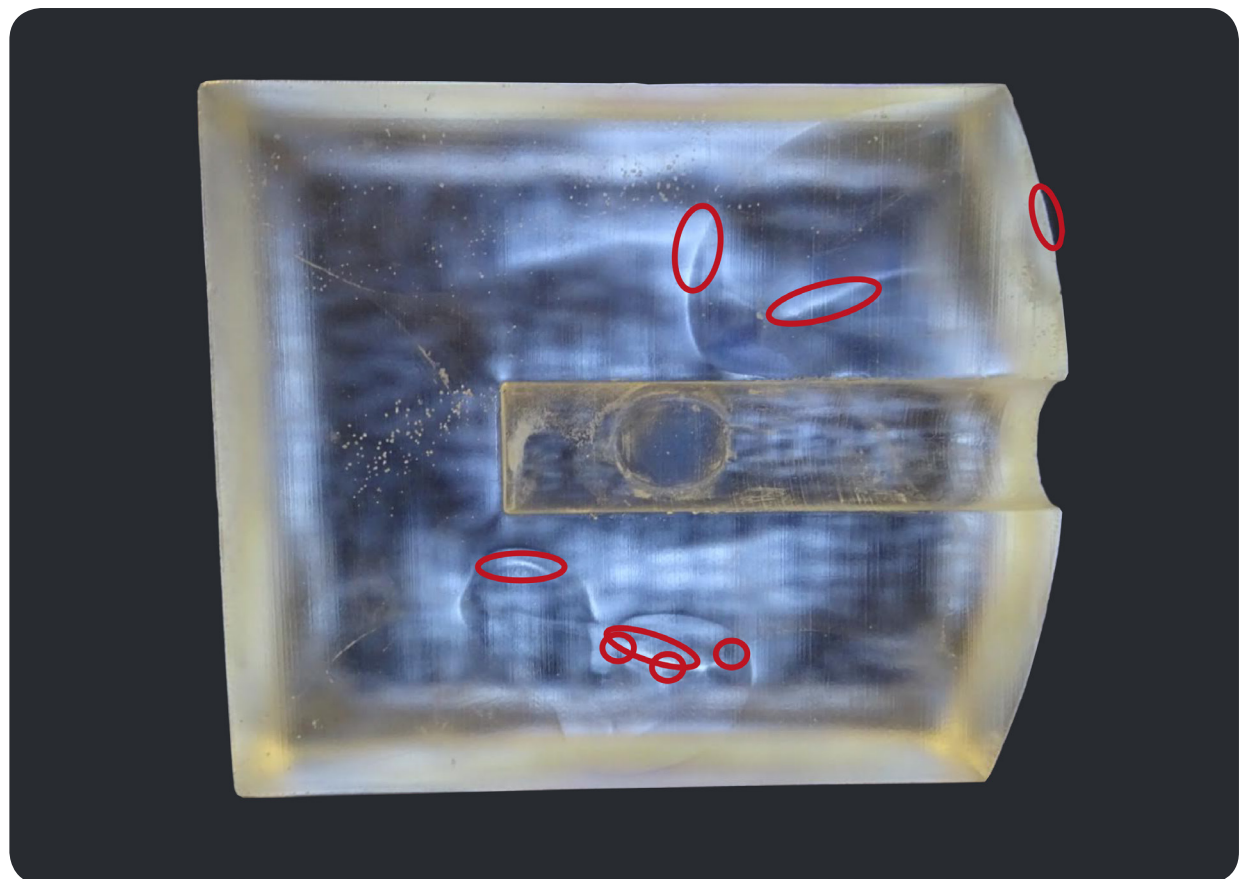
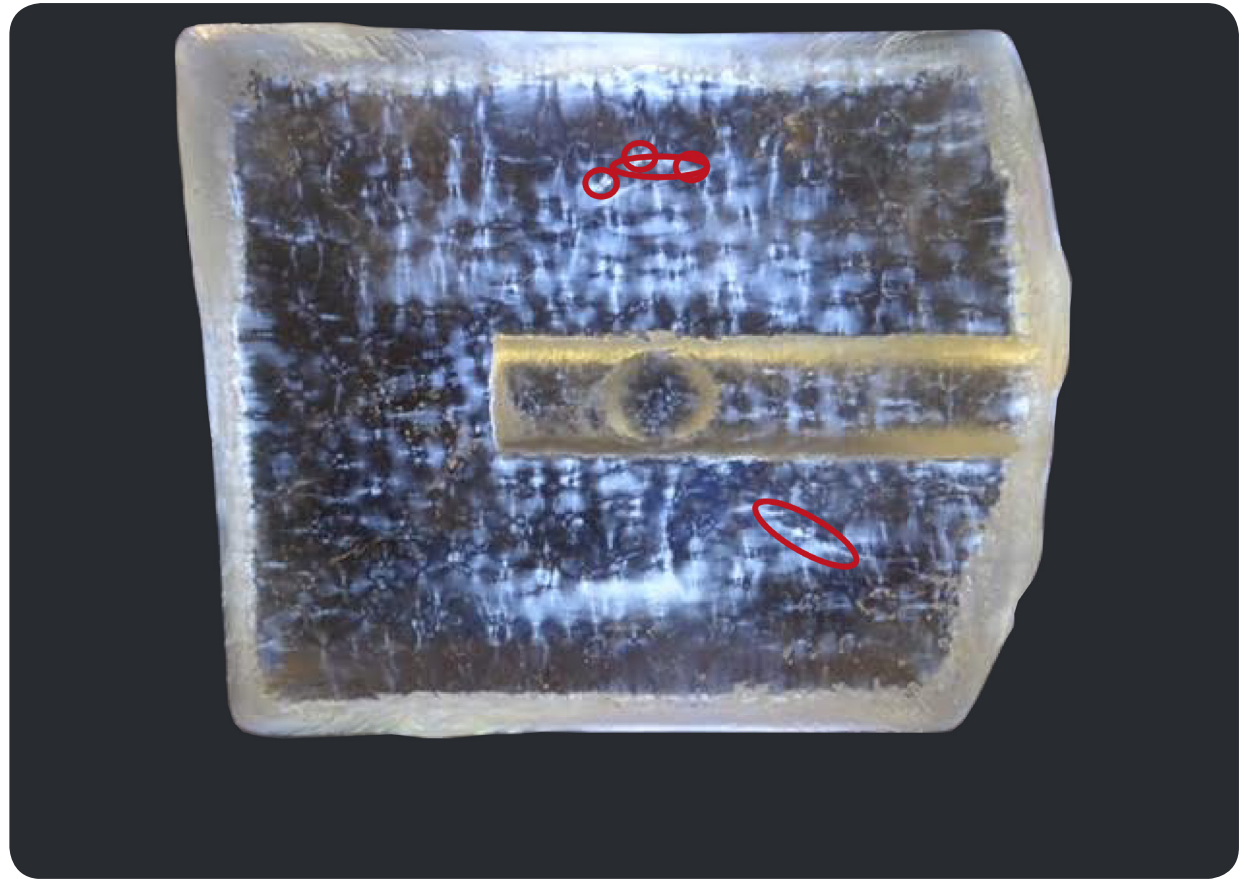
My glass



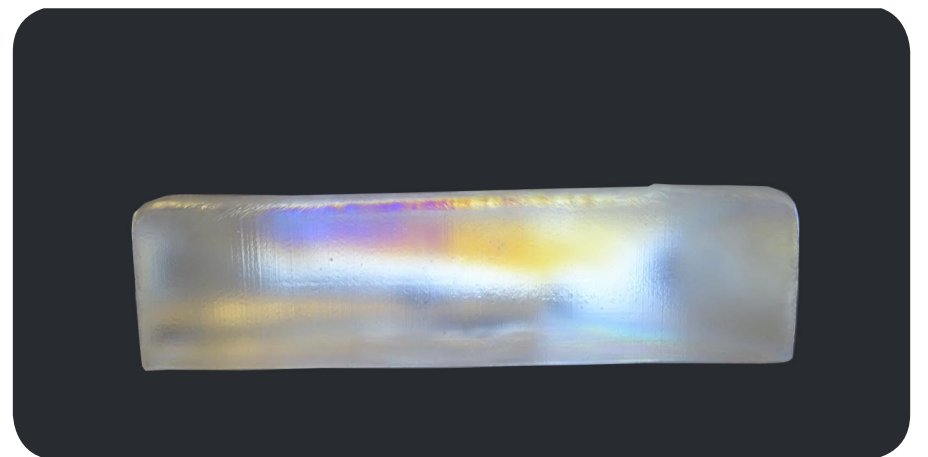
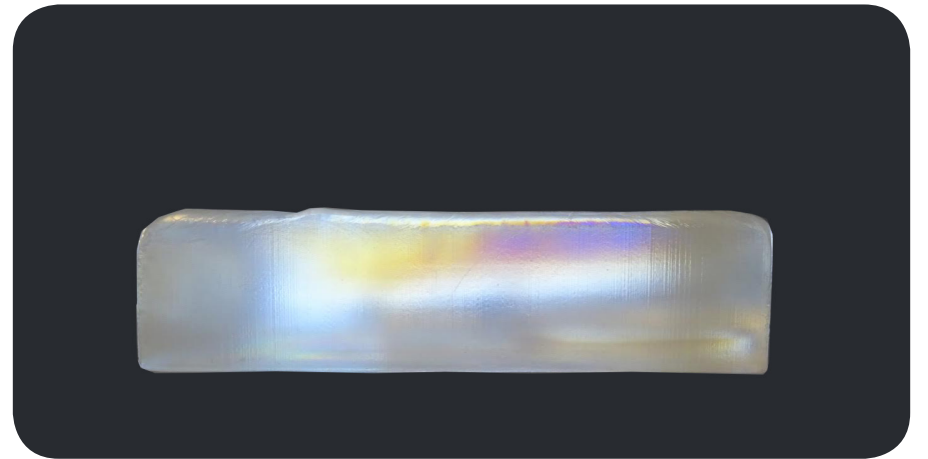
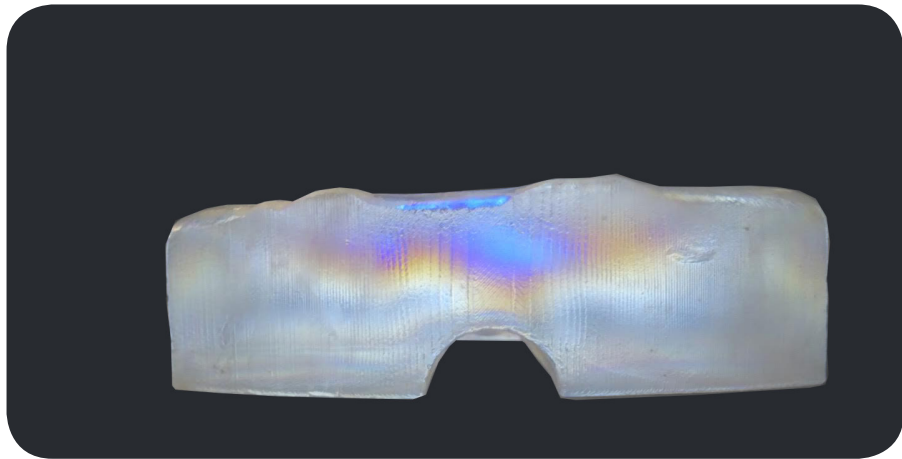
My glass



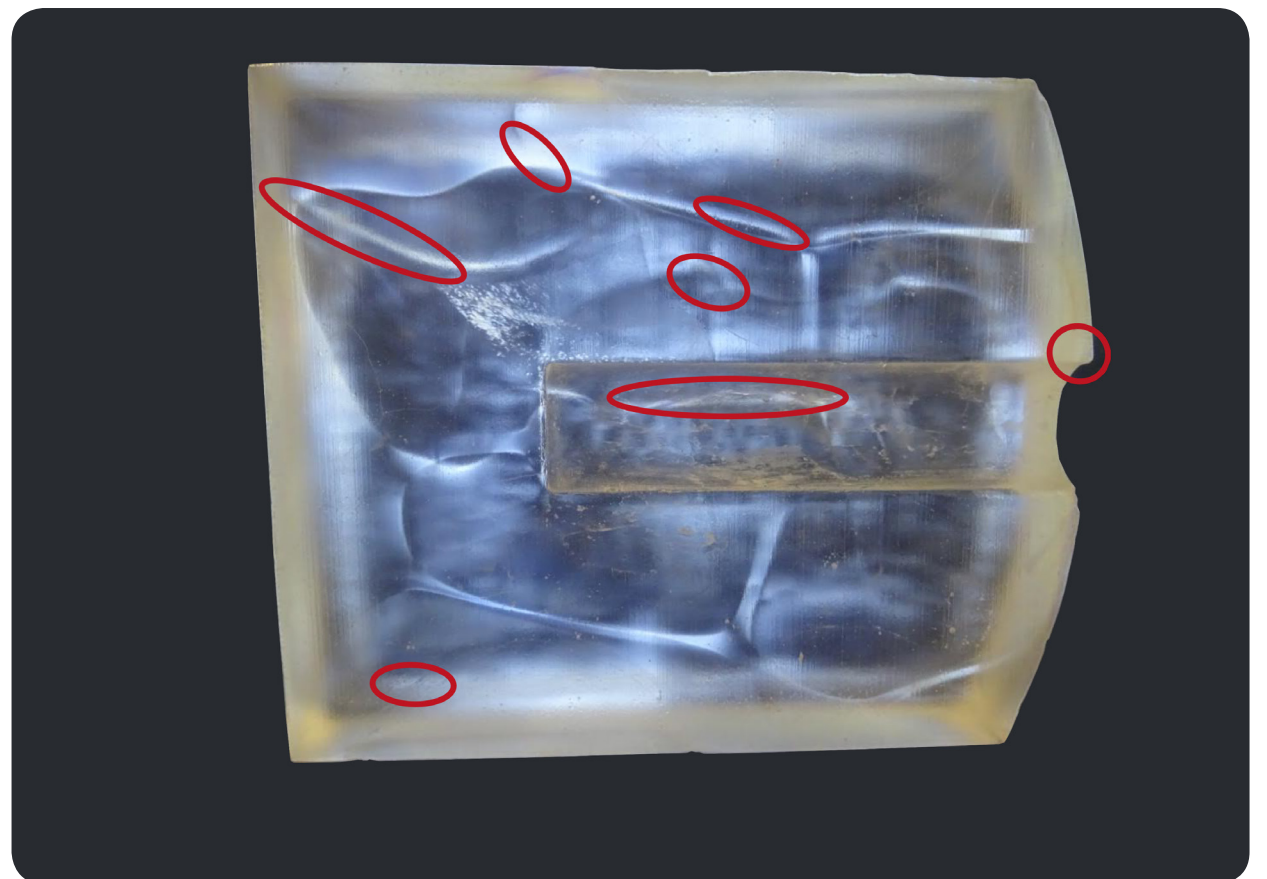
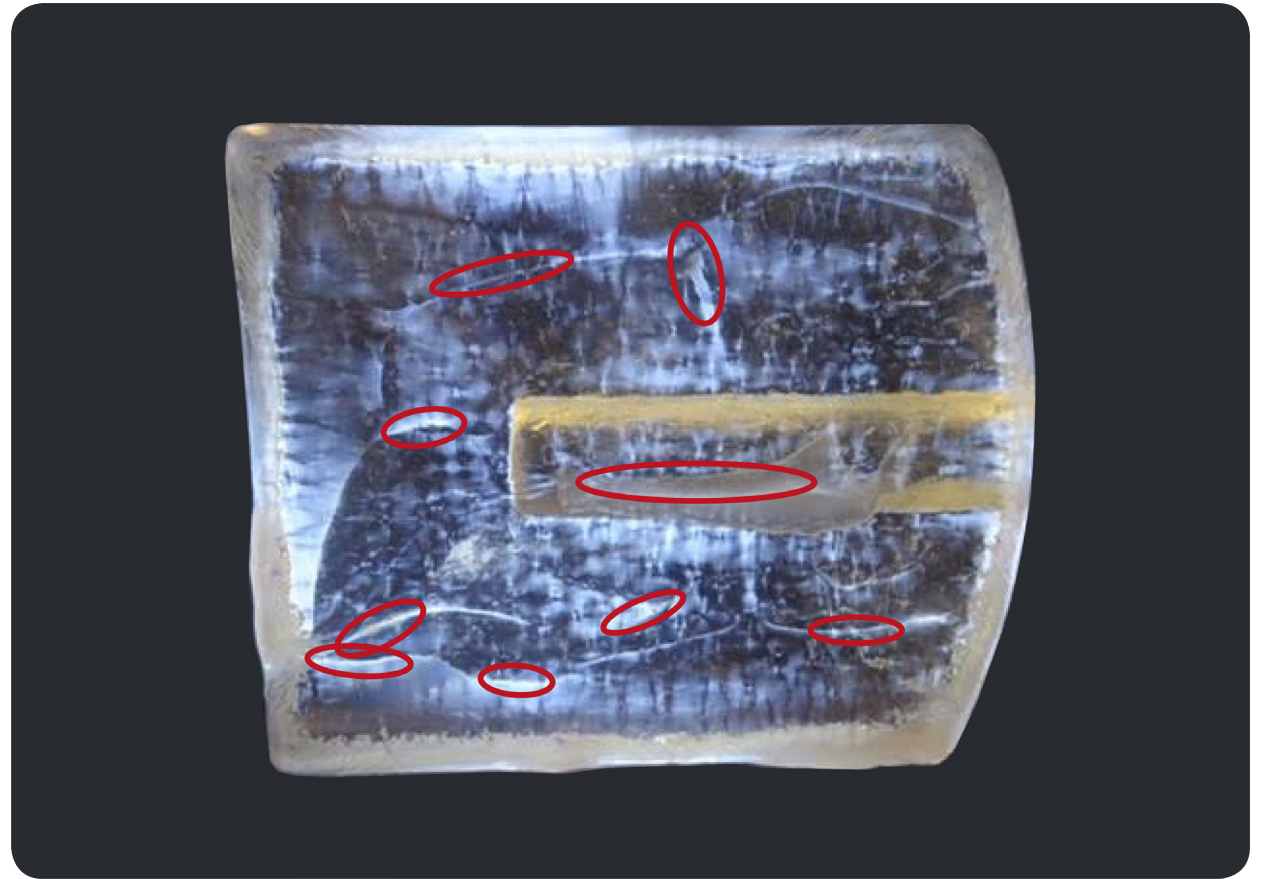
Stresses



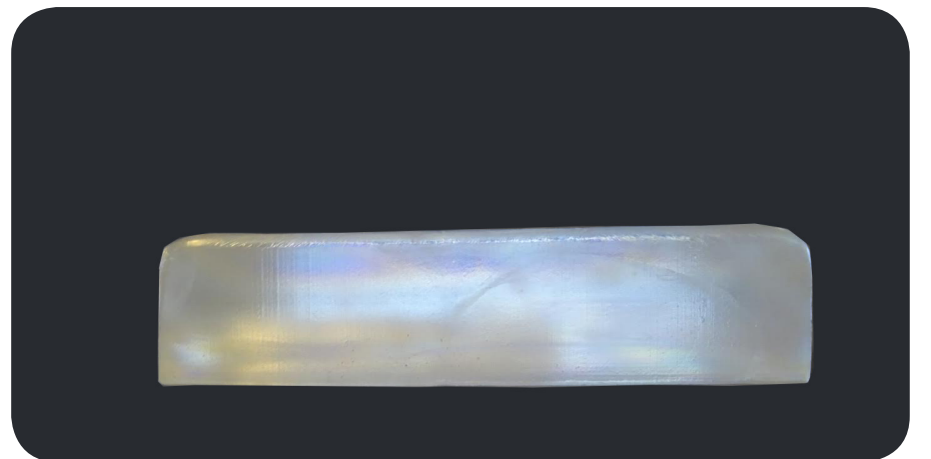
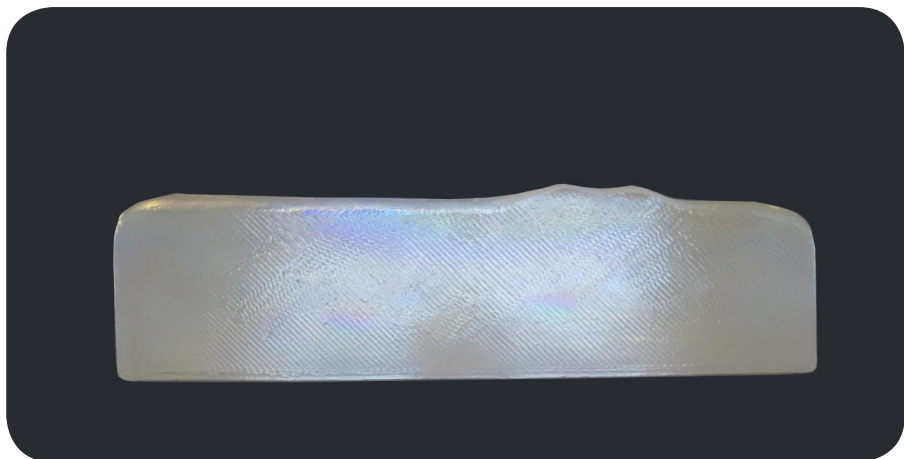
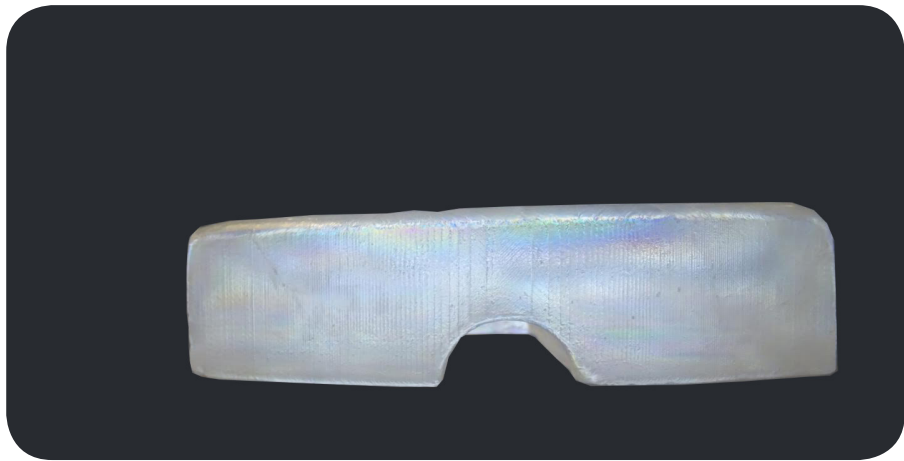
Stresses



