

# Appendix

## Setup for *dynamic* Solvent Vapor Annealing (*dSVA*)

*- design, operation and performance evaluation*

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### Part I – Photo Documentation of Implemented Setup(s)

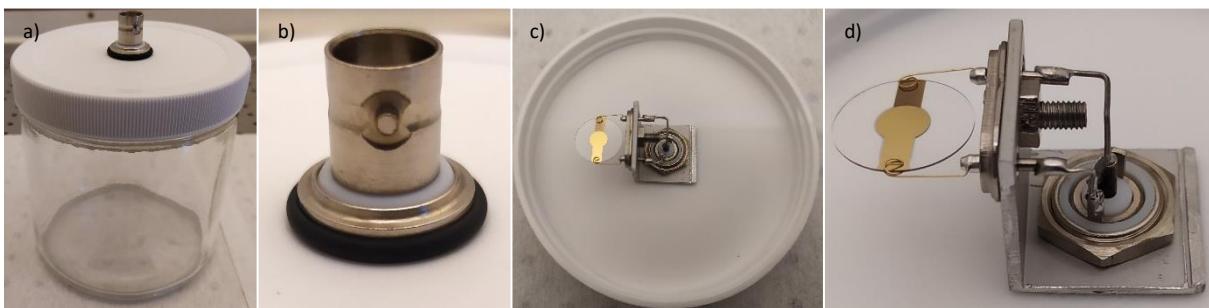


Figure S1: Air-tight glass jar, with PTFE-lined lid, for static SVA ('bell jar annealing') with option for QCM process monitoring. The panels depict (a) the closed jar, (b) the coaxial connector with an o-ring seal, (c) the inside of the lid and (d) the QCM crystal and its holder.

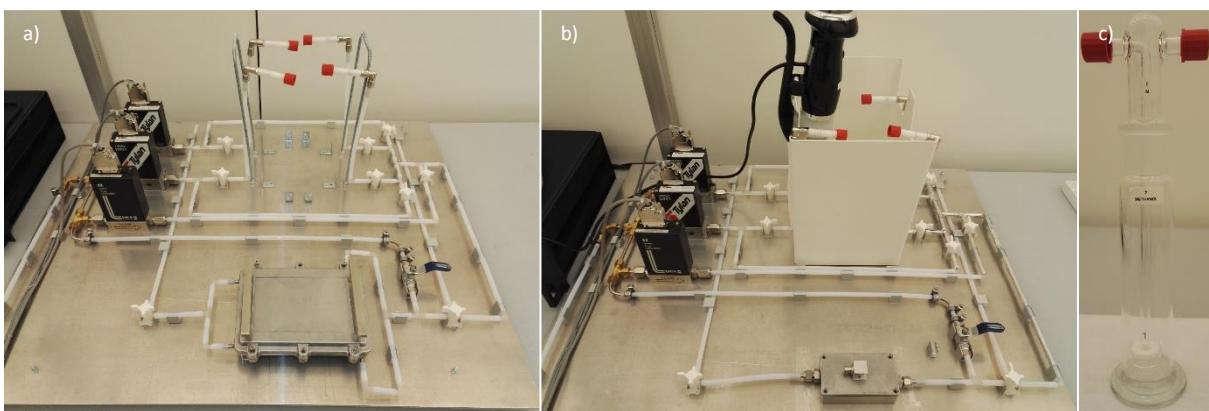


Figure S2: Previous iterations of the *dSVA* setup, mounted on Al plate, implemented using PTFE tubing, PVDF/PP tube connectors, PVDF valves and repurposed cast Al electronics boxes as SVA chambers (a and b). Glass wash bottles, with fritted glass disk for gas dispersion, were used as solvent bubblers (c).

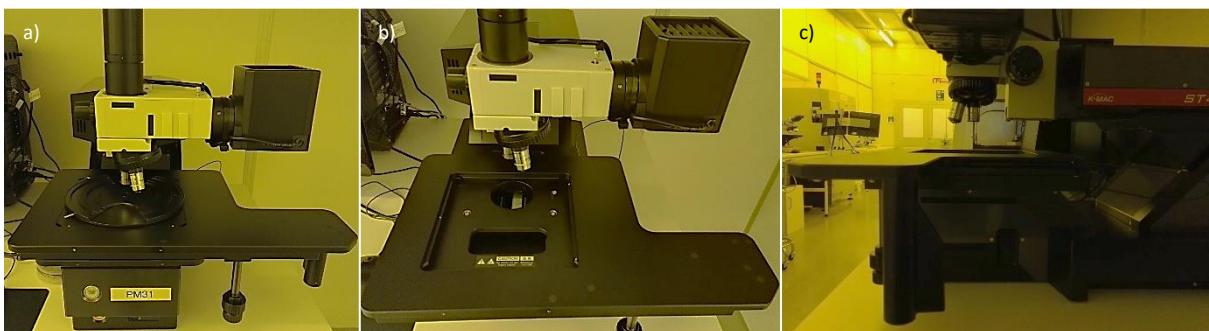


Figure S3: Front view of the K-MAC ST4000-DLX spectroscopic reflectometer (a) with and (b) without the stage inserts, respectively. The sideview in panel (c) illustrates the limited height of the *dSVA* chamber assembly possible.