Stresses

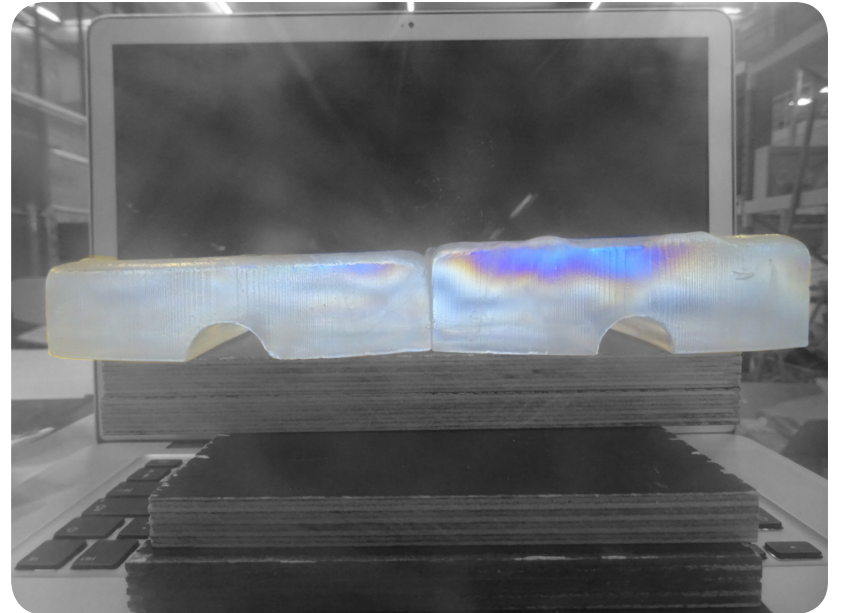


Stresses

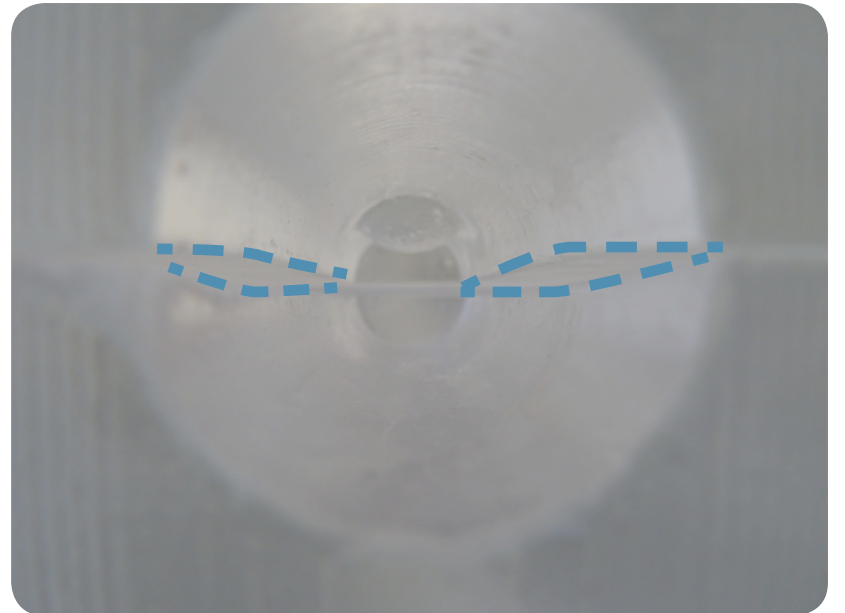


Observations

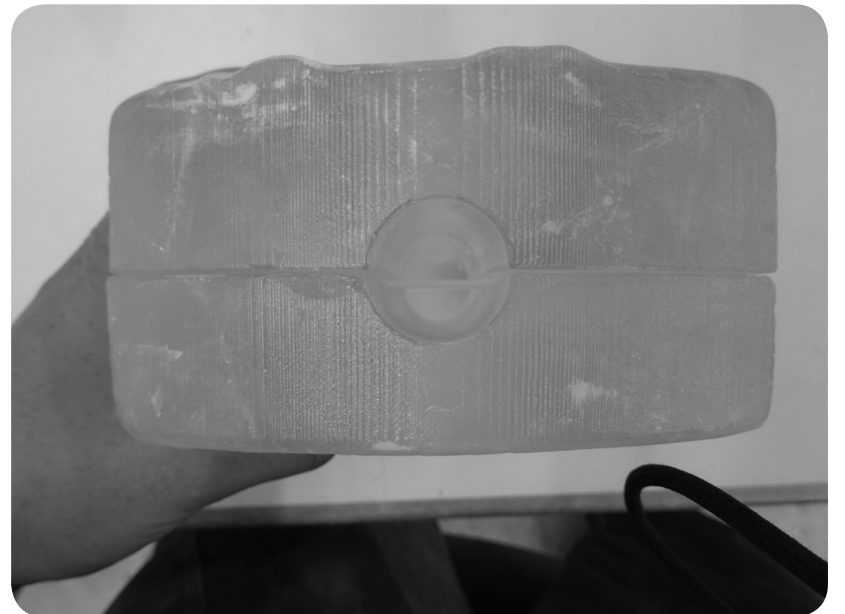
Stresses



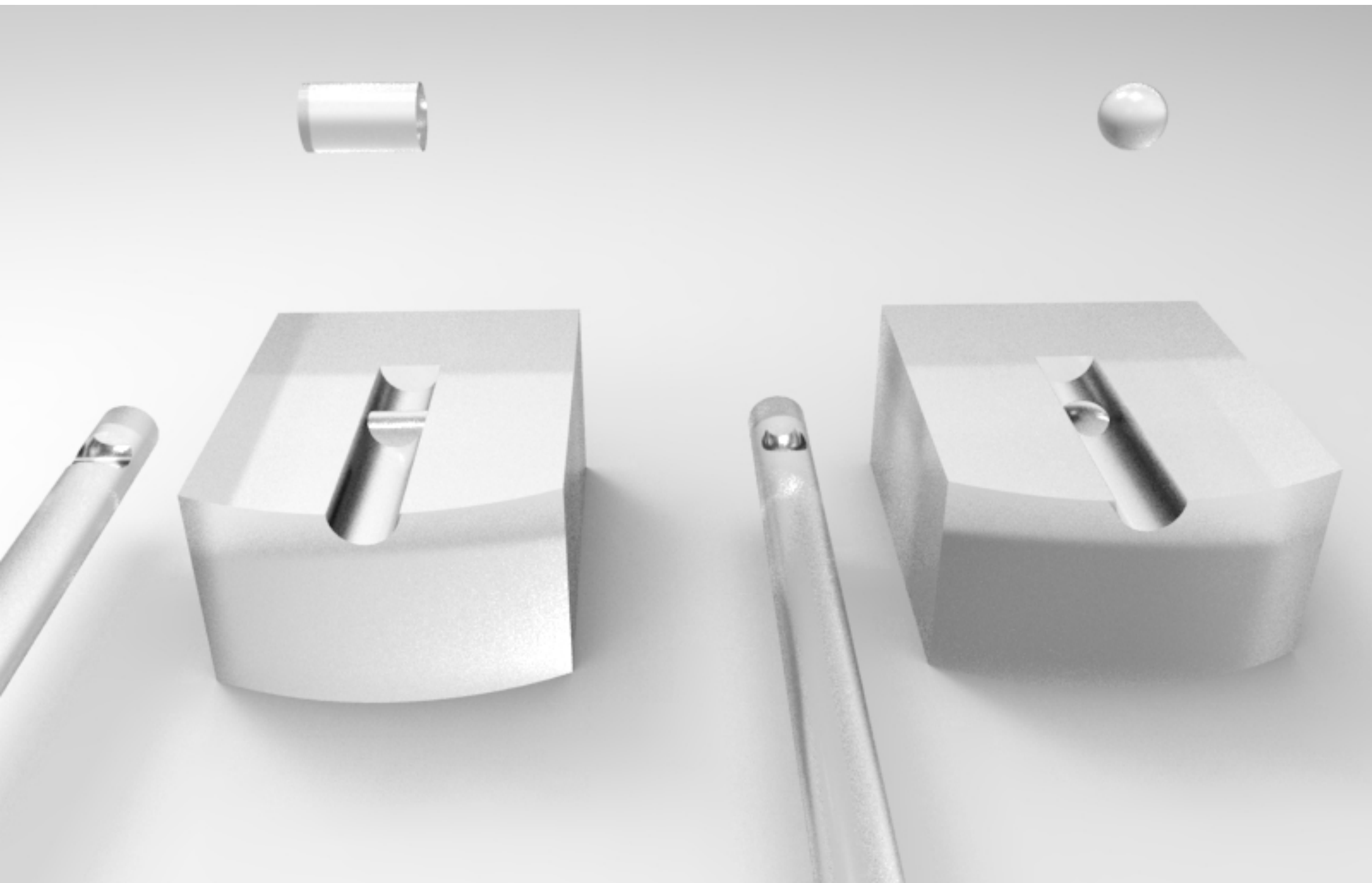
Convex



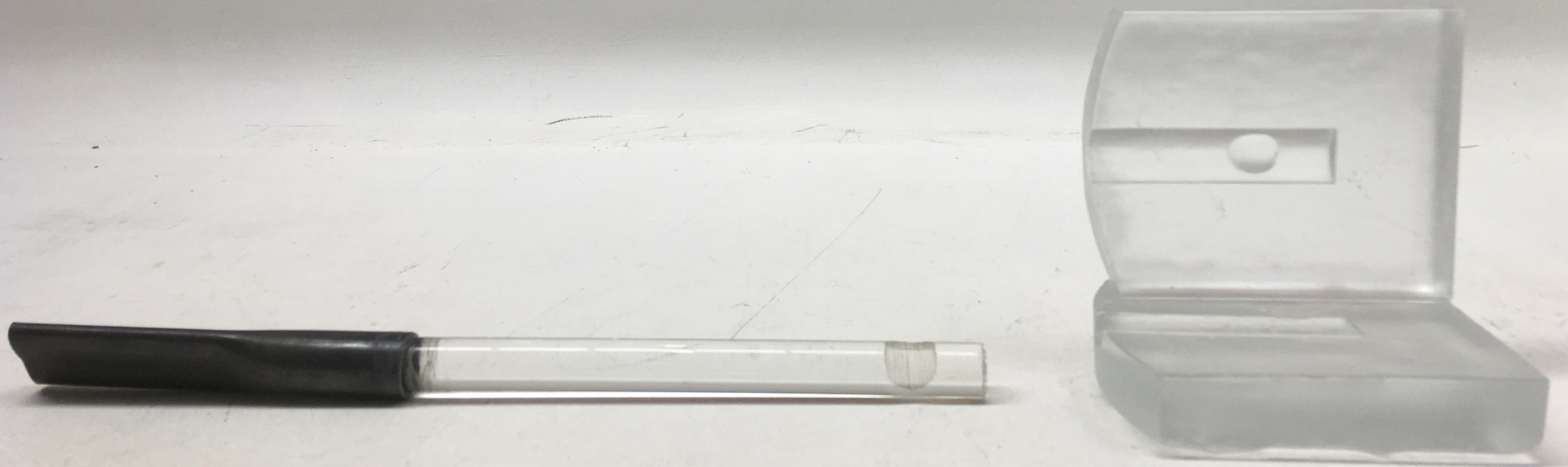
Imperfections



Change

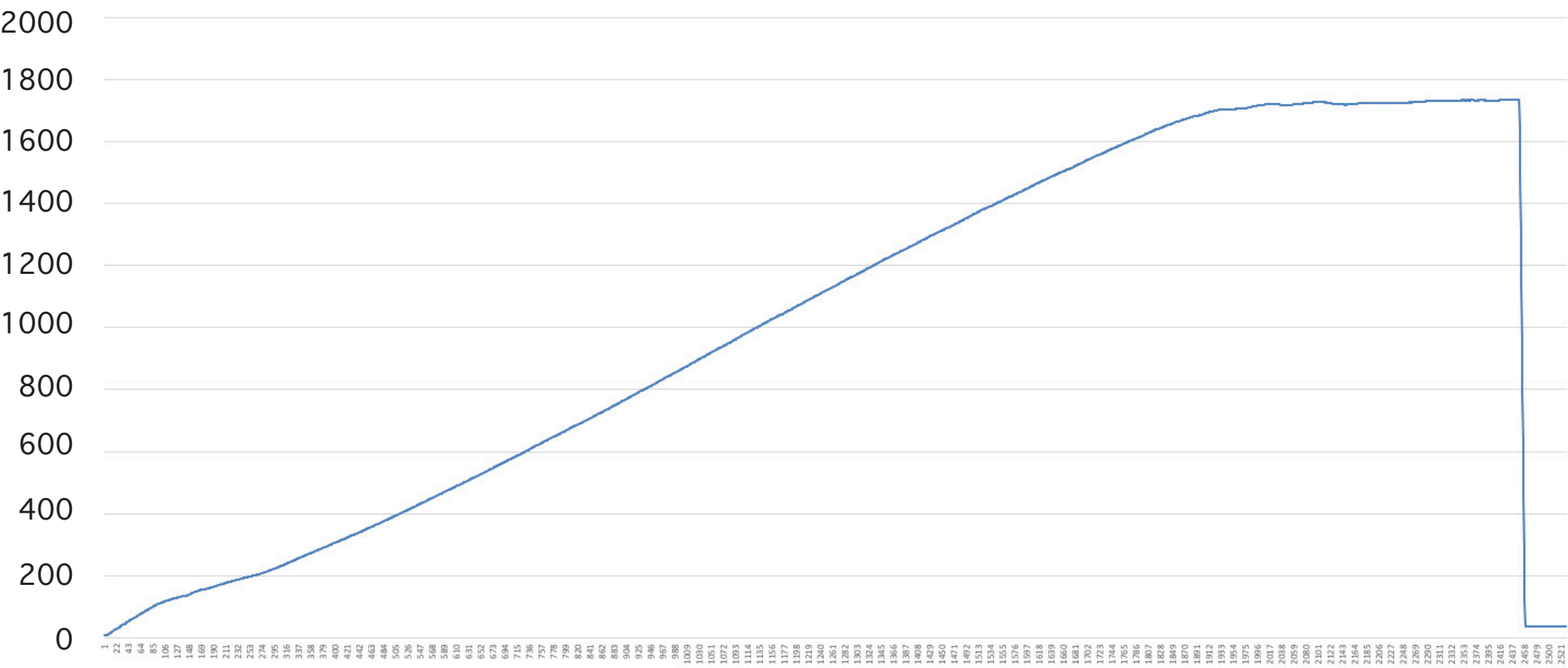


Steel



Steel

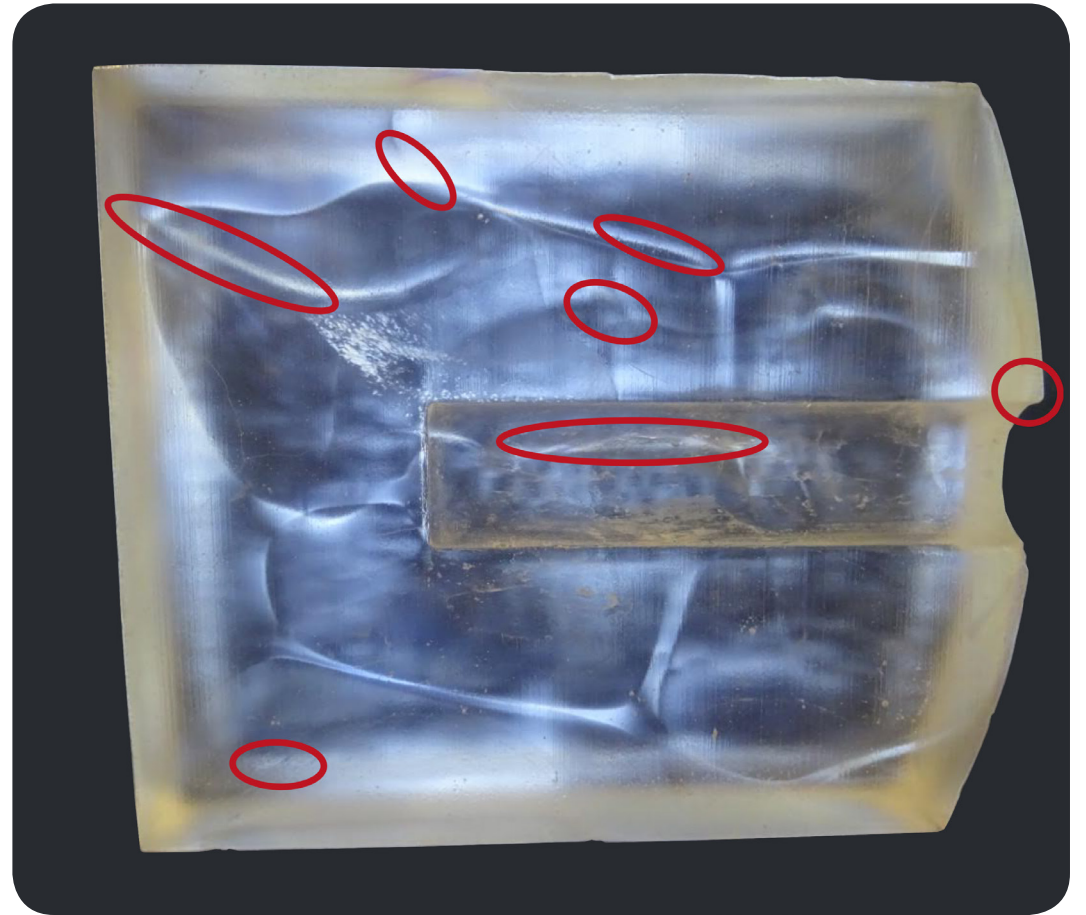