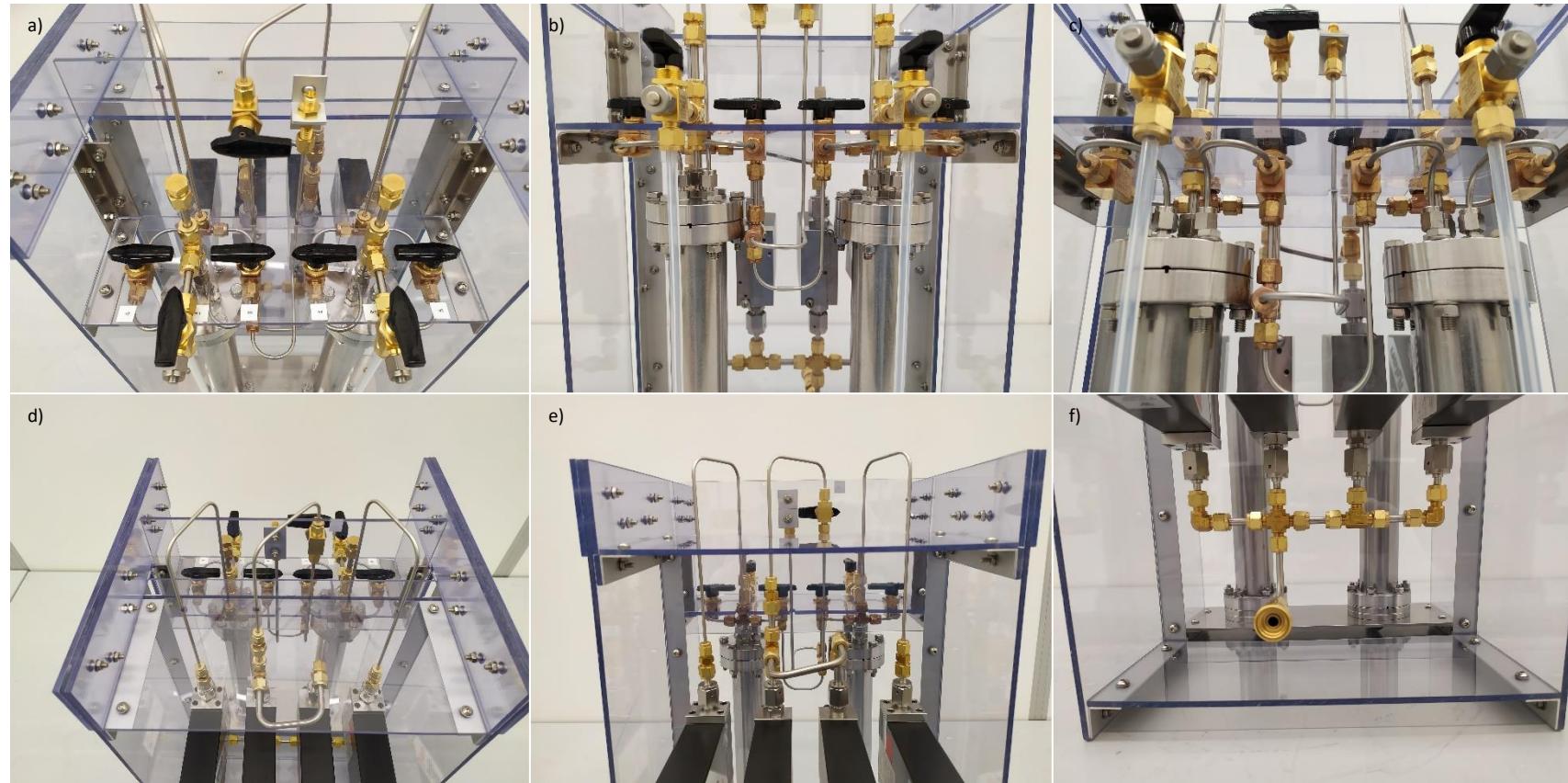


Figure S4: Closeups of the components on the front- (a-c) and backside (d-f) of *Module 1*.

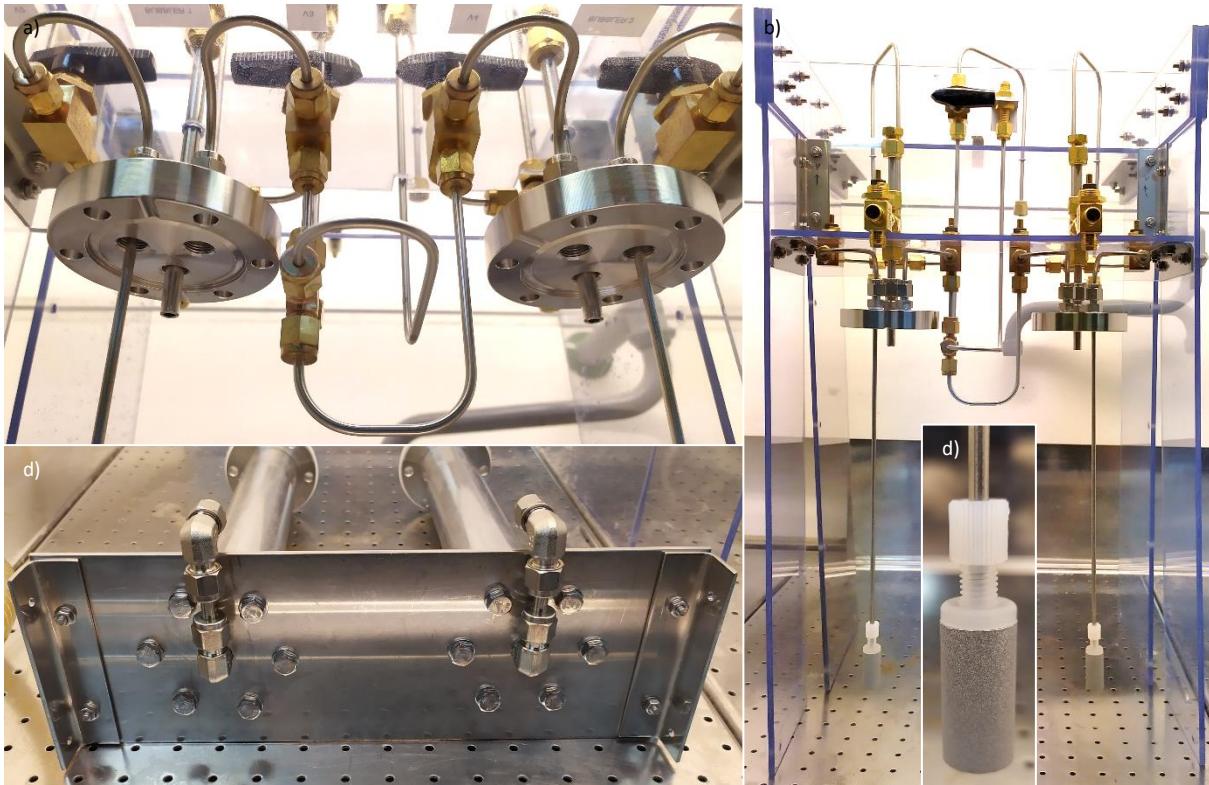


Figure S5: Compilation of images of *Module 1* during construction. Pipe feedthroughs in the top lid of the bubblers allow the carrier gas at the inlet to emerge at the bottom of the solvent column (a-b). The carrier gas is dispersed into smaller bubbles as the inlet descending pipe is terminated by a 10 µm PCTFE/stainless steel solvent filter (c). The connection of the sight-glasses to the bottom of the bubblers is illustrated in panel (d).