Steel and glass



Observations



Observations

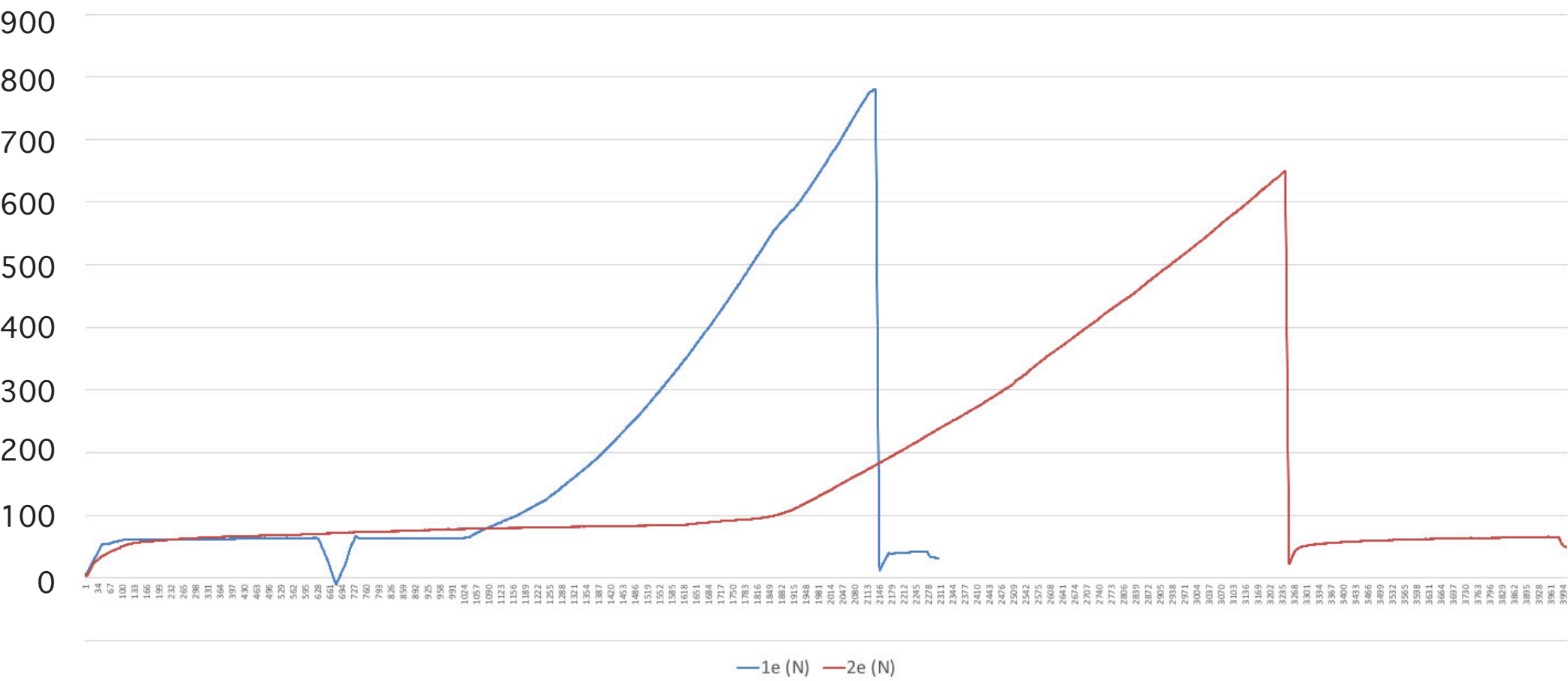


Aluminum

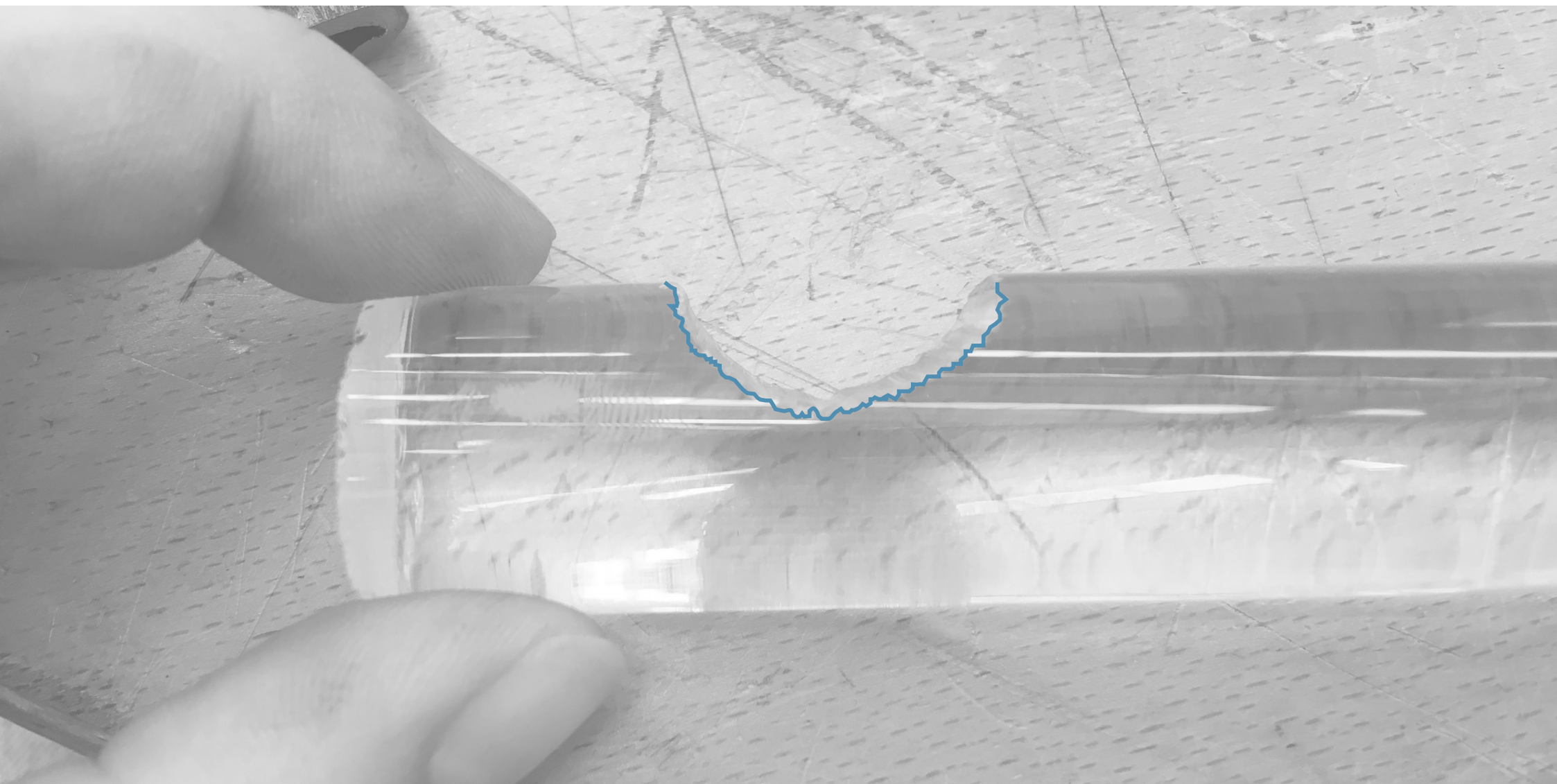


Aluminum

Aluminum and glass



Observations

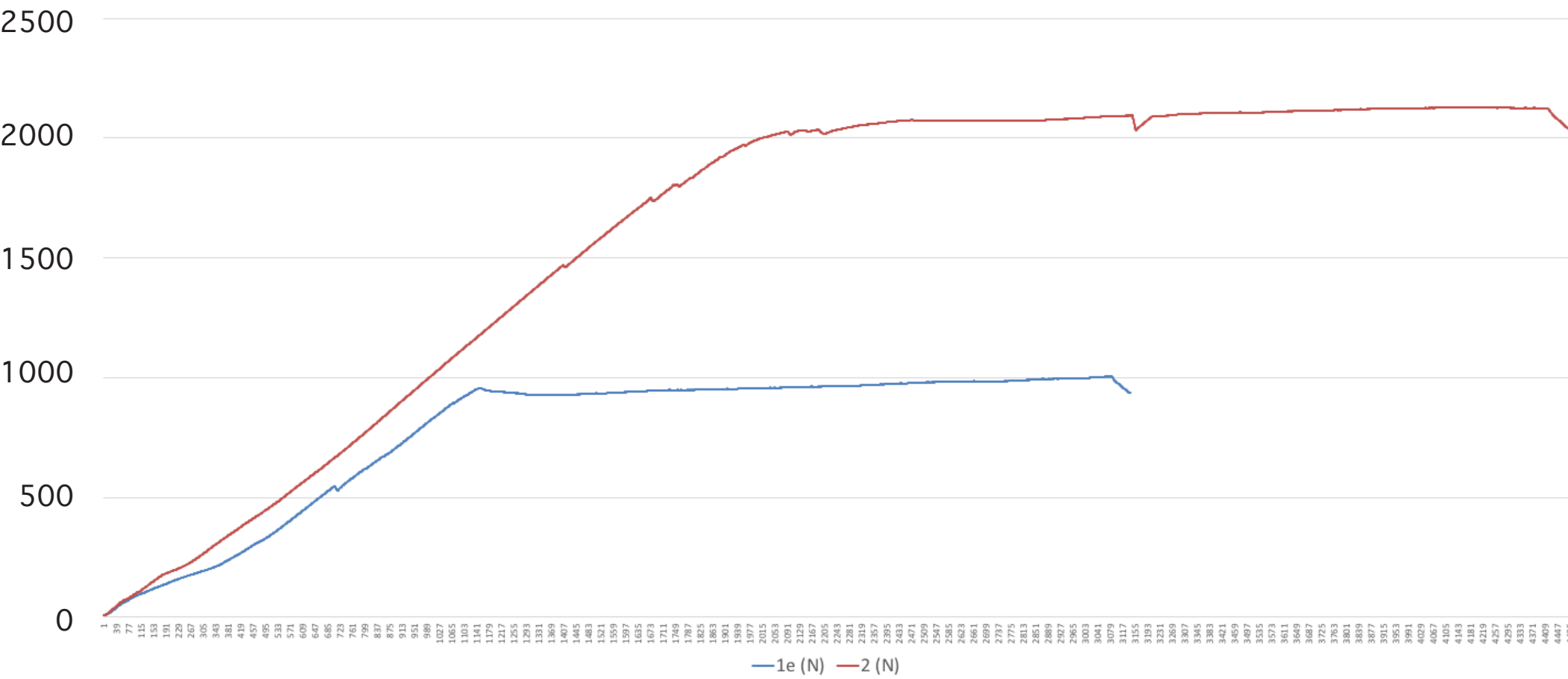


All aluminum



All aluminum

Aluminum rod



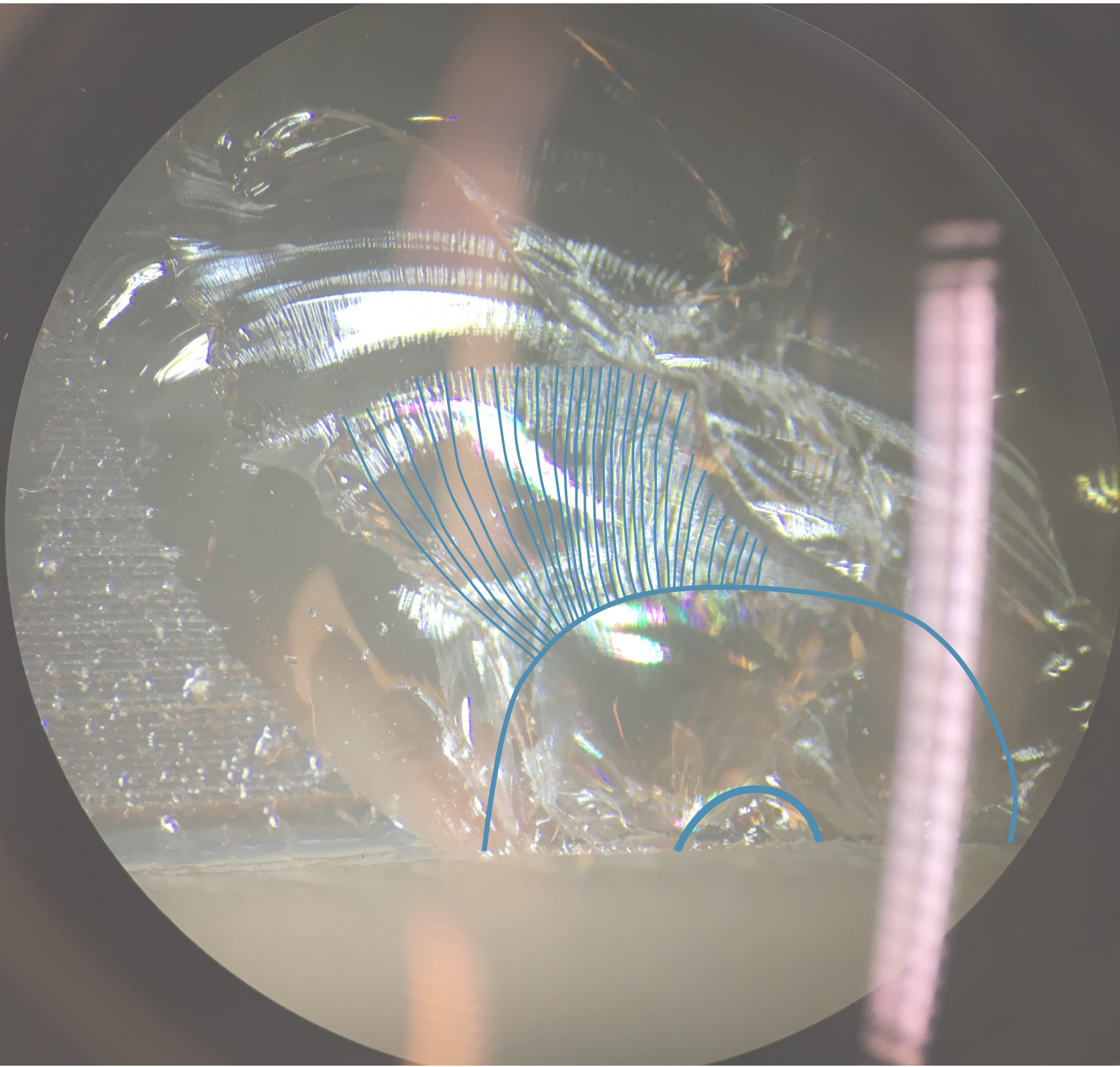
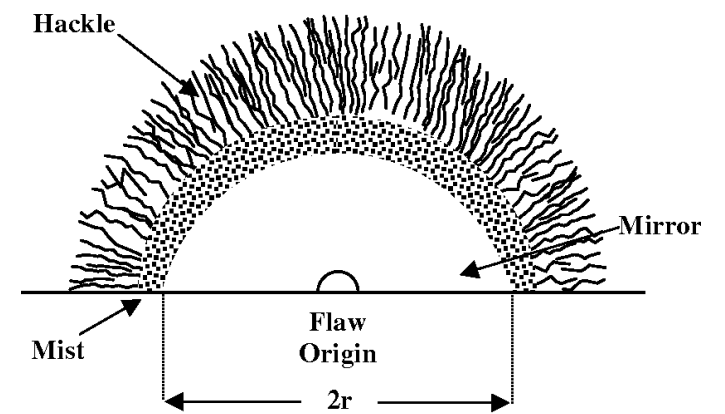
Observations