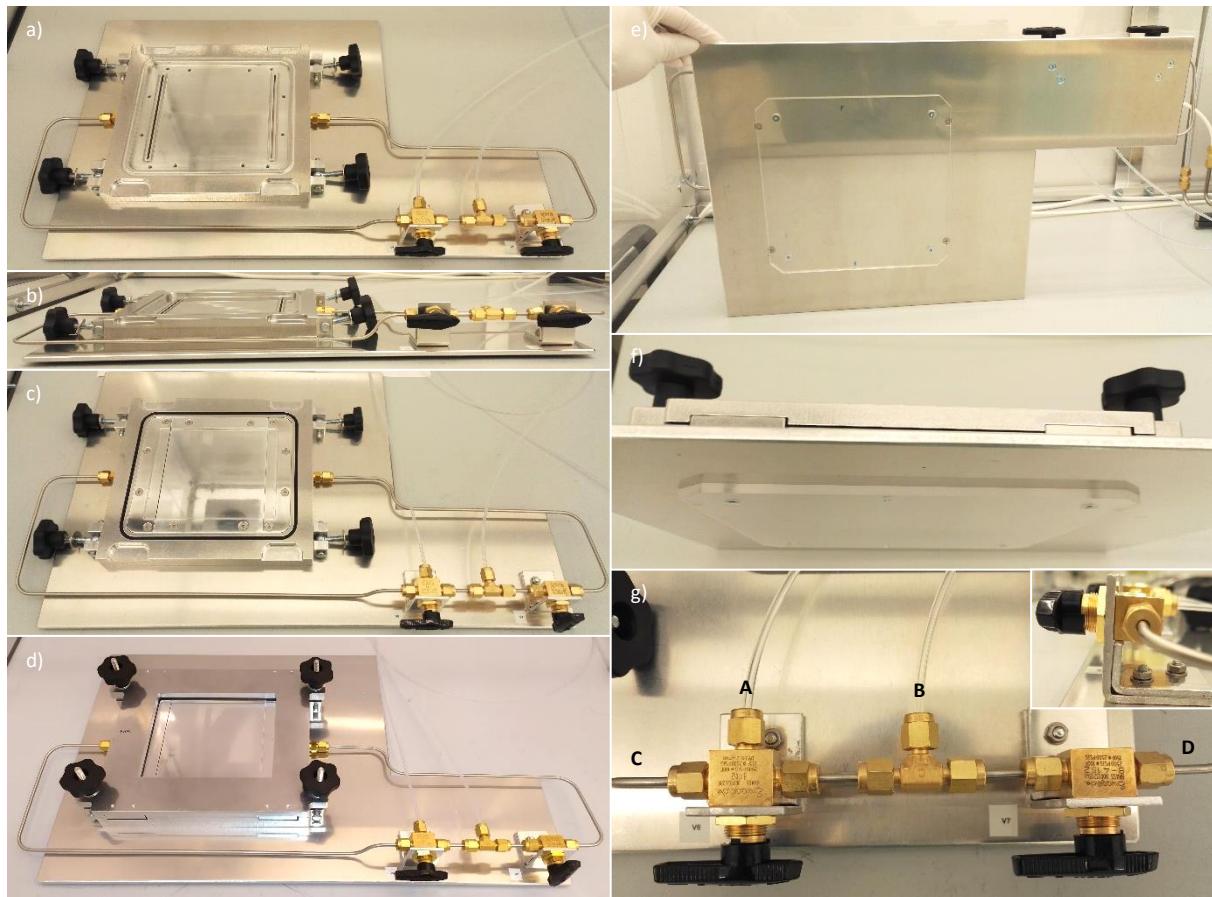


Figure S6: Image compilation of *Module 2* containing the *routing hub* and the *annealing chamber*. The chamber is depicted in different stages of assembly. To (a-b) the bare chamber body, (c) the o-rings, distribution nozzles, chamber inserts and (d) lid are added. The shaped acrylic plastic sheeting mounted on the backside of the module slots into a corresponding slot in reflectometer stage to immobilize the module relative to the stage (e-f). The routing hub is illustrated in panel (g). The PFA tubes labeled with 'A' and 'B' connects with the mixing network and venturi pump, respectively. The SS pipes labeled 'C' and 'D' connects to the inlet and outlet of the chamber assembly, respectively.

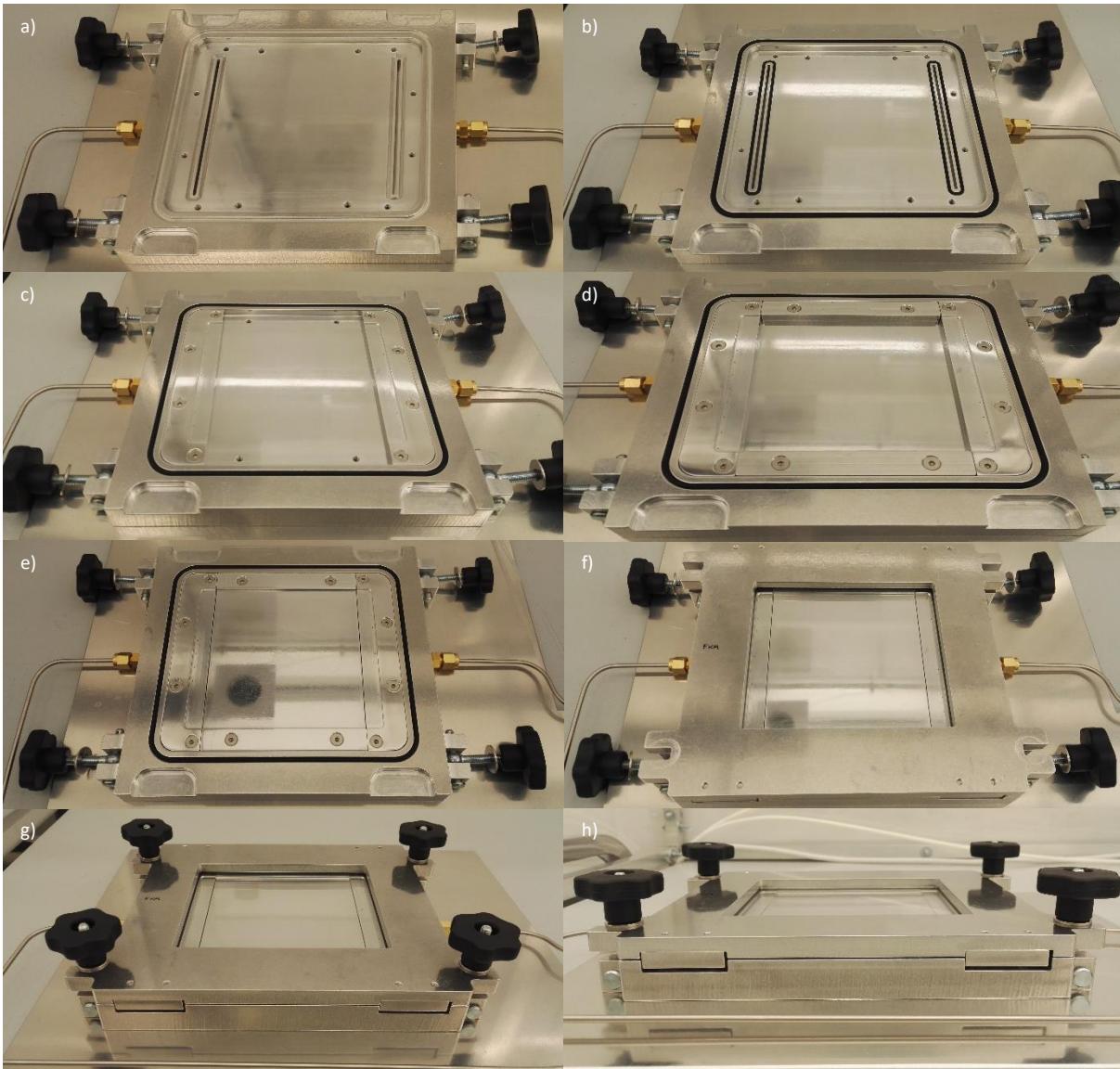


Figure S7: The *dSVA* chamber in various stages of assembly. To (a) the chamber body are added (b) the o-rings, (c) the gas distribution nozzles, (d) the cavity side lanes, (e) the chamber insert (instead of side lanes), and the lid (f-h).

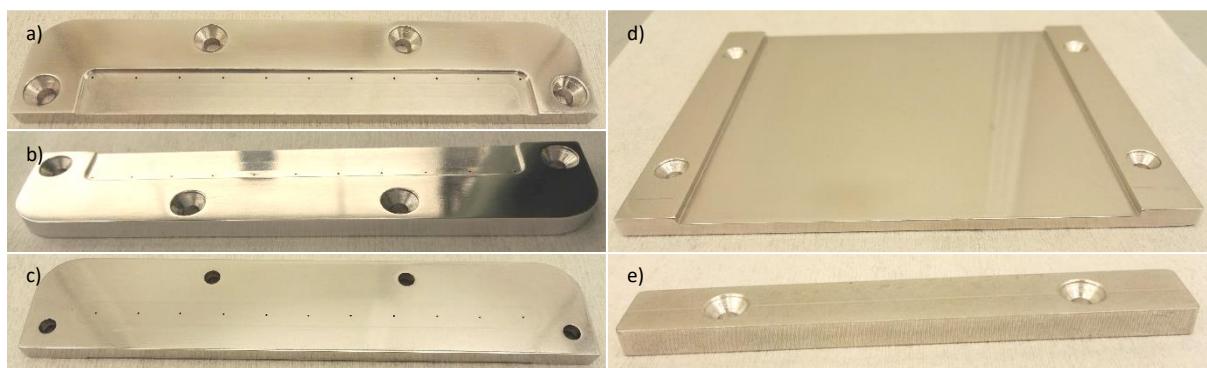


Figure S8: The gas distribution nozzles (a-c), chamber insert (d) and cavity side lanes (e) are all machined Al components that can be mounted inside the annealing volume of the chamber body.