Observations



Observations

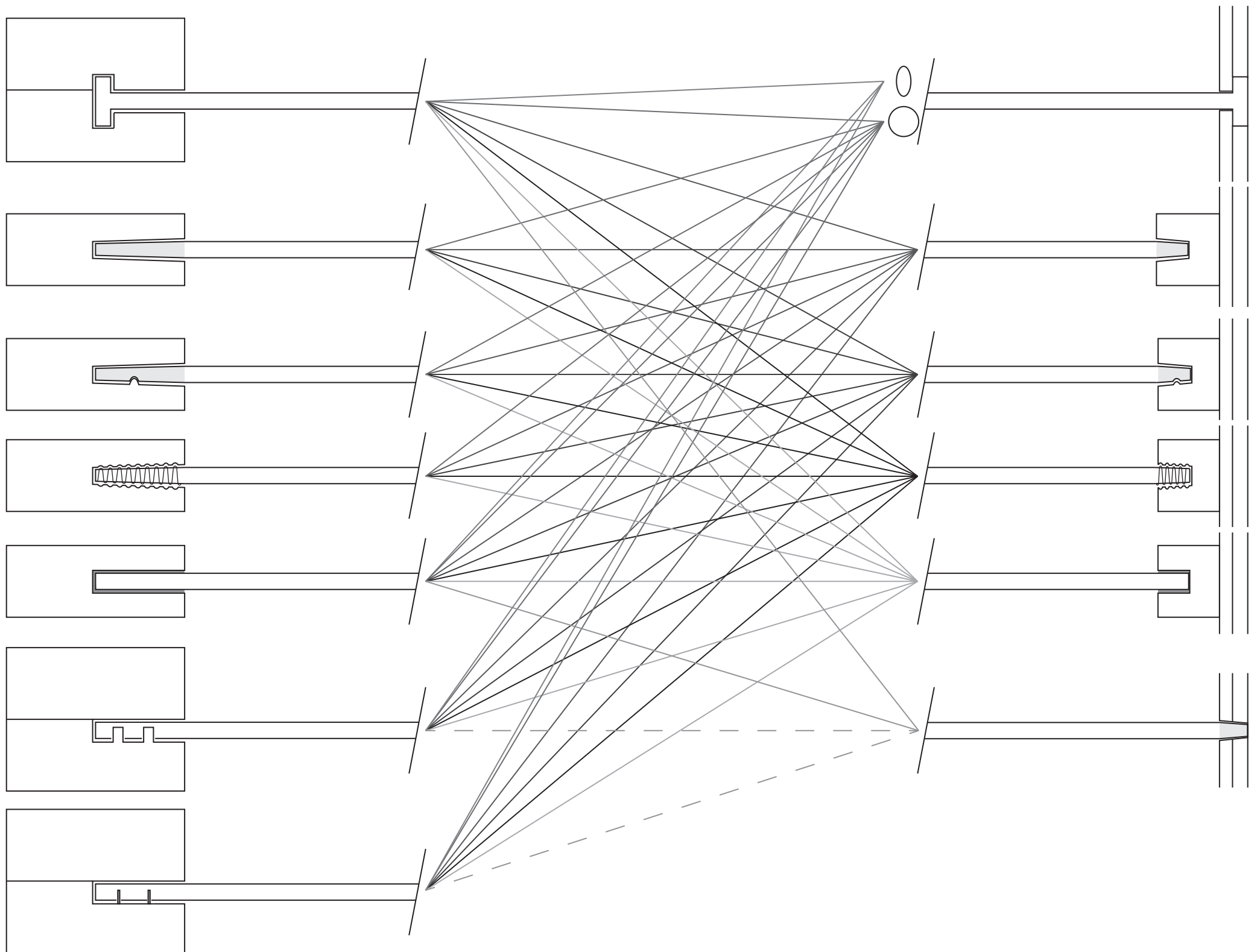


Conclusion

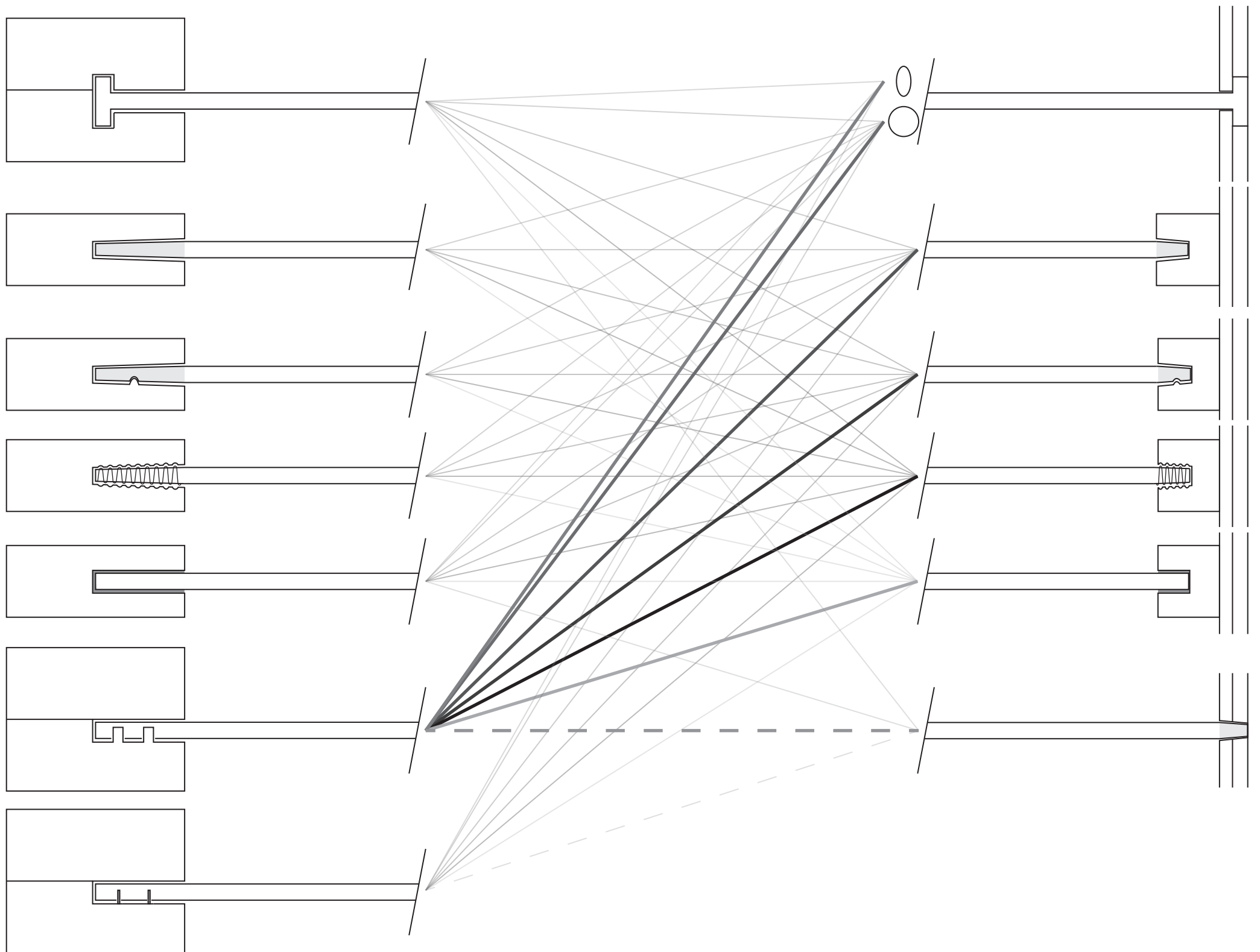


Feasibility

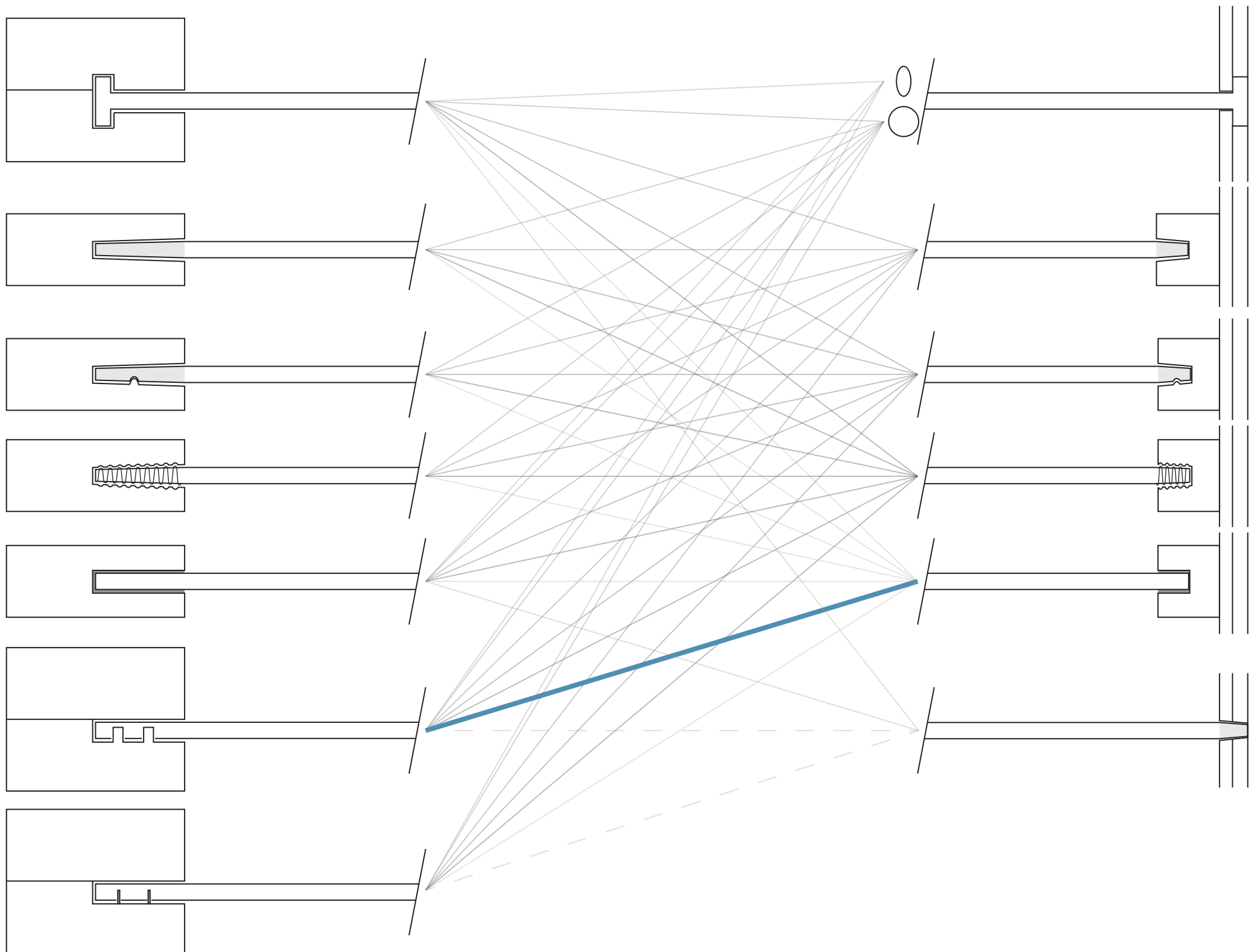
Connections



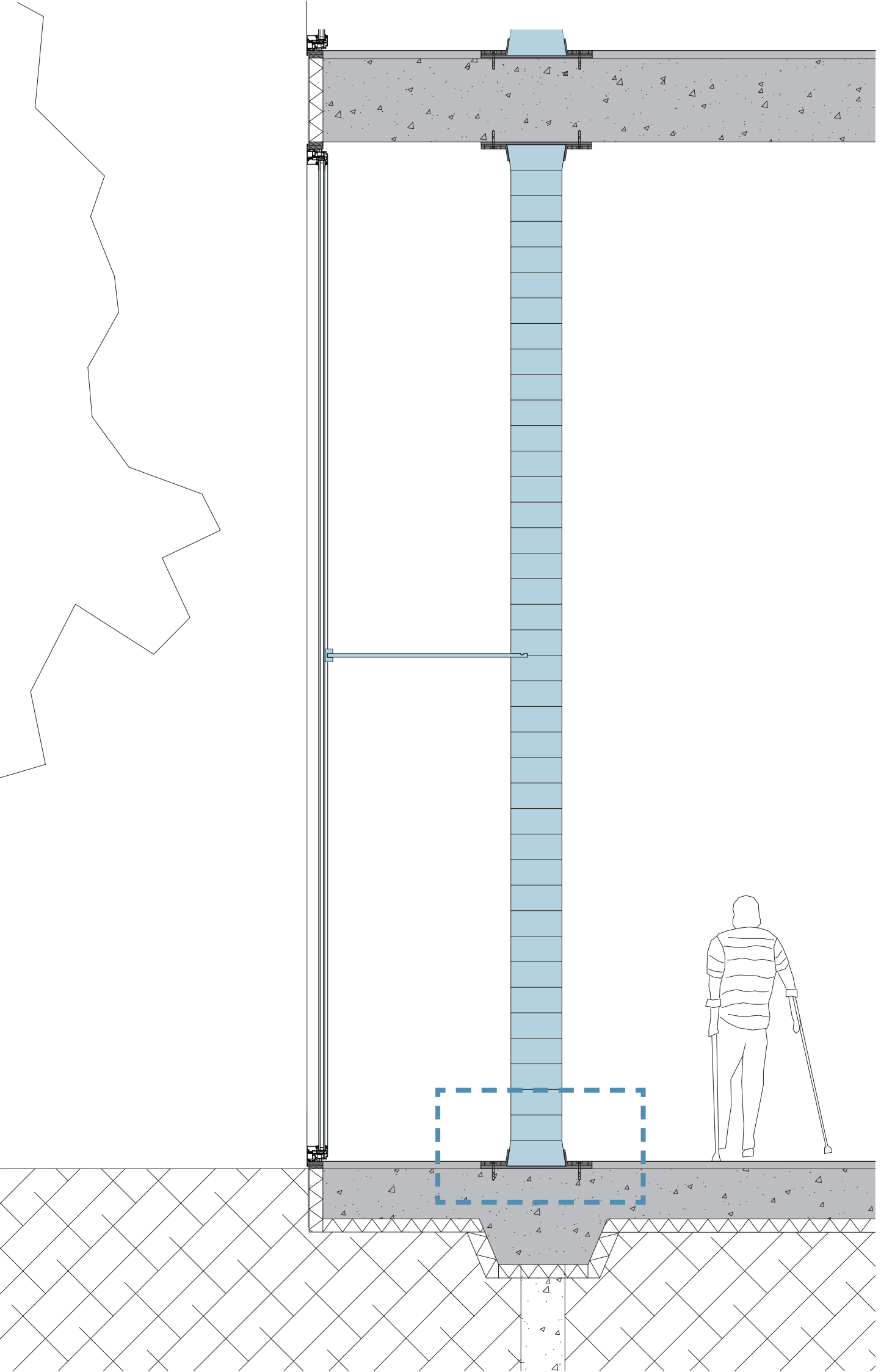
Connections



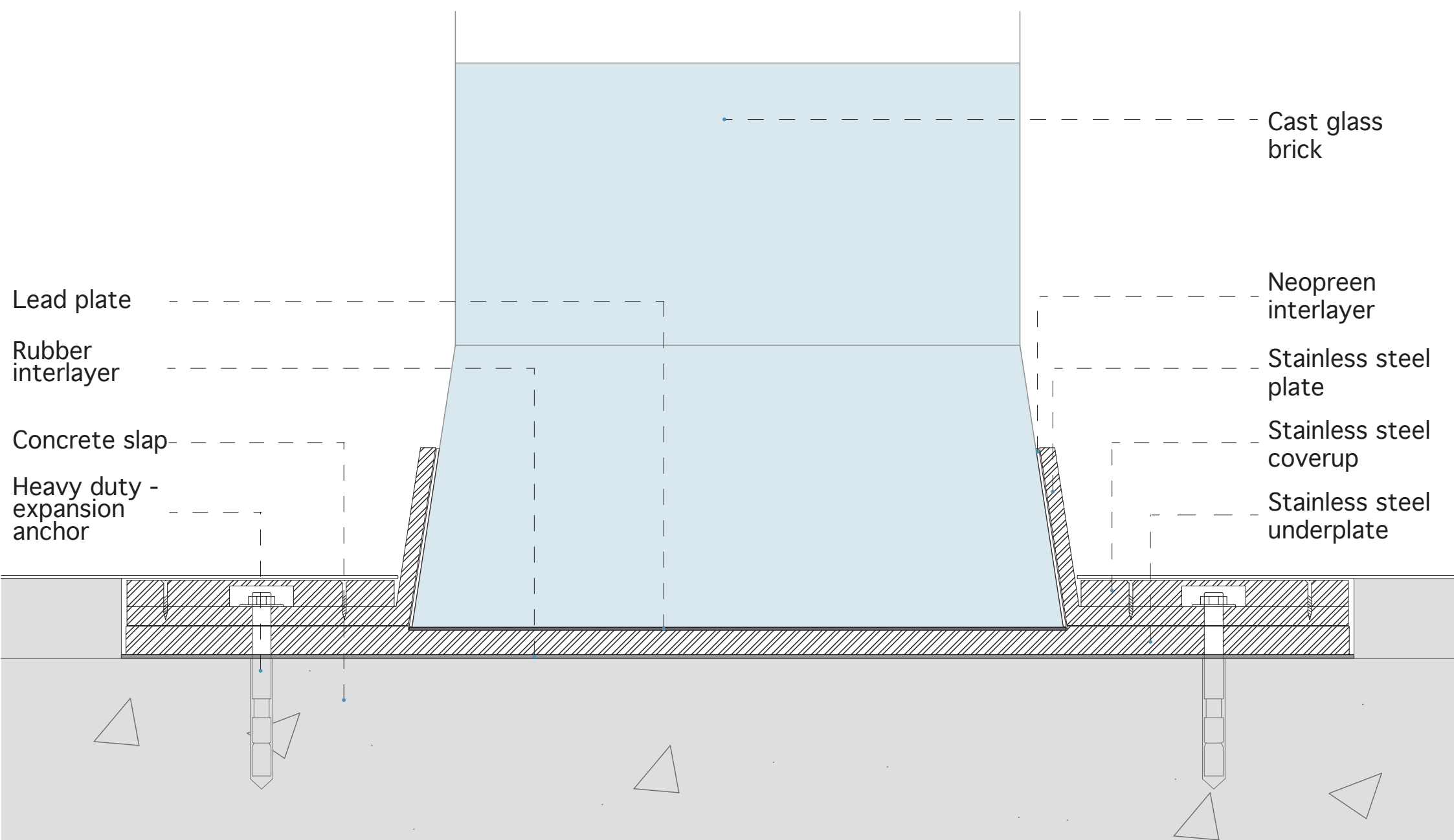
Connections



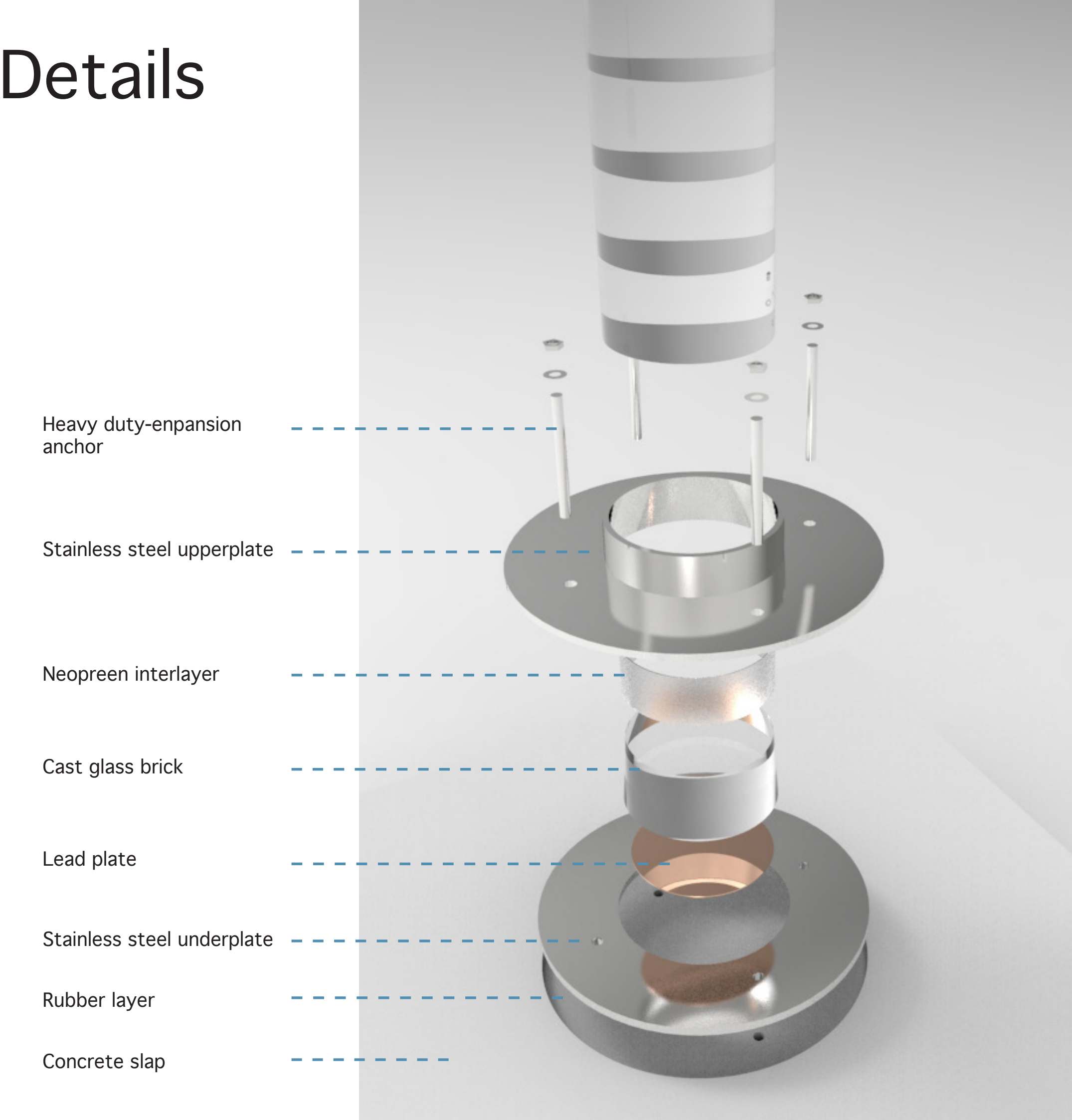
Details



Details



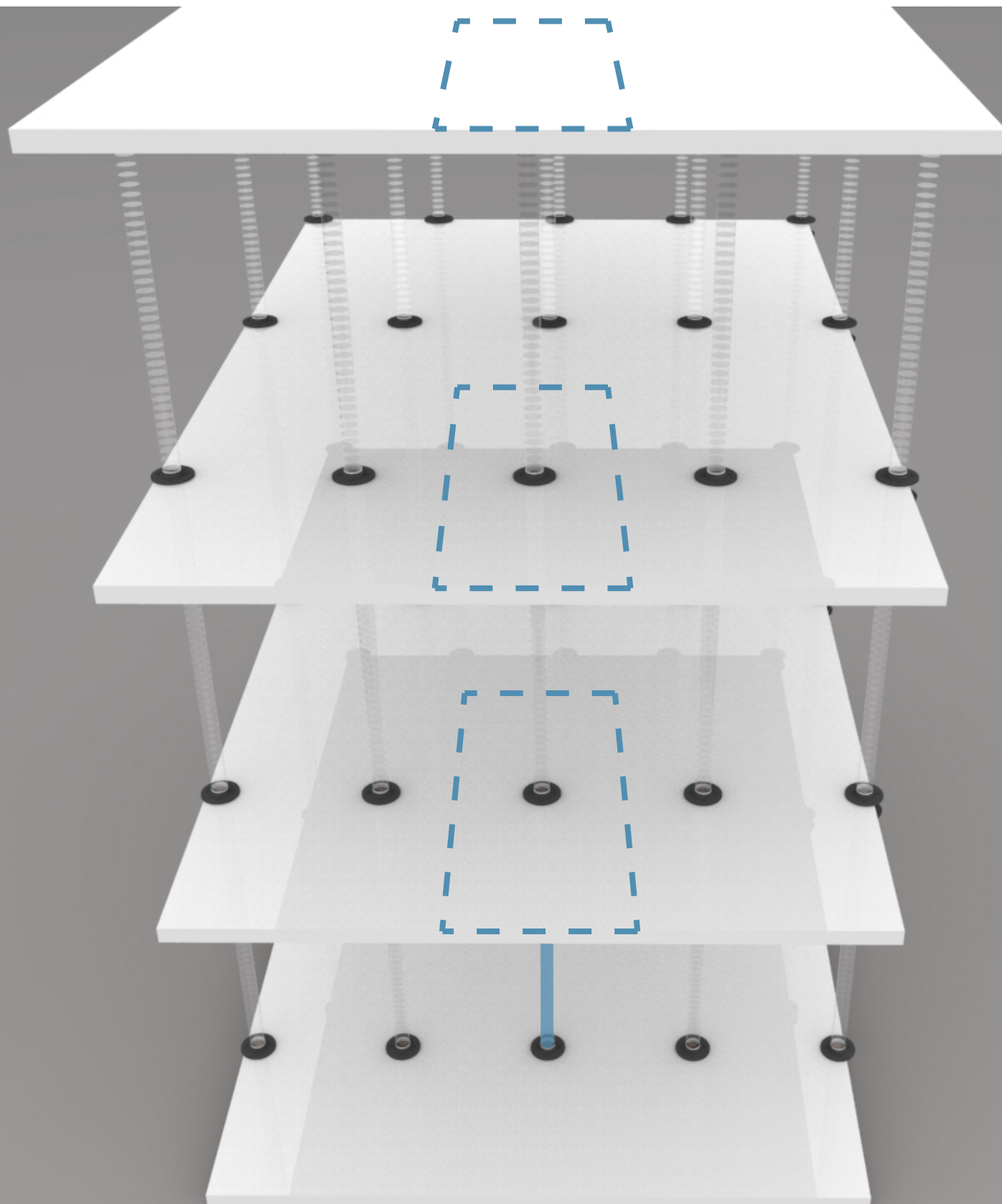
Details



Impression



Calculations



Calculations

		300 x 150 mm²	200 x 100 mm²
I _y	($\pi \cdot r^4$)/4	397607820,2	7853981,34
E		72000	72000
l _{cr hinge}		1	1
l		6000	6000
r		150	100
Pi		3,14159...	3,14159...
EI		2,8627E+10	5,65487E+12
F _{cr}	($\pi^2 \cdot EI$)/l _{cr} ²	7848463,785 N	1550313,834 N
		7848,463785 kN	1550,313834 kN
Safety	F _{cr} /5	1569,692757 kN	310,0627668 kN

Safety factor rest	1,2
Safety factor variable	1,5

		kN/m³
Surface 3000 x 7500 mm²	22,5 m²	
Concrete 300 mm	0,3 m	7,2
Concrete deck floor 60 mm	0,06 m	1,44
Floor finish		0,5
Roof		0,5
Instalations		0,25
Total		9,89

Example	kg/m³	kg/m³
Water	1000	10
Wood	800	8
Plaster work	2000	20
Concrete	2400	24
Glass	2500	25
Steel	7850	78,5

		kN/m²
Roof		1
Residence		1,75
Offices		2,5 - 3,5
Stores		4
Theater		5,0 - 7,0

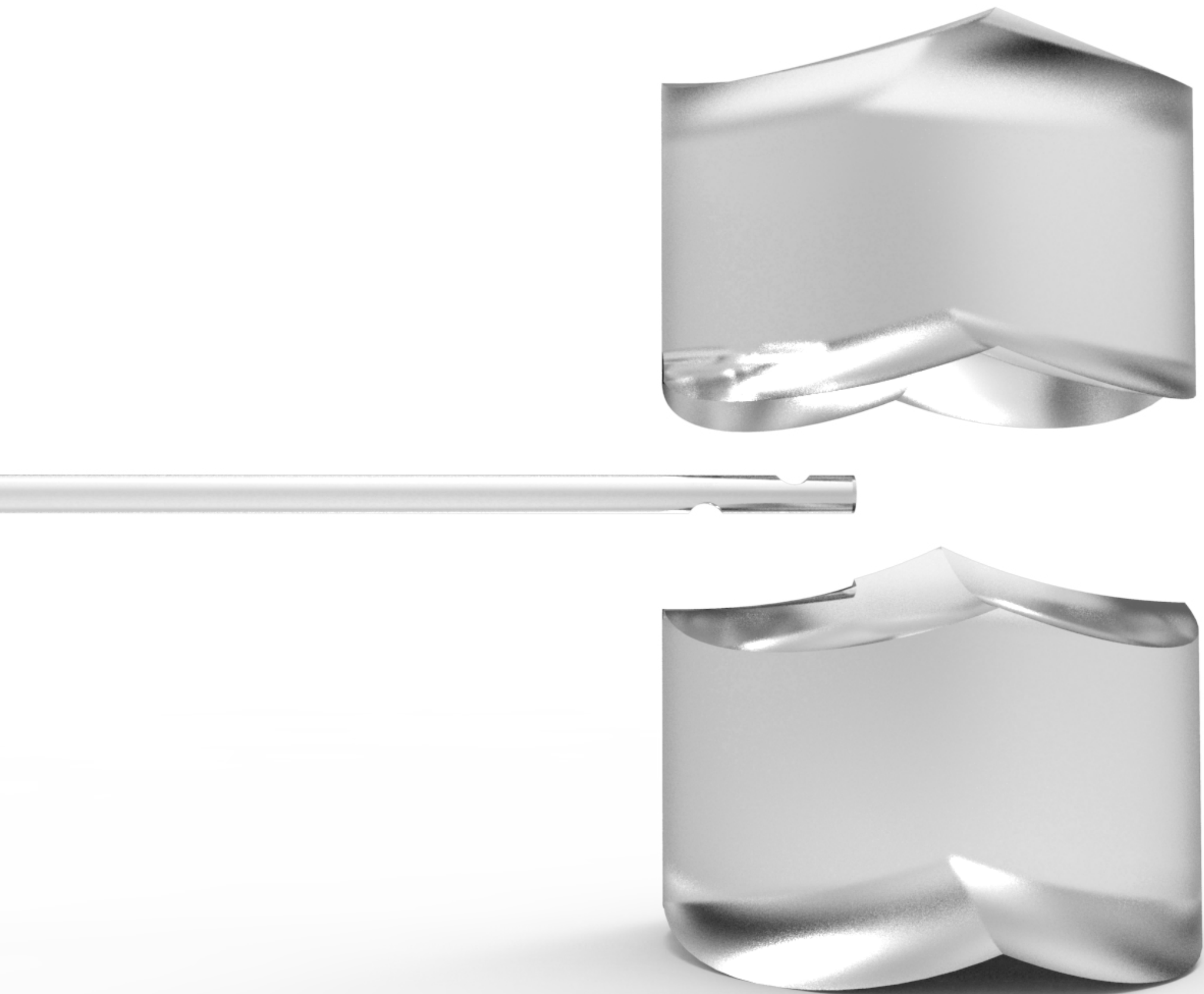
		kN
Roof	Rest	267,03
	Variable	33,75
Residence	Rest	267,03
	Variable	59,06
Residence	Rest	267,03
	Variable	59,06
Total		953 kN