Figure S9: The SVA chamber in various stages of assembly and from different angles. To the chamber body (a and c) are added the o-rings (b and d), the gas distribution nozzles (e), and the chamber insert (f-h).

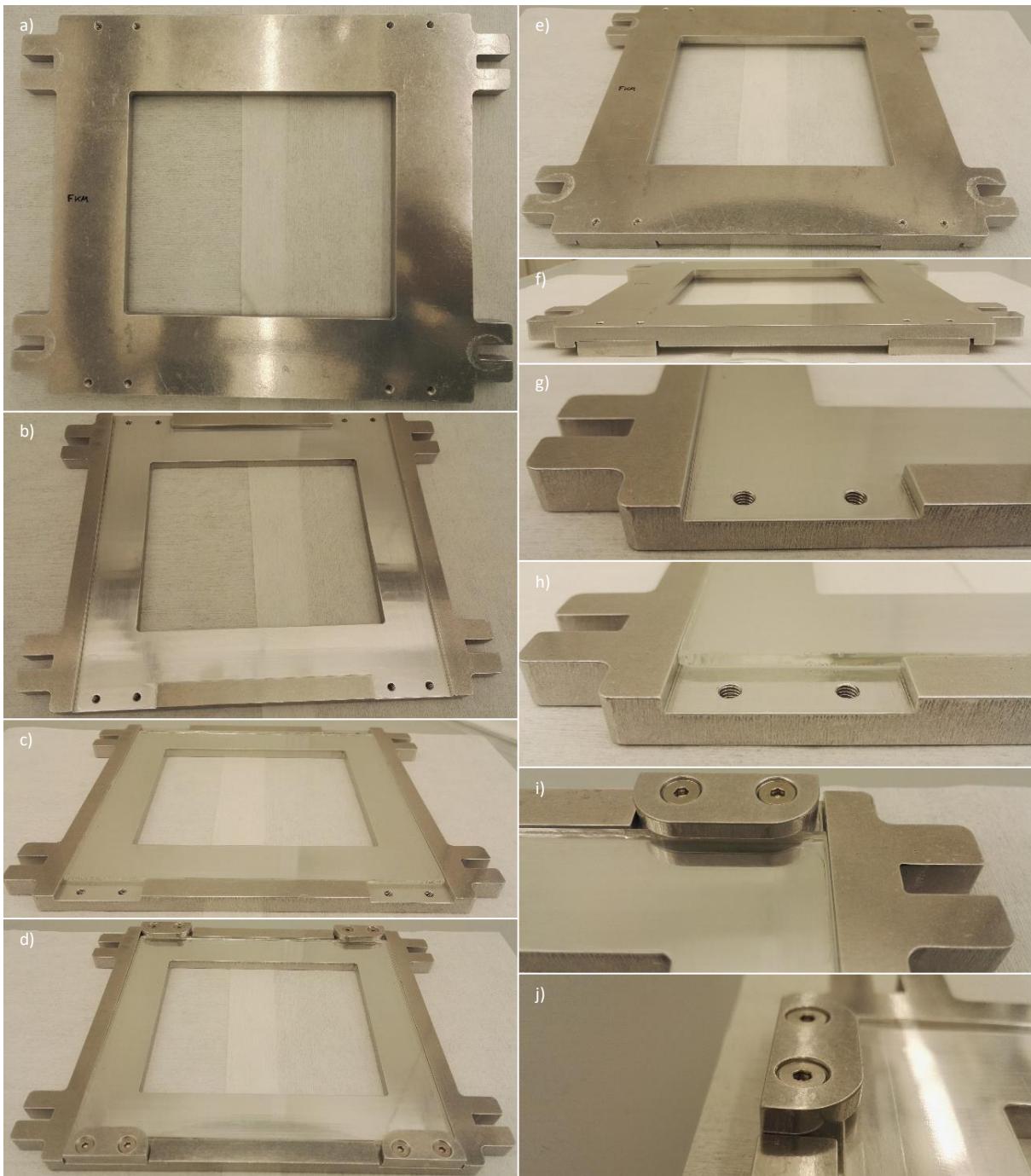


Figure S10: SVA chamber lid in various stages of assembly. To the Al frame (a and b) is added the Borofloat 33 inspection window (c) and the fastening blocks (d-f). Closeups of mounting details are depicted in panels (g-j).