Conclusions

Conclusions



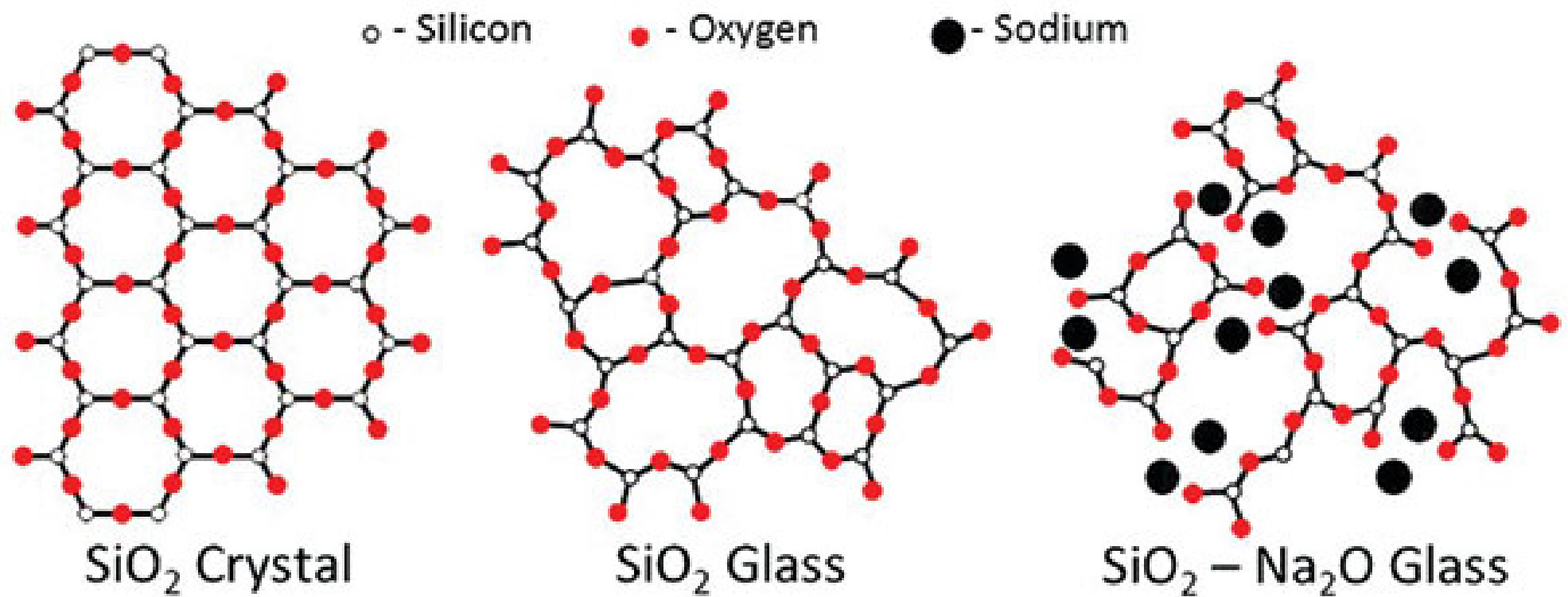
Recommendations



Thank you

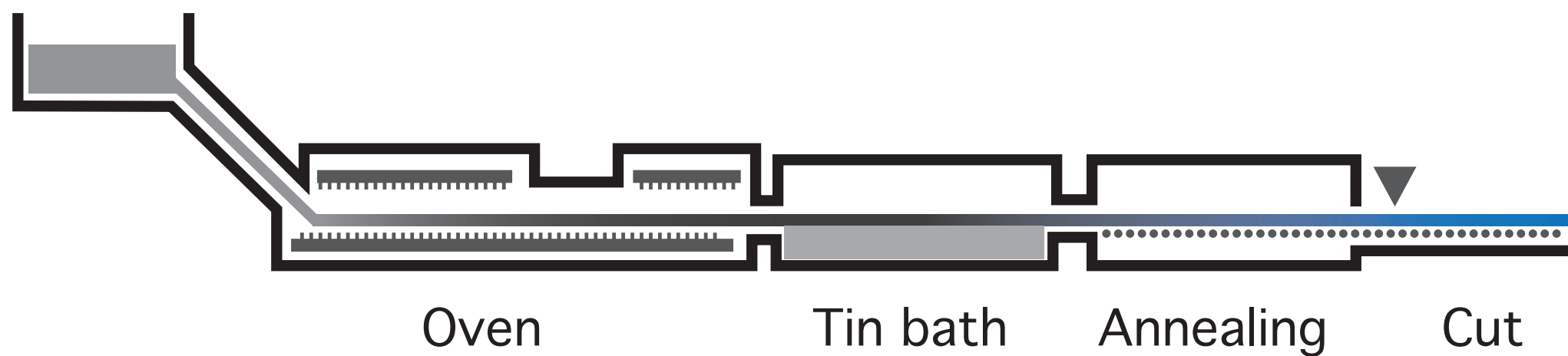


What is glass?

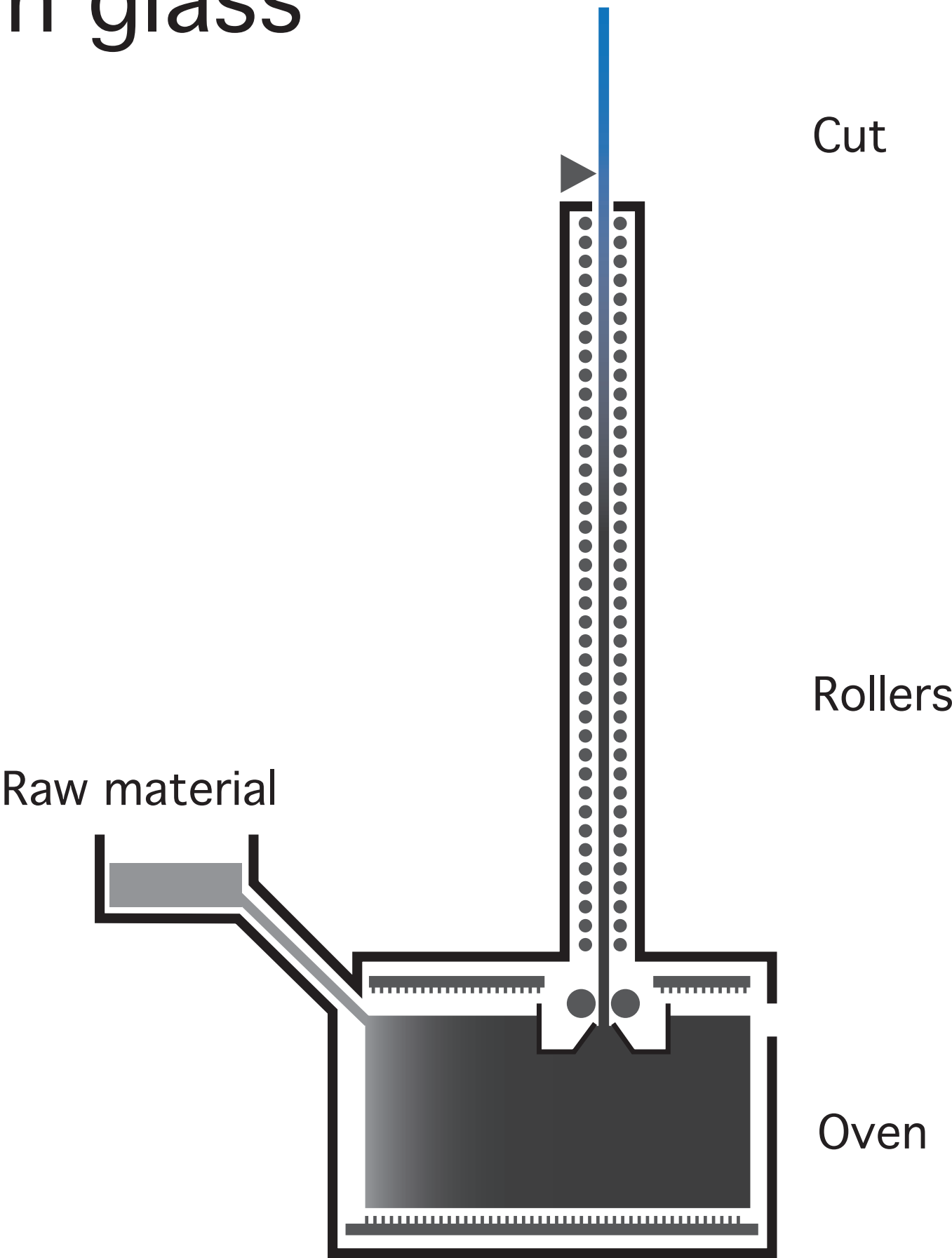


Float glass

Raw material

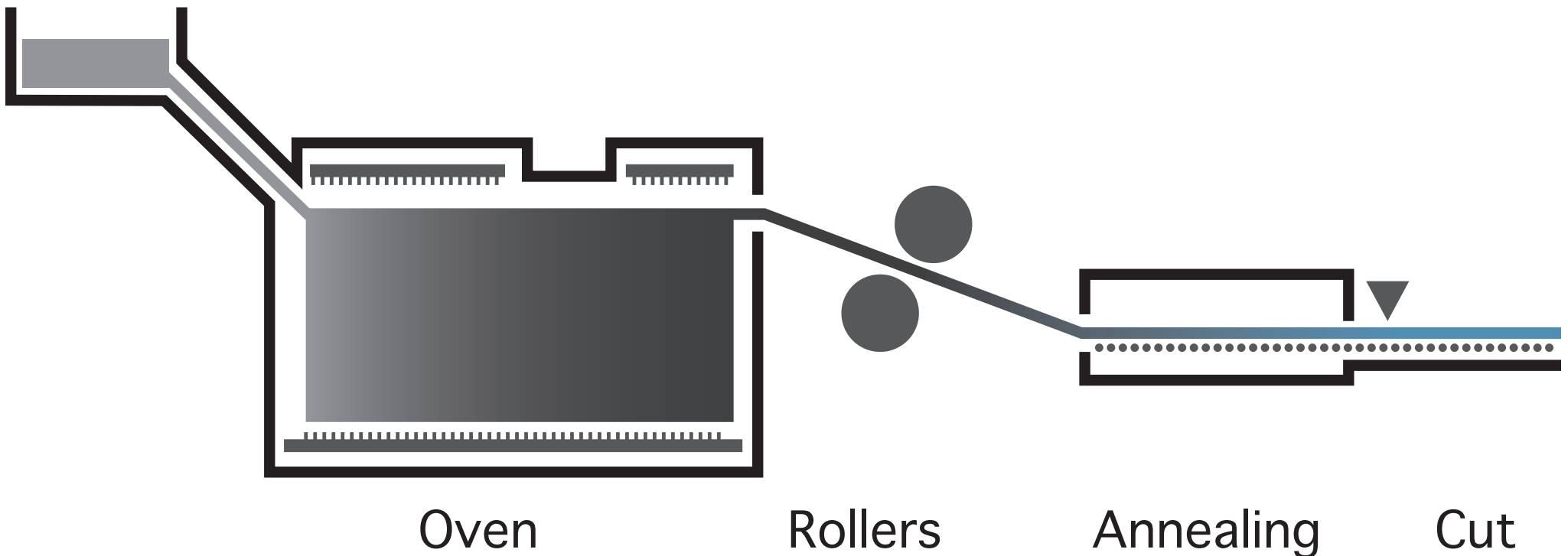


Drawn glass

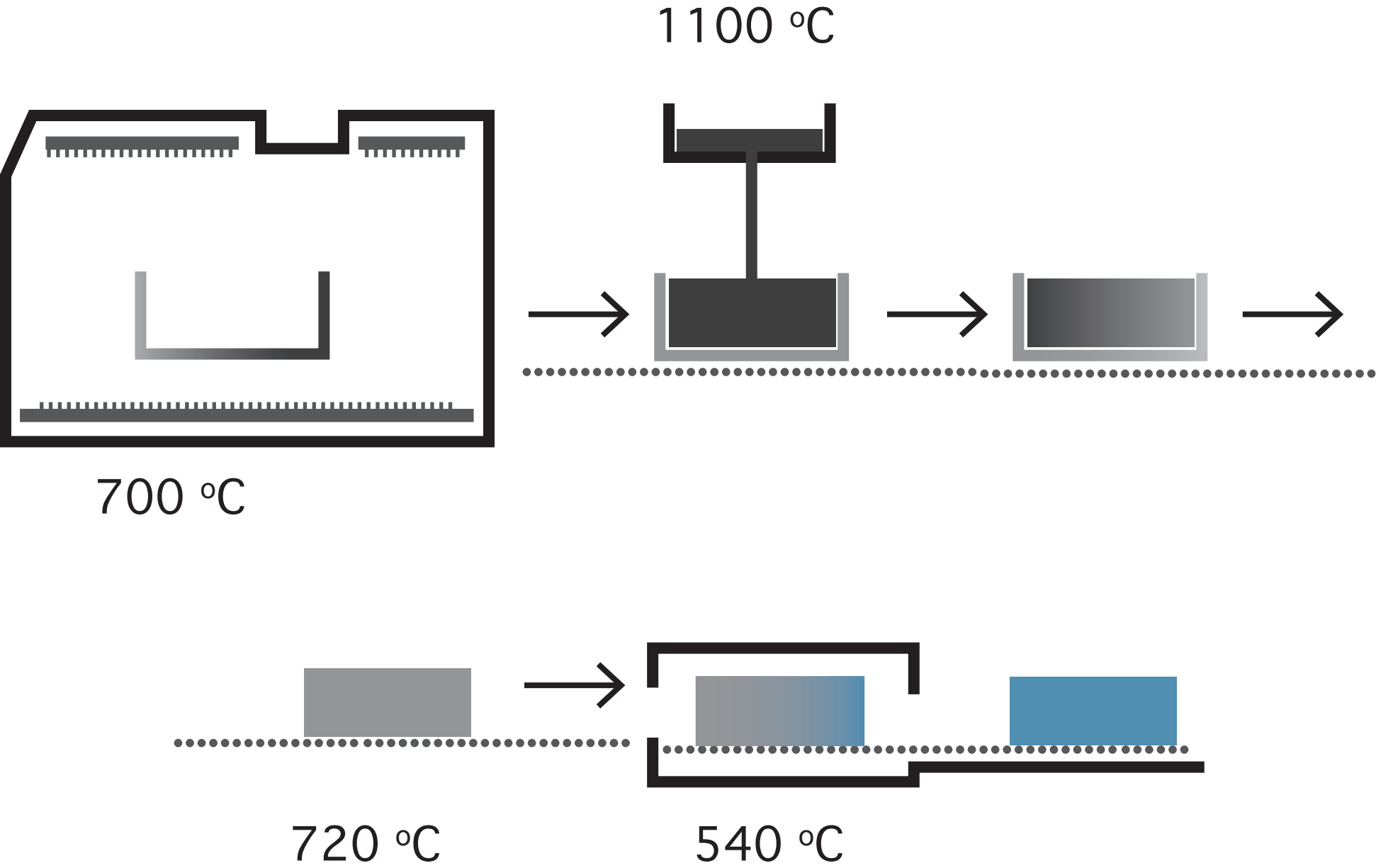


Patterned or rolled glass

Raw material

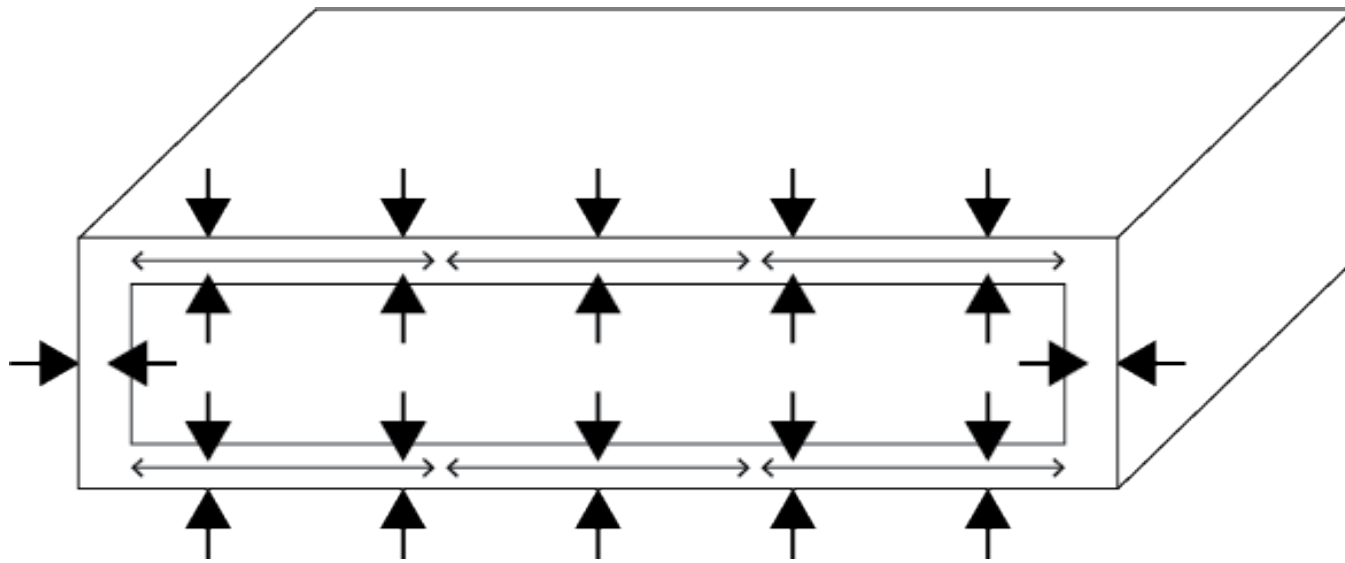


Cast glass

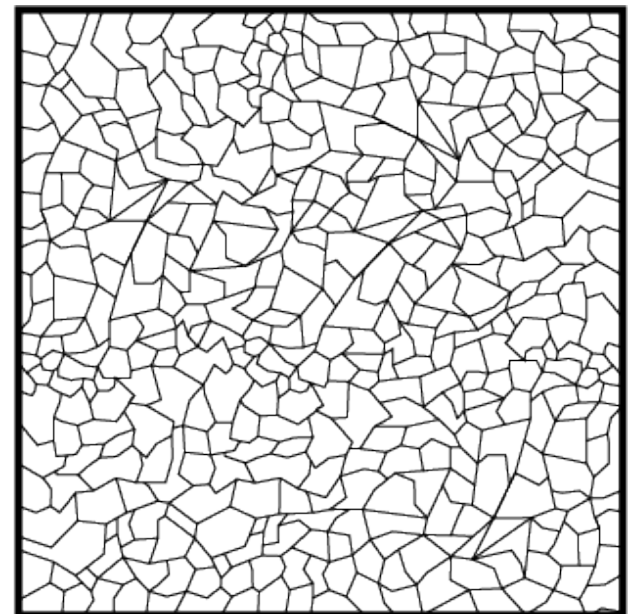
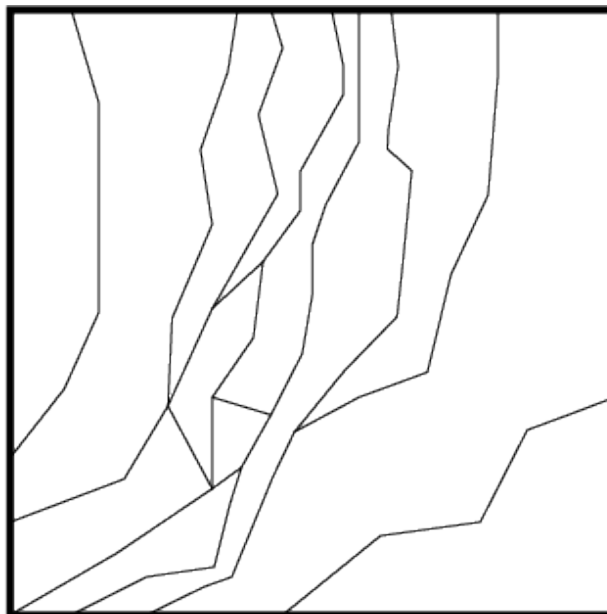
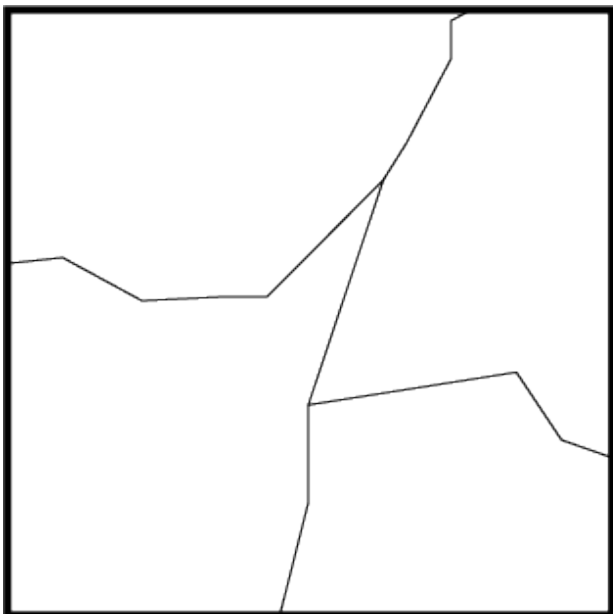


Types of glass

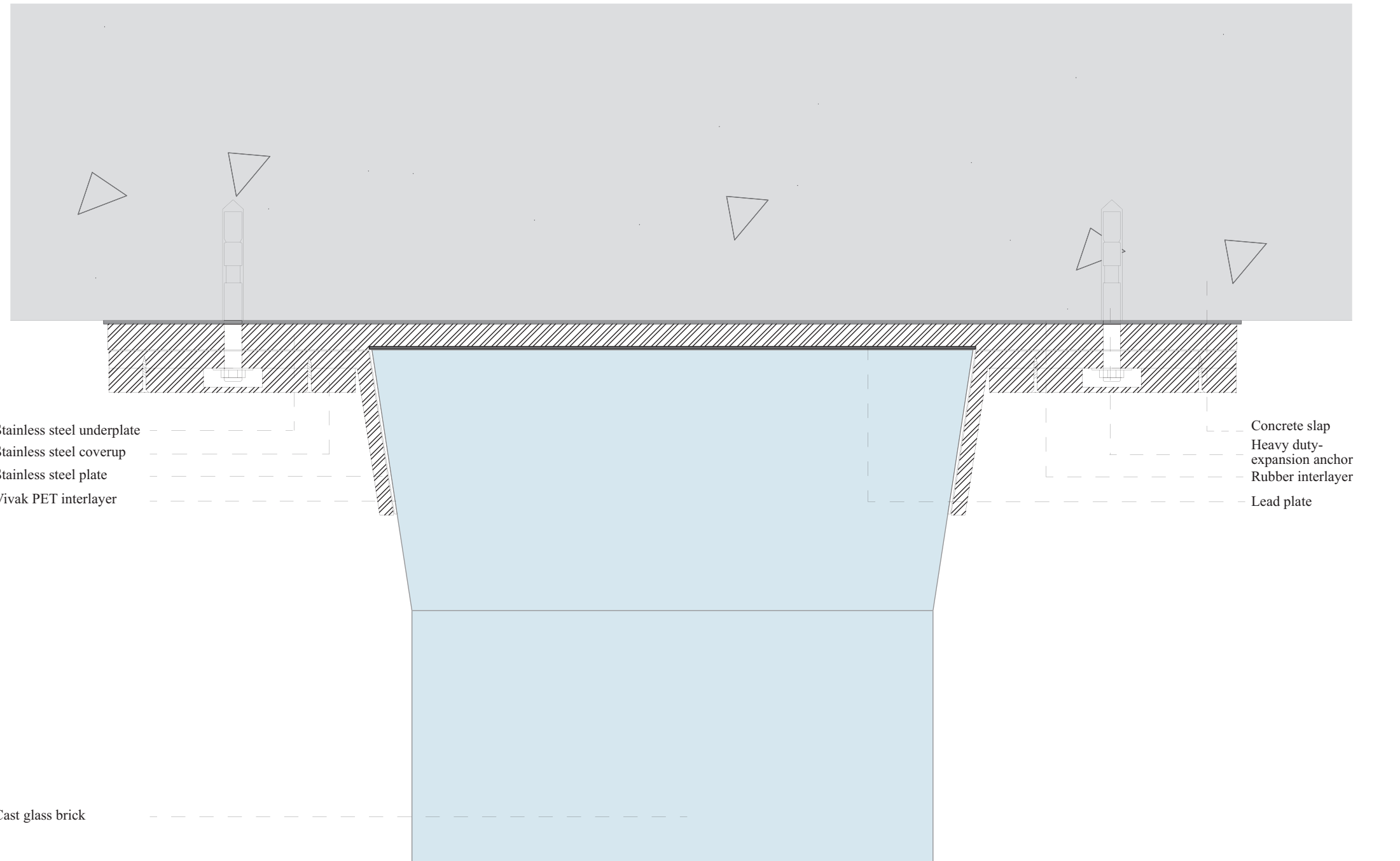
Thermally toughened safety glass &
heat strengthened glass



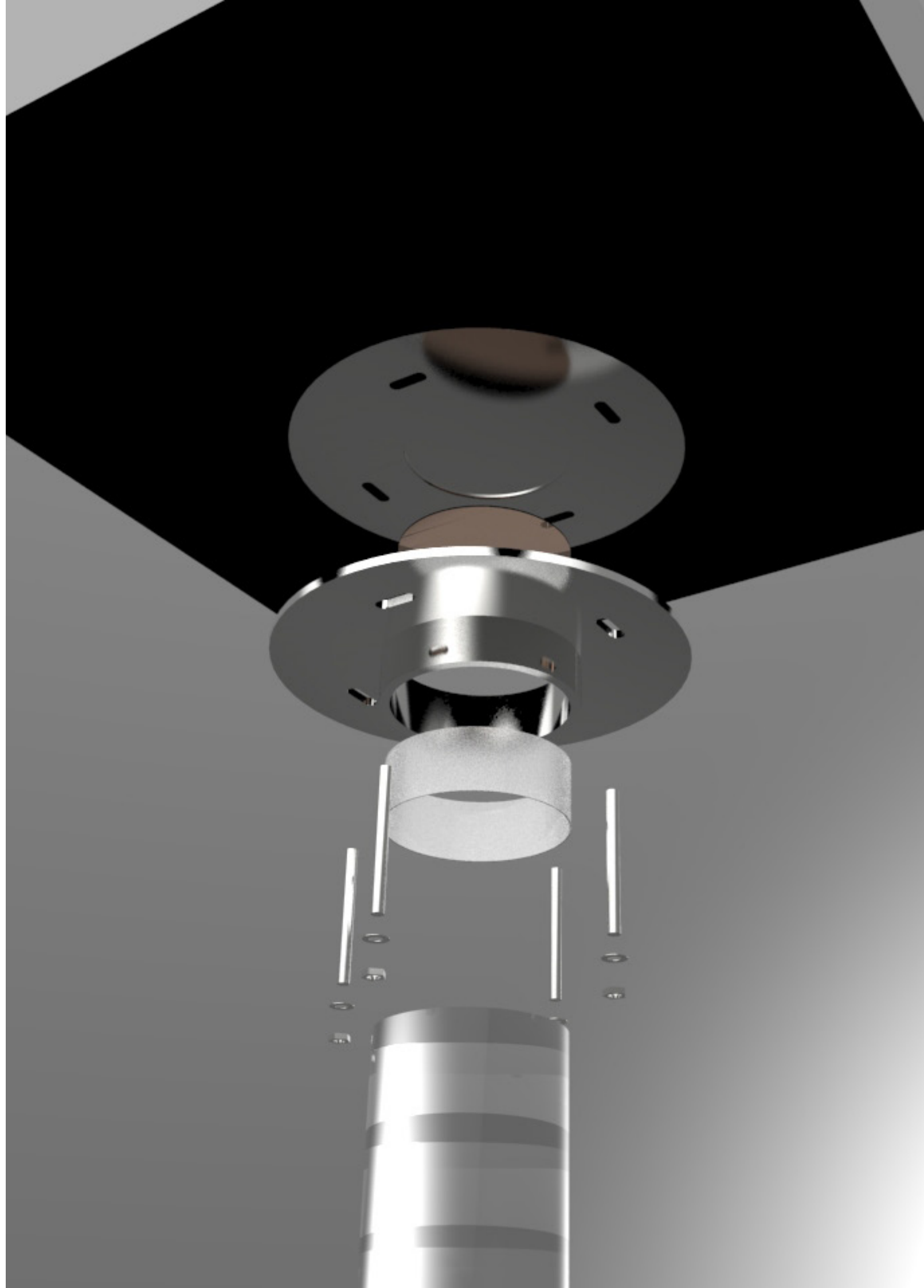
Breakage



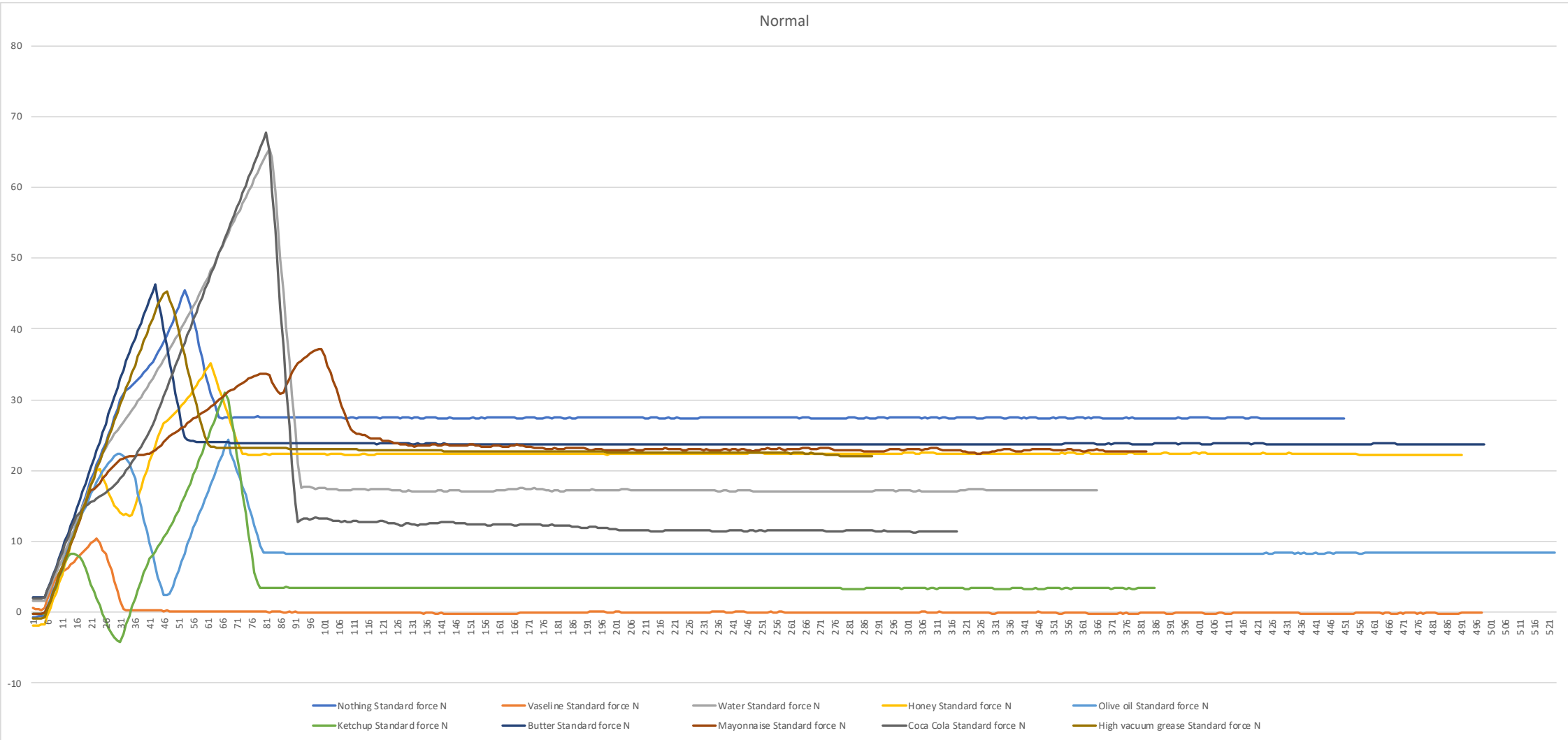
Details



Details

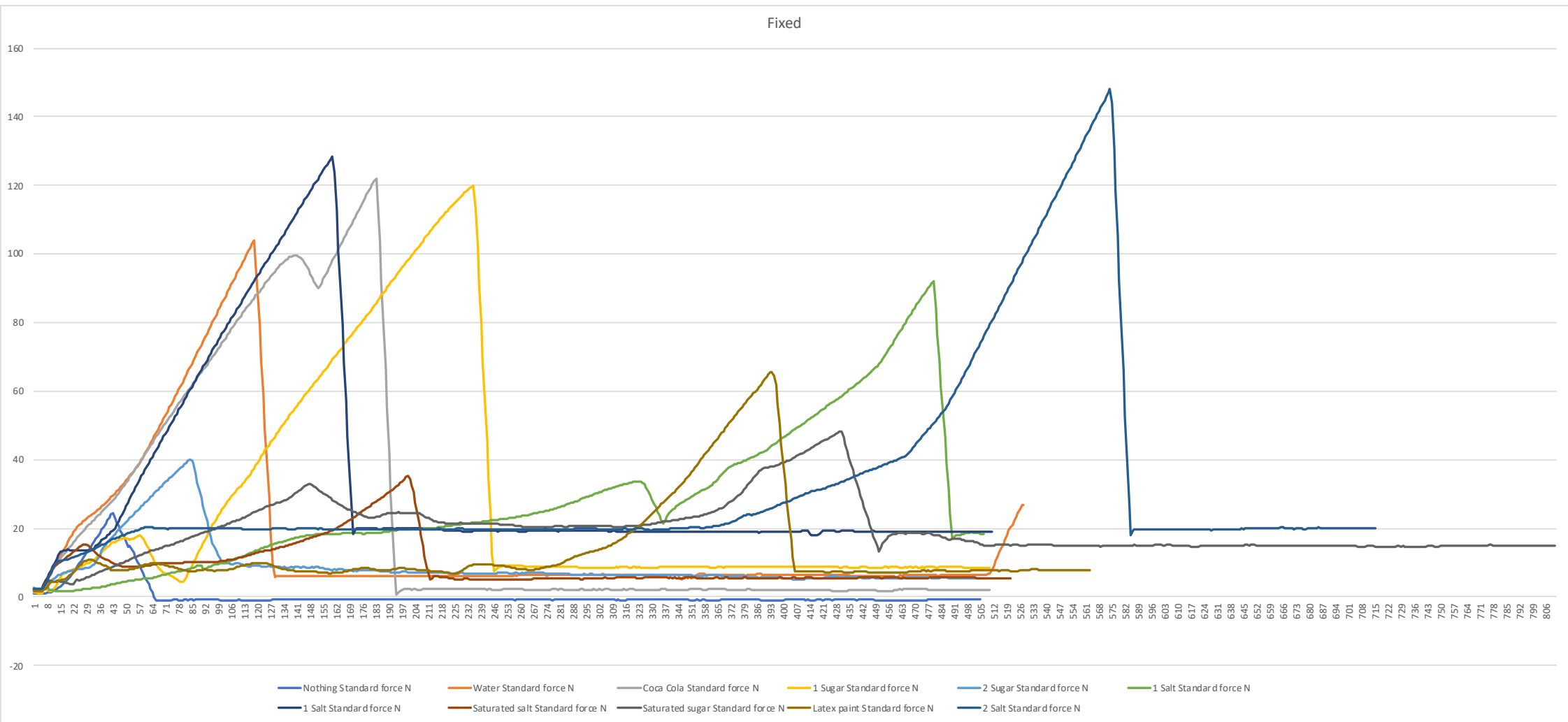


Test



The first tests that are done were to see how different liquids would behave when in between two surfaces of glass. Some of the liquids are known for their ability to stick very good, others to vacuum the space in between. Looking at the peak forces, Coca Cola and water work the best. These are both water based. These test results gave the idea to do the next experiments with water-based liquids. In this figure it is visible that Coca Cola works a bit better than water. The reason behind this could be sugar. Sugar gives water a different viscosity what can relate to the better results. This is worth testing.

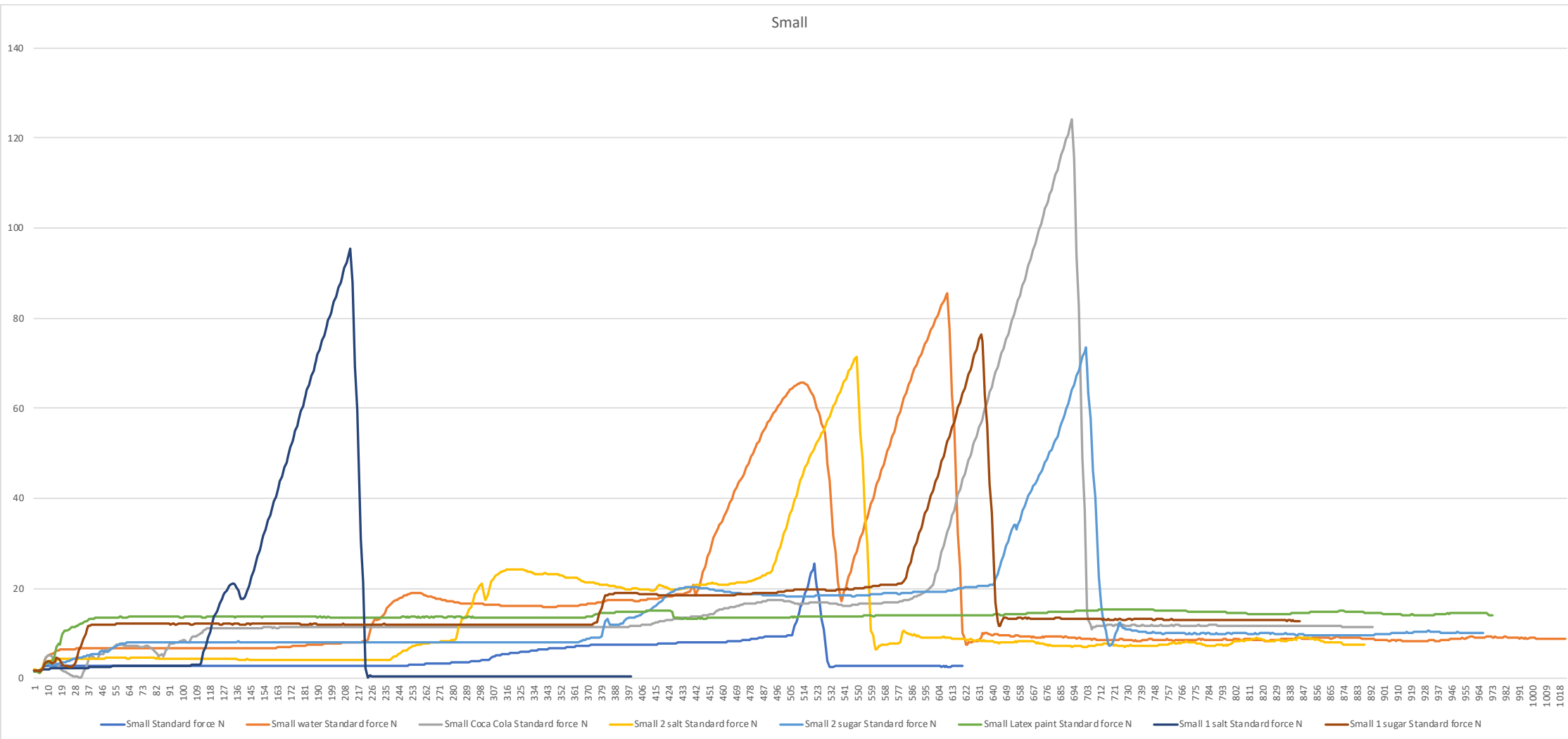
Test



During the second test session the stops are pushed into the Erlenmeyer. This way the frozen connections that are explained before are imitated. The forces will for this be higher than the previous tests. Visible in this graph is that two bags of salt work very well. One bag of salt is also performing fine. Water with 1 bag of sugar and Coca Cola work just as good. All the better working liquids are around 130 N. This is higher than the first tests, but still not workable in a construction. Saturated salt doesn't work at all, because all the water molecules are already attracted to a Sodium or Calcium ion.

The next set of tests is done to see if there is a difference when it comes to surface. An Erlenmeyer with a slimmer neck is used. The amount of surface is less what might give lower results, due to less contact friction.