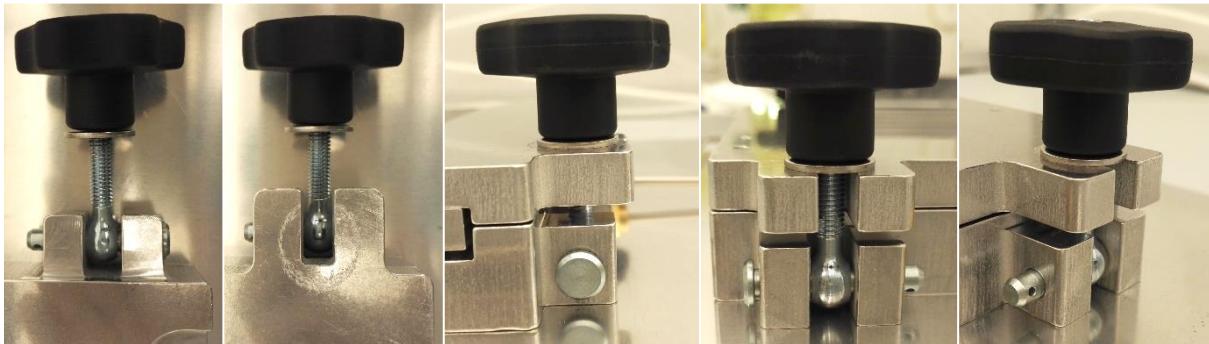


Figure S11: One of the four lid-closing assemblies from various angles.

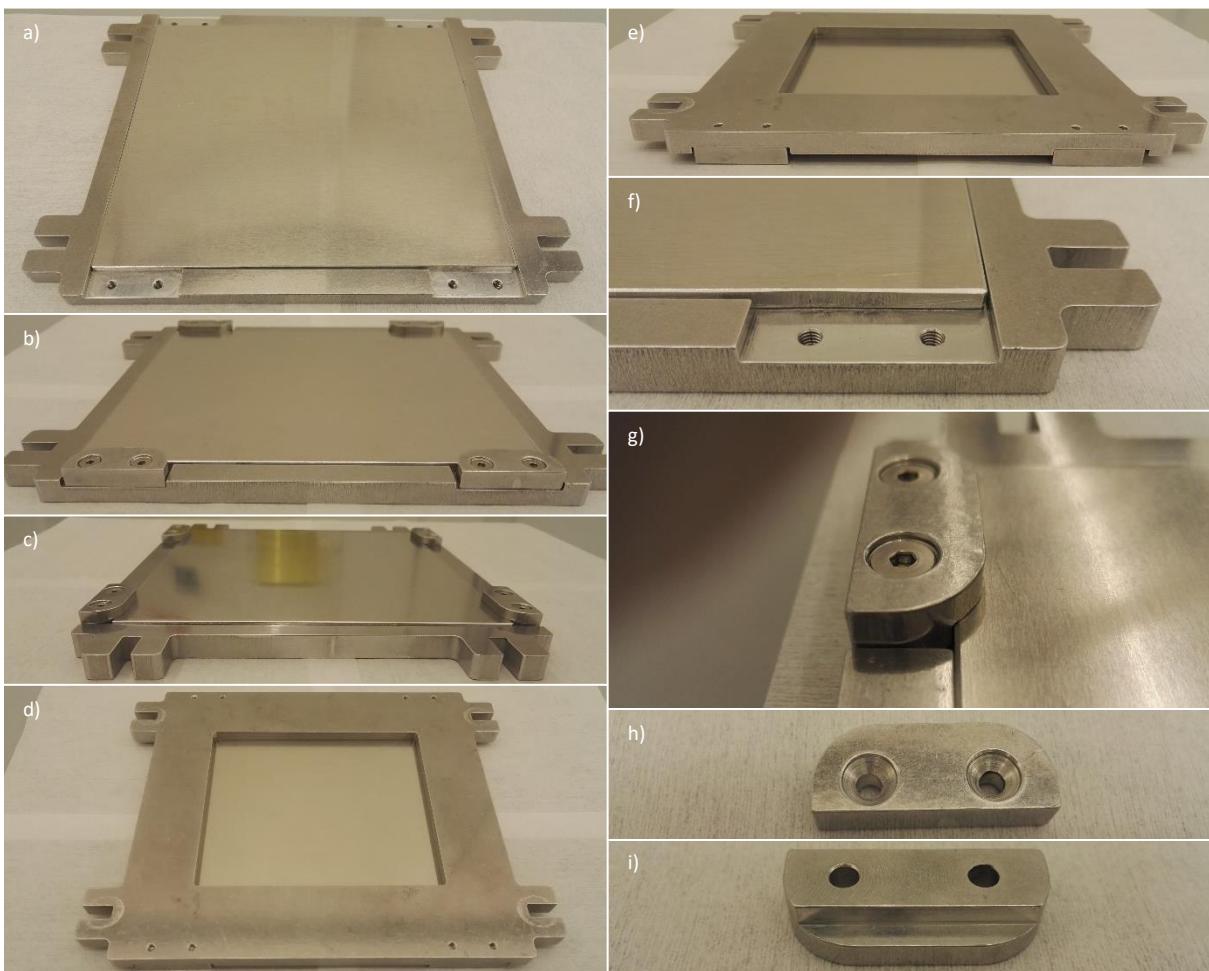


Figure S12: SVA chamber lid with Al insert (for use with vacuum pump) in various stages of assembly.