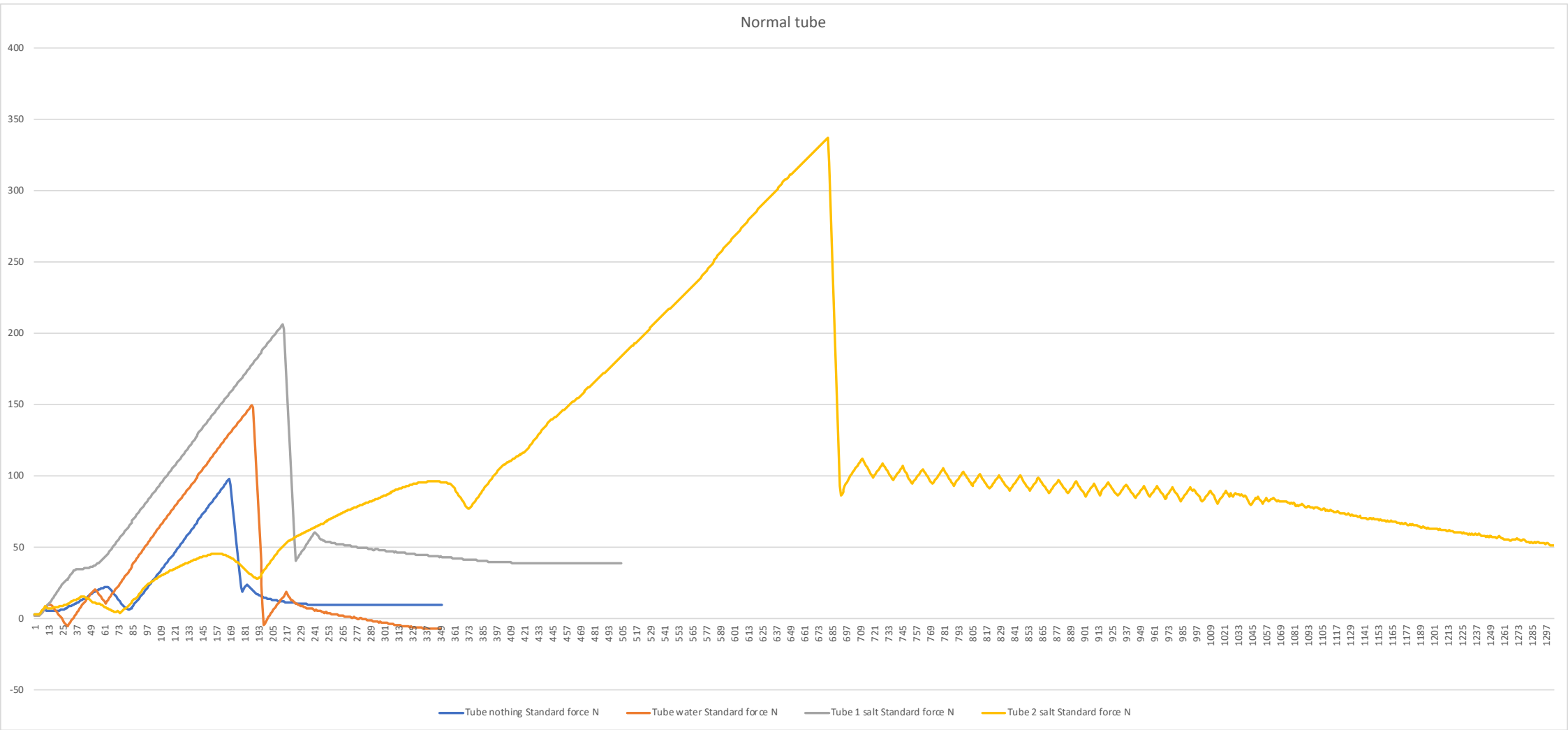
Test



Here Coca Cola works the best. It works almost as good as with the bigger neck. The rest of the liquids work less good. The second one is 1 salt. What is weird is that 2 salt don't really work here. This might be because there is less surface the water with salt can connect to

The next tests will show us if a tube behaves differently than a stop.

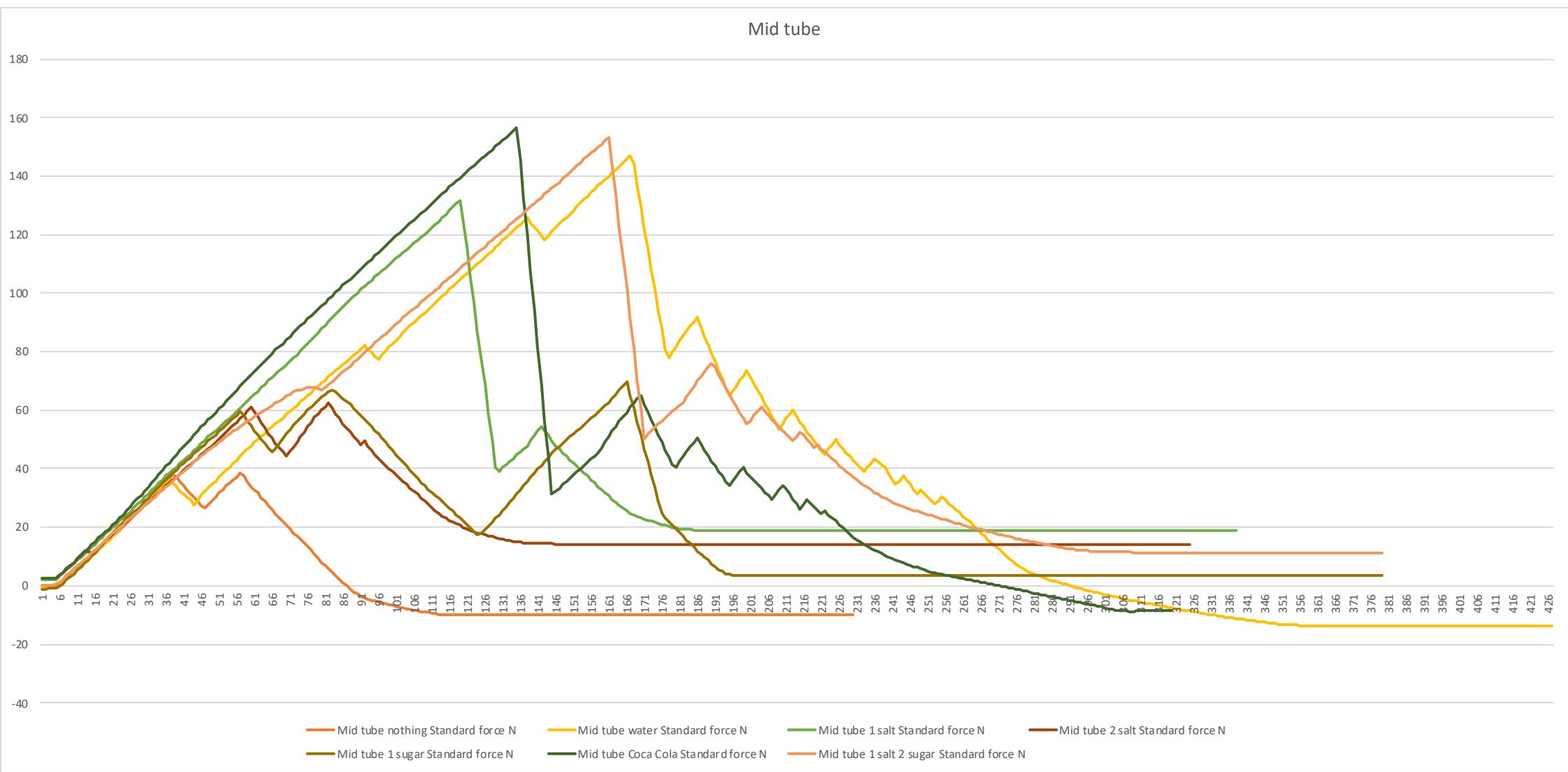
Test



During this set of tests the last Erlenmeyer with these sizes broke. This means that there are not many results. It does give the new record. Again 2 bags of salt work well and give us a result of around 320 N, So, around 32 Kilograms. The results also show that a tube seems to be working better than a stop. This can still be because of many reasons. For instance, it was signifyingly warmer that day, than the previous test days.

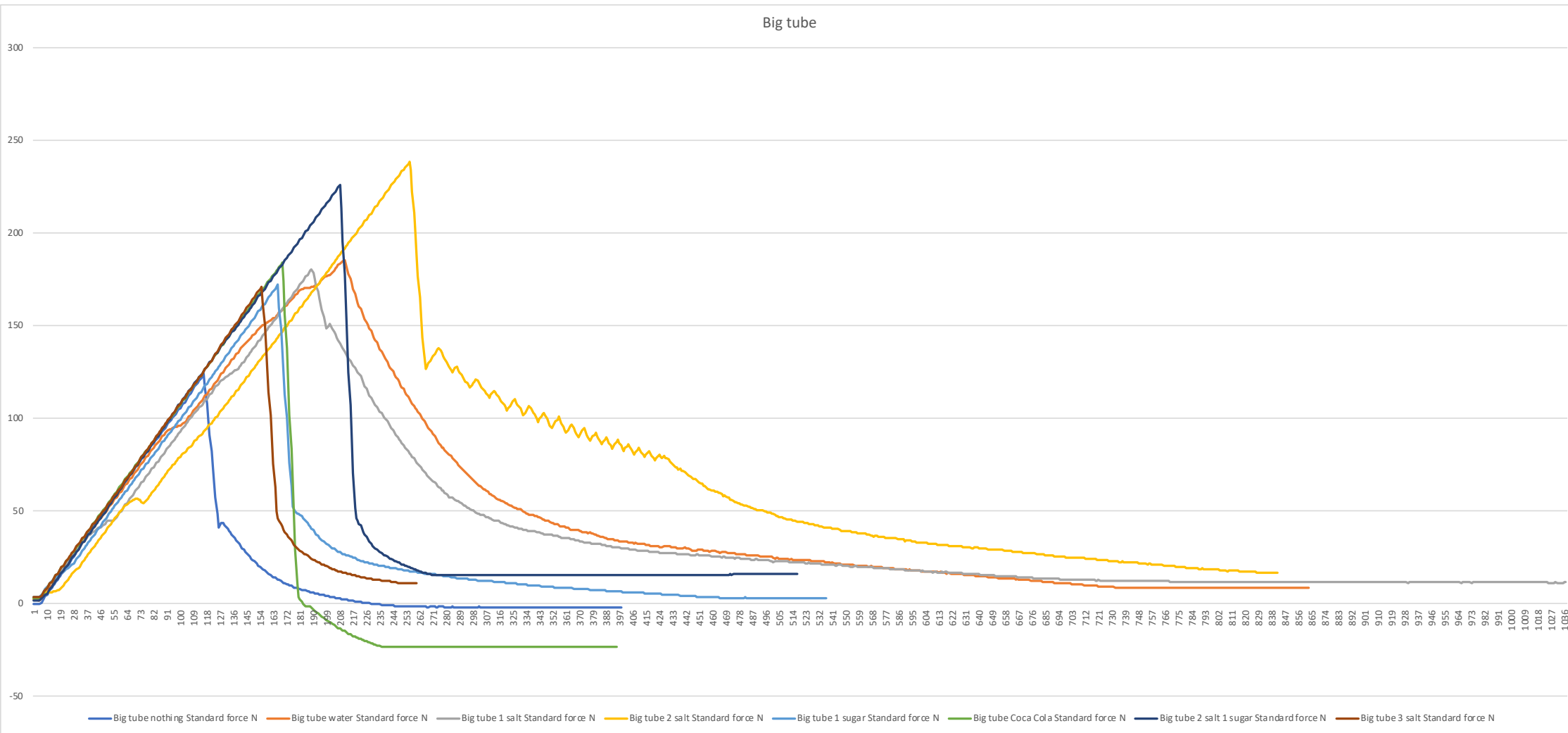
The next test will be done with a Erlenmeyer with sizes that are close to this one. This might give results that can be compared to the first stop tests.

Test



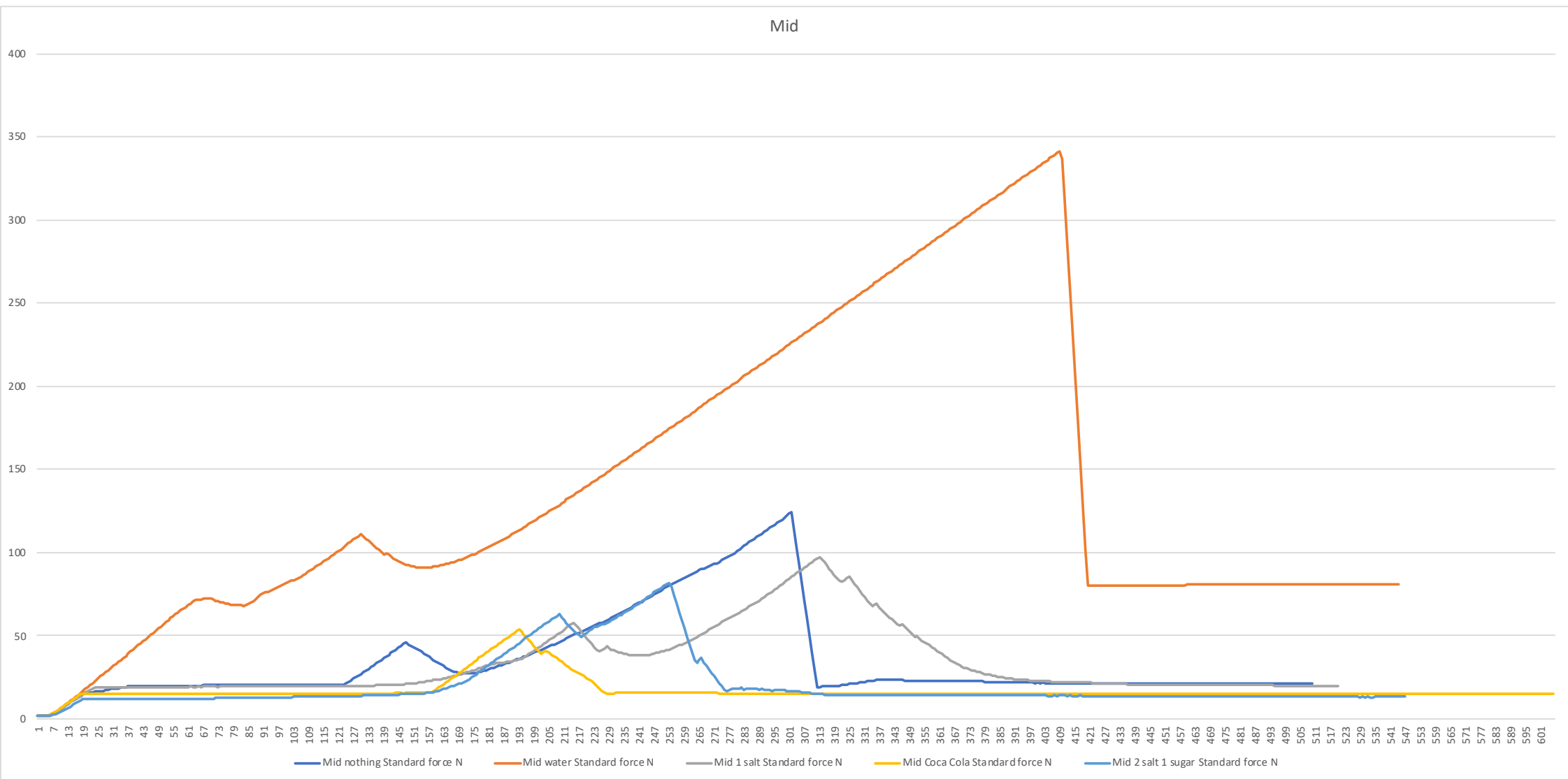
The results are not very promising. The top results give a maximum force of 150 N. It does stand out that 2 bags of salt didn't work well. This might still be because there is less surface. Because salt and sugar are giving pretty well results, the thought occurred to combine these two. Maybe, when the water is made less aqueous and eclectically charged with the salt, the results would increase. This did give one of the better results, but not higher than others that perform good.

Test



To look at the differences in results compared to the amount of surface, there are tests done with a bigger neck. This means that there now 3 sizes to compare. The results are higher than the small tube, and it stands out that 2 bags of salt again works well. This approves the theory that there is now again more surface to hold on to. Because this also has more surface than the normal Er-lenmeyer there is a test done with three bags of salt. This is apparently to much salt.

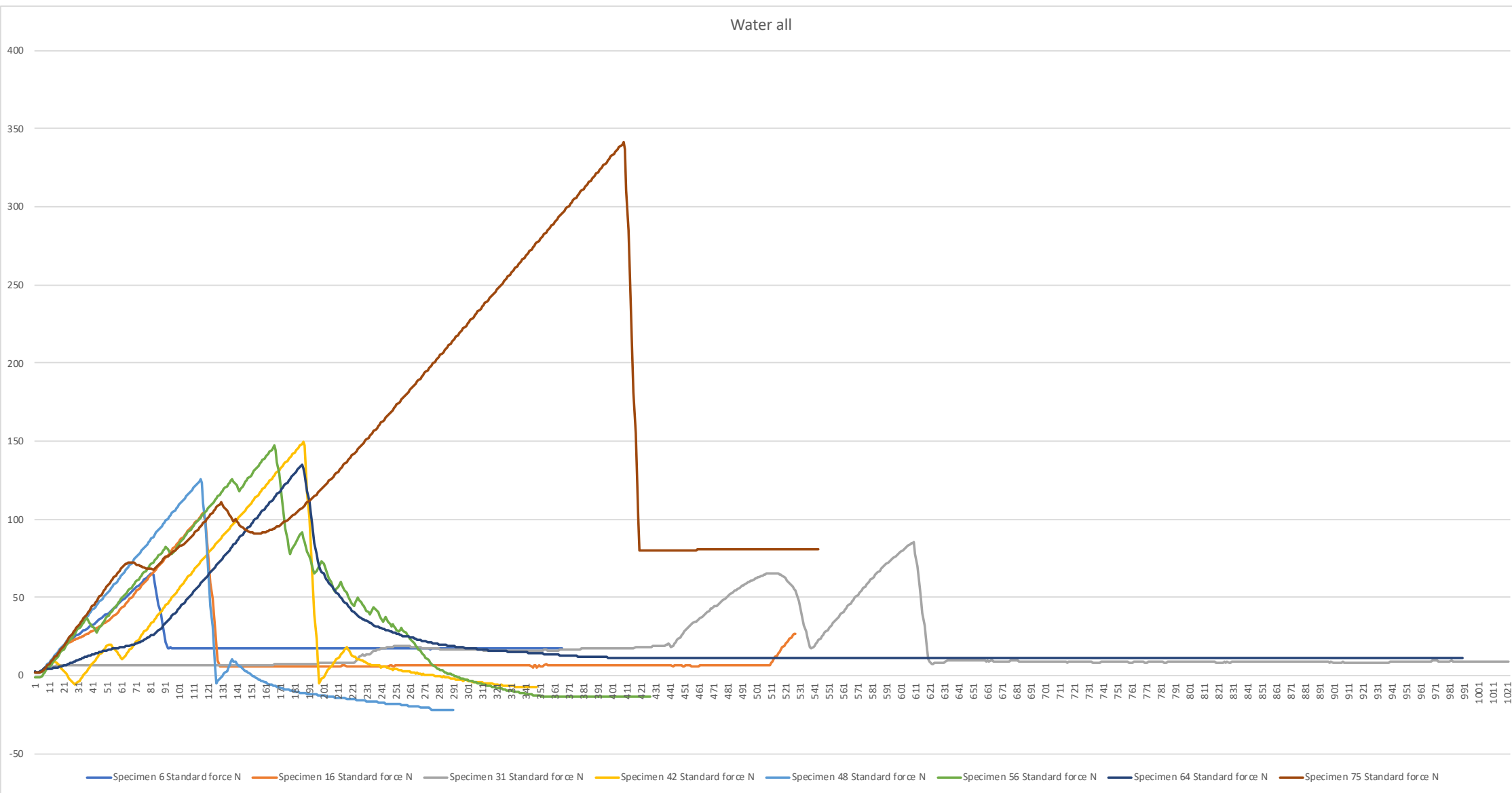
Test



The mid Erlenmeyer has the closest diameter to the real rod. It is good to properly test this one. That is why even though the tests with the tube gave a better result than the stop ones, the stops are still tested. These tests did show surprising results. Water gave an extremely good result and second in line is nothing.

The results depend on a lot of different things, but to try an explanation for these results, the glass of the mid Erlenmeyer and the tube and the stop will be tested.

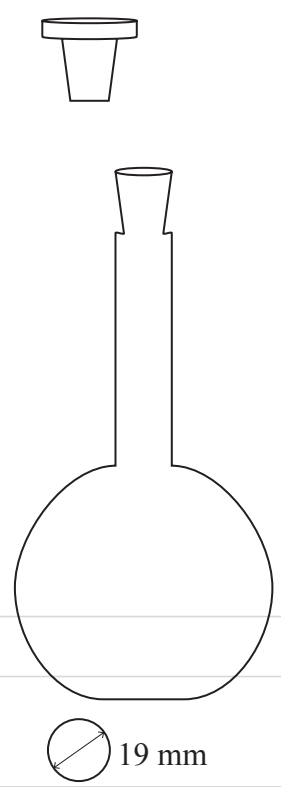
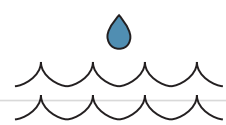
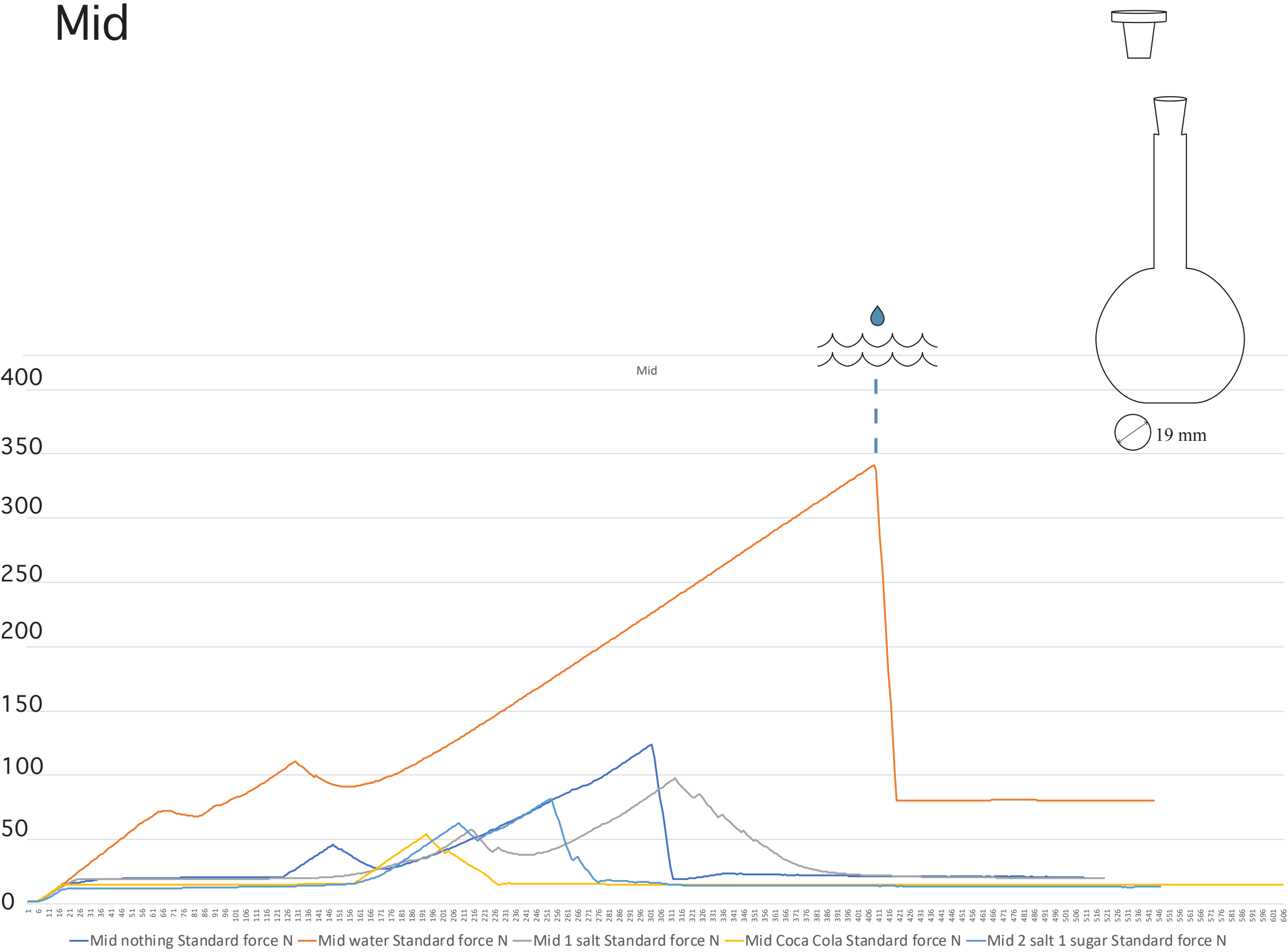
Test



Even though there are more than 80 tests done, it is hard to give a conclusion. Water gave a pretty constant result. So, this graph shows how all the different sizes worked with water. One of the conclusions that can get out of this, is that it is possible to get a high result like the 350 N. It is just not a constant result. It is better to assume to get a result around 150 N.

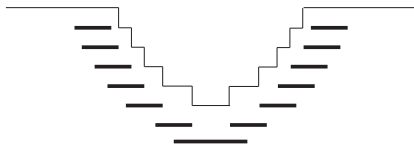
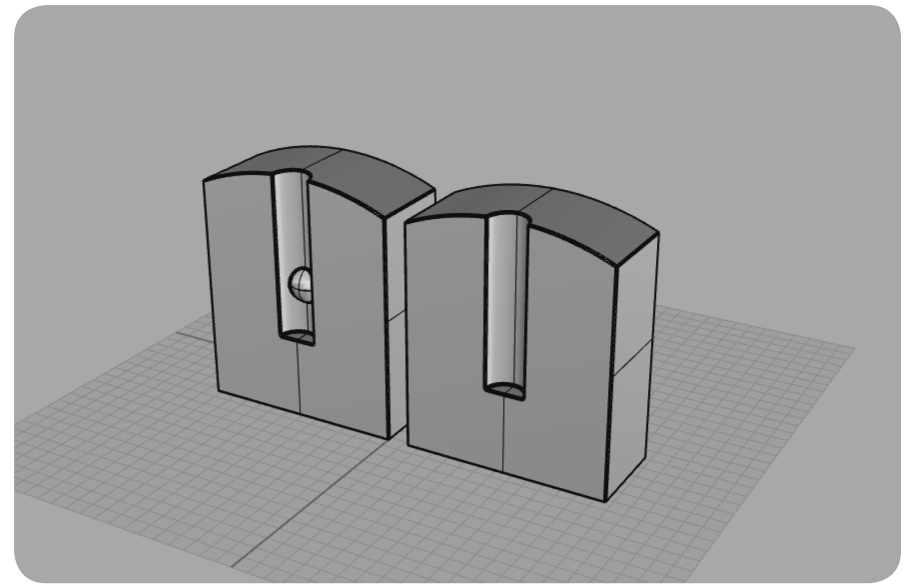
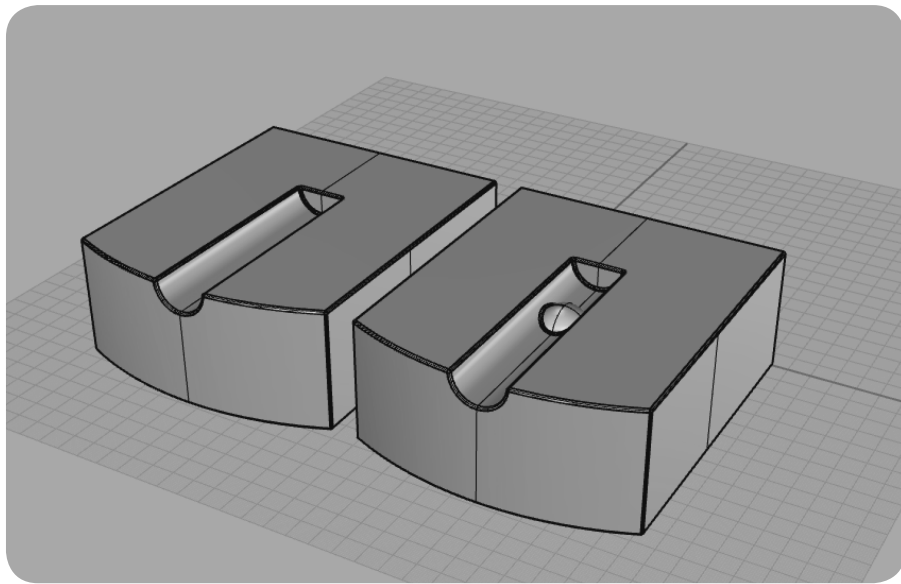
Relevant tests

Mid



19 mm

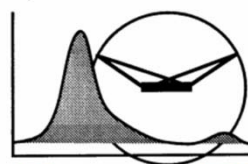
My glass



Glass test



Glass test



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X-ray diffraction facilities

Experimental conditions:

For XRF analysis the measurements were performed with a Panalytical Axios Max WD-XRF spectrometer and data evaluation was done with SuperQ5.0i/Omnian software. 18/12/2015 09:37:03

25/05/2018 13:27:15

PANalytical

Quantification of sample Veerle, sample "colf" 25may18

Sum before normalization: 64.0 wt%

Normalised to: 100.0 wt%

Sample type: Pressed powder

Initial sample weight (g): 2.000

Weight after pressing (g): 3.000

Correction applied for medium: No

Correction applied for film: No

Used Compound list: Oxides

Results database: omnian 4kw 27mm

Results database in: c:\panalytical\superq\userdata

	Compound Name	Conc. (wt%)	Absolute Error (wt%)
1	SiO2	81.291	0.1
2	BaO	9.4	0.09
3	Na2O	4.698	0.06
4	Al2O3	3.617	0.06
5	As2O3	0.528	0.02
6	Fe2O3	0.152	0.01
7	Cl	0.102	0.01
8	CaO	0.089	0.009
9	K2O	0.059	0.007
10	SO3	0.024	0.005
11	SrO	0.018	0.004
12	ZnO	0.011	0.003
13	P2O5	0.011	0.003

Glass test

25/05/2018 13:29:23

PANalytical

Quantification of sample Veerle, sample "stop" 25may18

Sum before normalization: 48.5 wt%

Normalised to: 100.0 wt%

Sample type: Pressed powder

Initial sample weight (g): 2.000

Weight after pressing (g): 3.000

Oxygen validation factor: 0.00

Correction applied for medium: No

Correction applied for film: No

Used Compound list: Oxides

Results database: omnian 4kw 27mm

Results database in: c:\panalytical\superq\userdata

	Compound	Conc.	Absolute
	Name	(wt%)	Error (wt%)
1	SiO2	91.736	0.1
2	Na2O	5.263	0.07
3	Al2O3	2.258	0.04
4	Cl	0.184	0.01
5	ZrO2	0.097	0.009
6	Fe2O3	0.09	0.009
7	CaO	0.079	0.008
8	MgO	0.074	0.008
9	K2O	0.051	0.007
10	SO3	0.05	0.007
11	CeO2	0.042	0.006
12	TiO2	0.028	0.005
13	P2O5	0.019	0.004
14	Cr2O3	0.012	0.003
15	CuO	0.008	0.003
16	ZnO	0.007	0.002
17	SrO	0.002	0.001

25/05/2018 13:30:48

PANalytical

Quantification of sample Veerle, sample "tube" 25may18

Sum before normalization: 53.5 wt%

Normalised to: 100.0 wt%

Sample type: Pressed powder

Initial sample weight (g): 2.000

Weight after pressing (g): 3.000

Oxygen validation factor: 0.00

Correction applied for medium: No

Correction applied for film: No

Used Compound list: Oxides

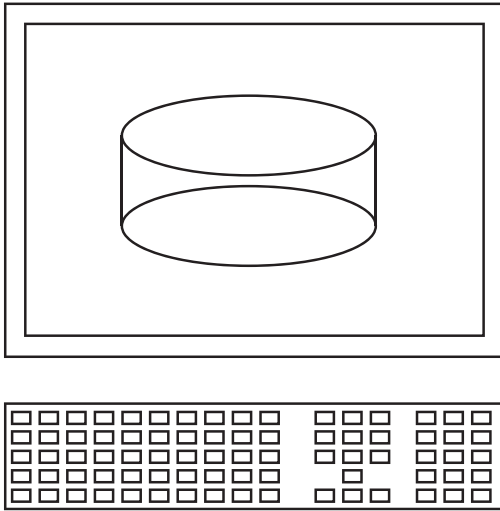
Results database: omnian 4kw 27mm

Results database in: c:\panalytical\superq\userdata

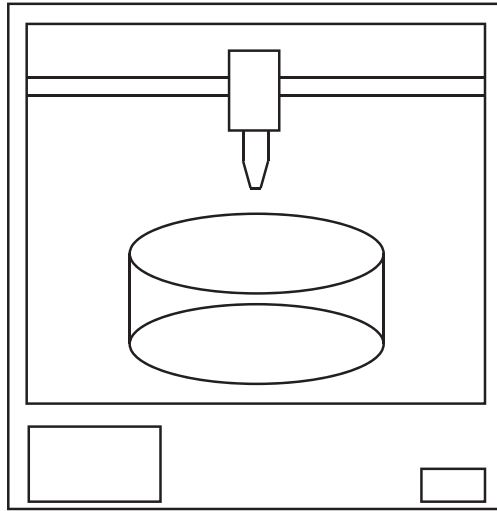
	Compound	Conc.	Absolute
	Name	(wt%)	Error (wt%)
1	SiO2	92.154	0.1
2	Na2O	4.158	0.06
3	Al2O3	2.725	0.05
4	K2O	0.542	0.02
5	Cl	0.101	0.01
6	ZrO2	0.09	0.009
7	Fe2O3	0.071	0.008
8	CaO	0.059	0.007
9	MgO	0.037	0.006
10	TiO2	0.026	0.005
11	SO3	0.026	0.005
12	P2O5	0.01	0.003

9 steps to make glass

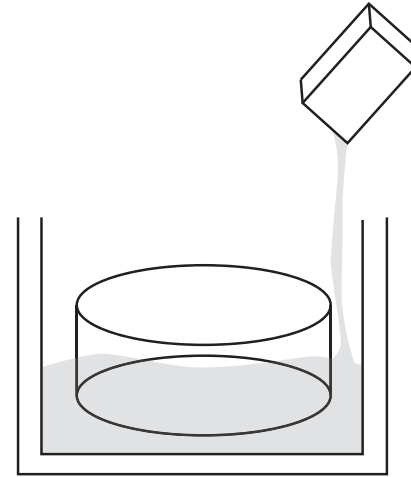
1. Computer model



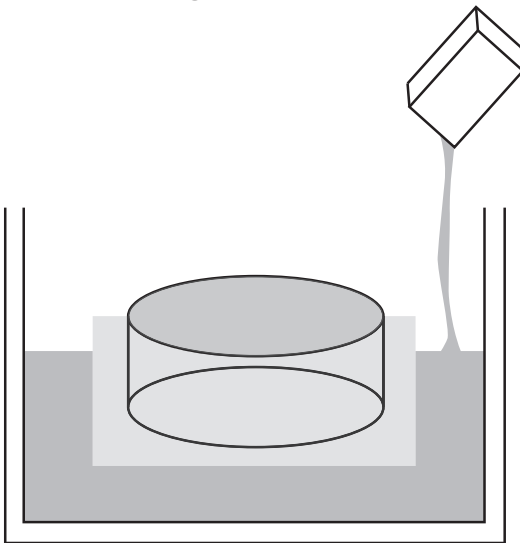
2. 3D print model



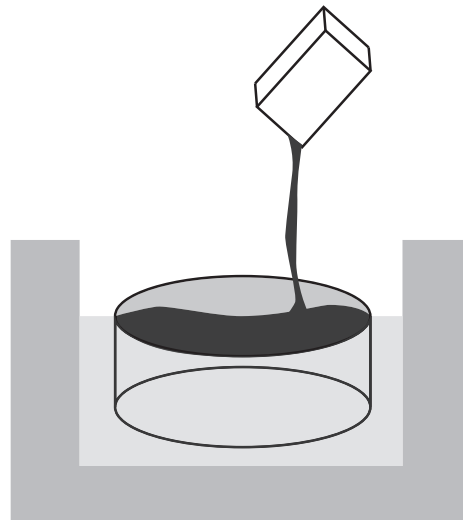
3. Make silicon mould



4. Make gypsum mould



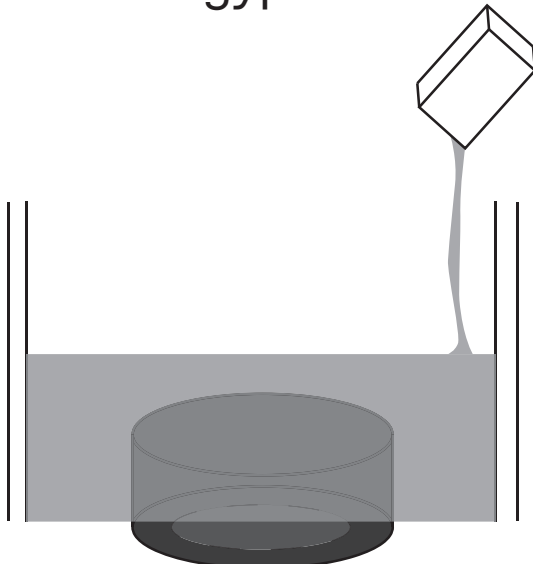
5. Pour wax



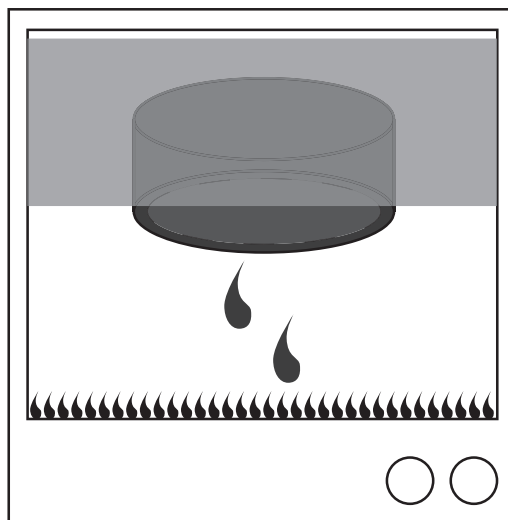
6. Slice wax



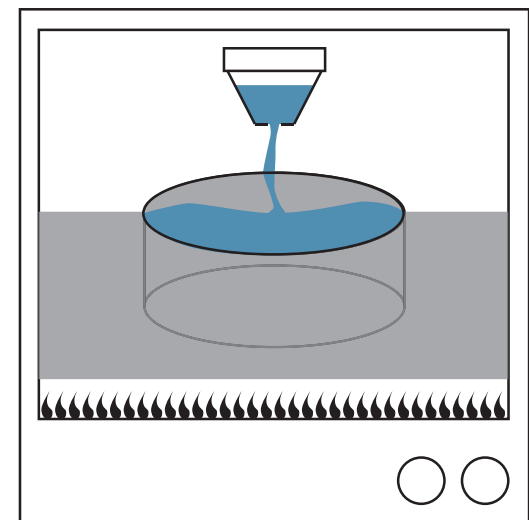
7. Make gypsum mould



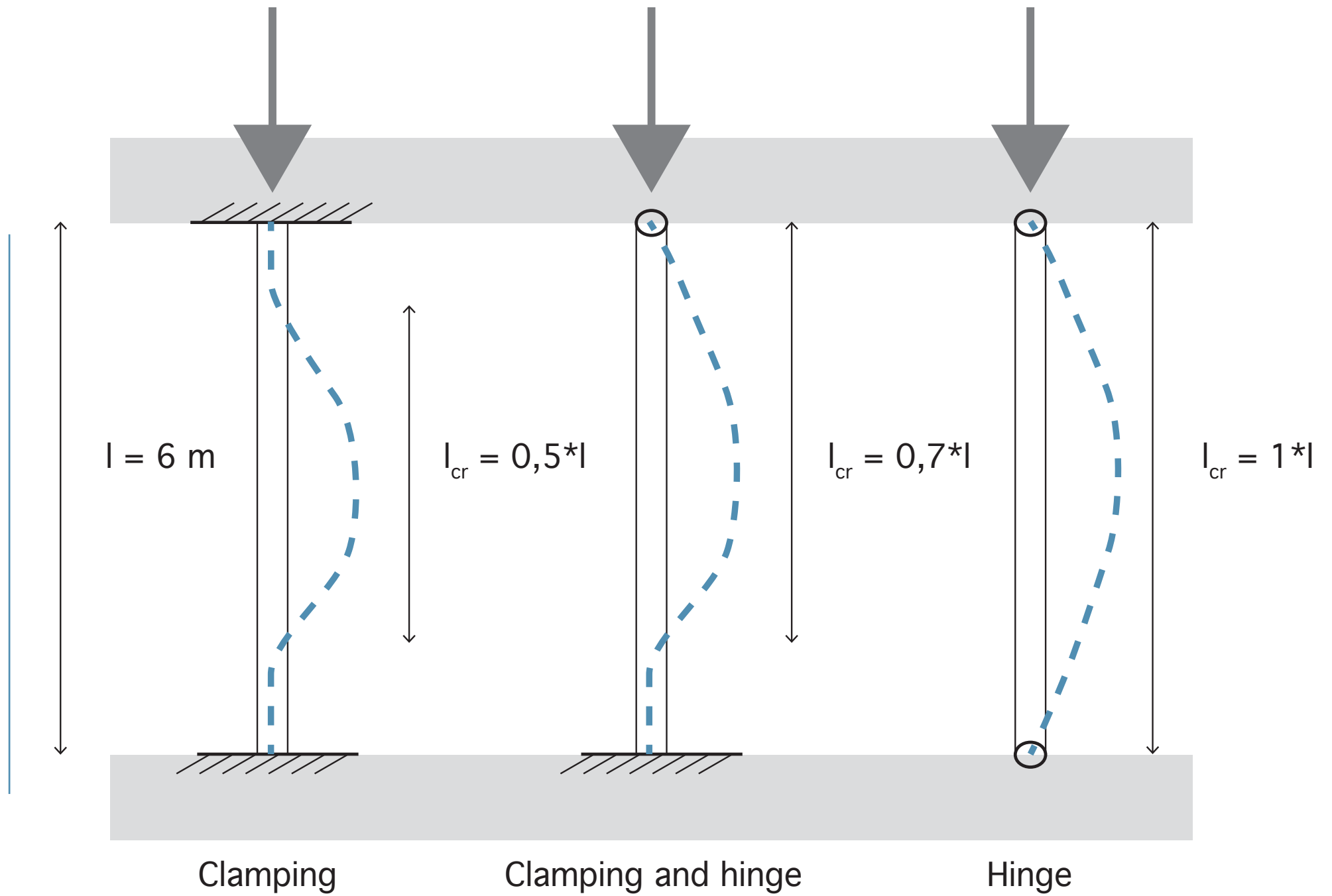
8. Melt wax



9. Pour the glass



Calculations



Thank you