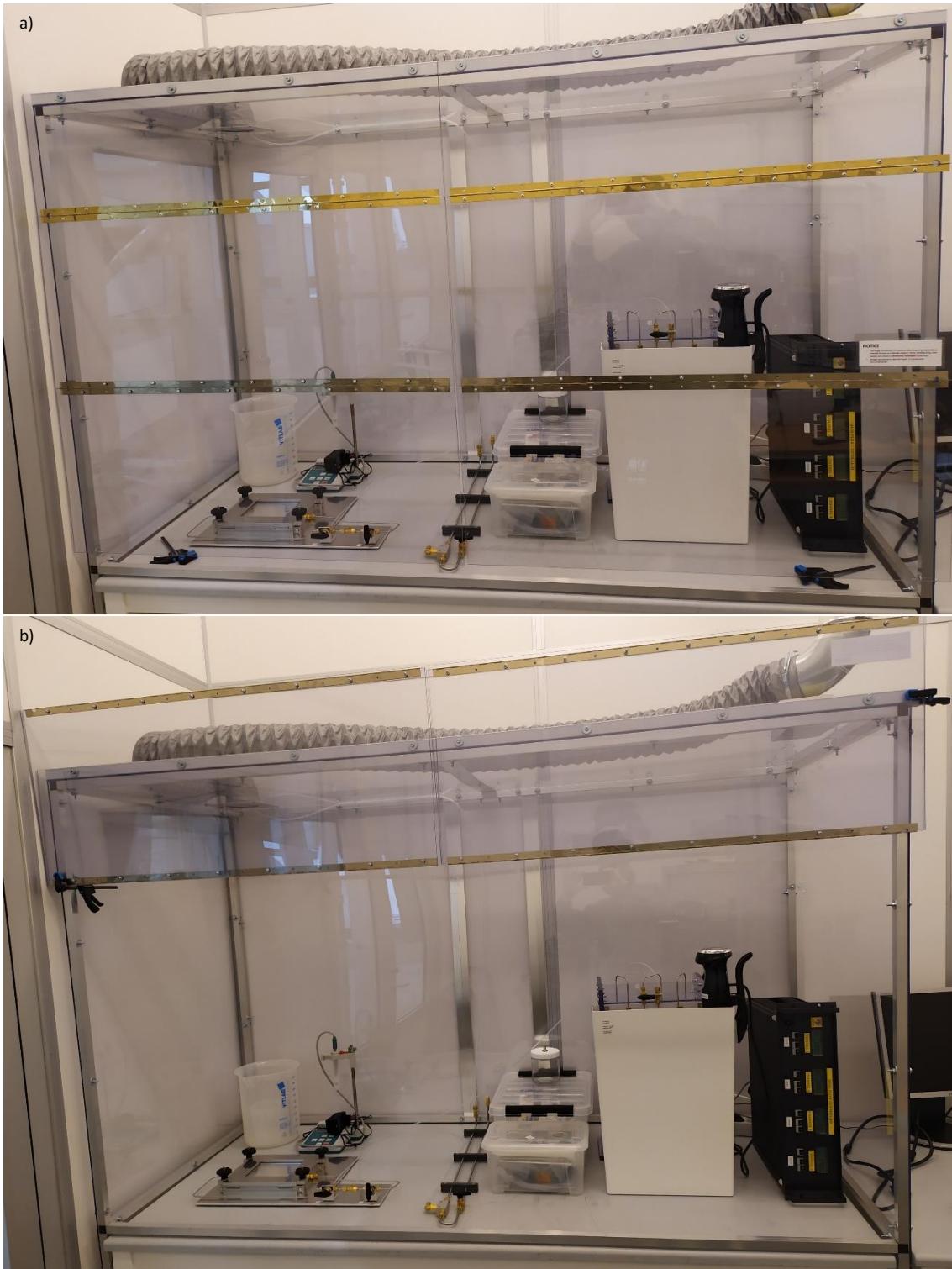


Figure S13: Ventilated protective hood of Al profiles and acrylic plastic sheeting with the front sash down (a) and up (b).

## Part II – Technical Drawings of Chamber Assembly Components

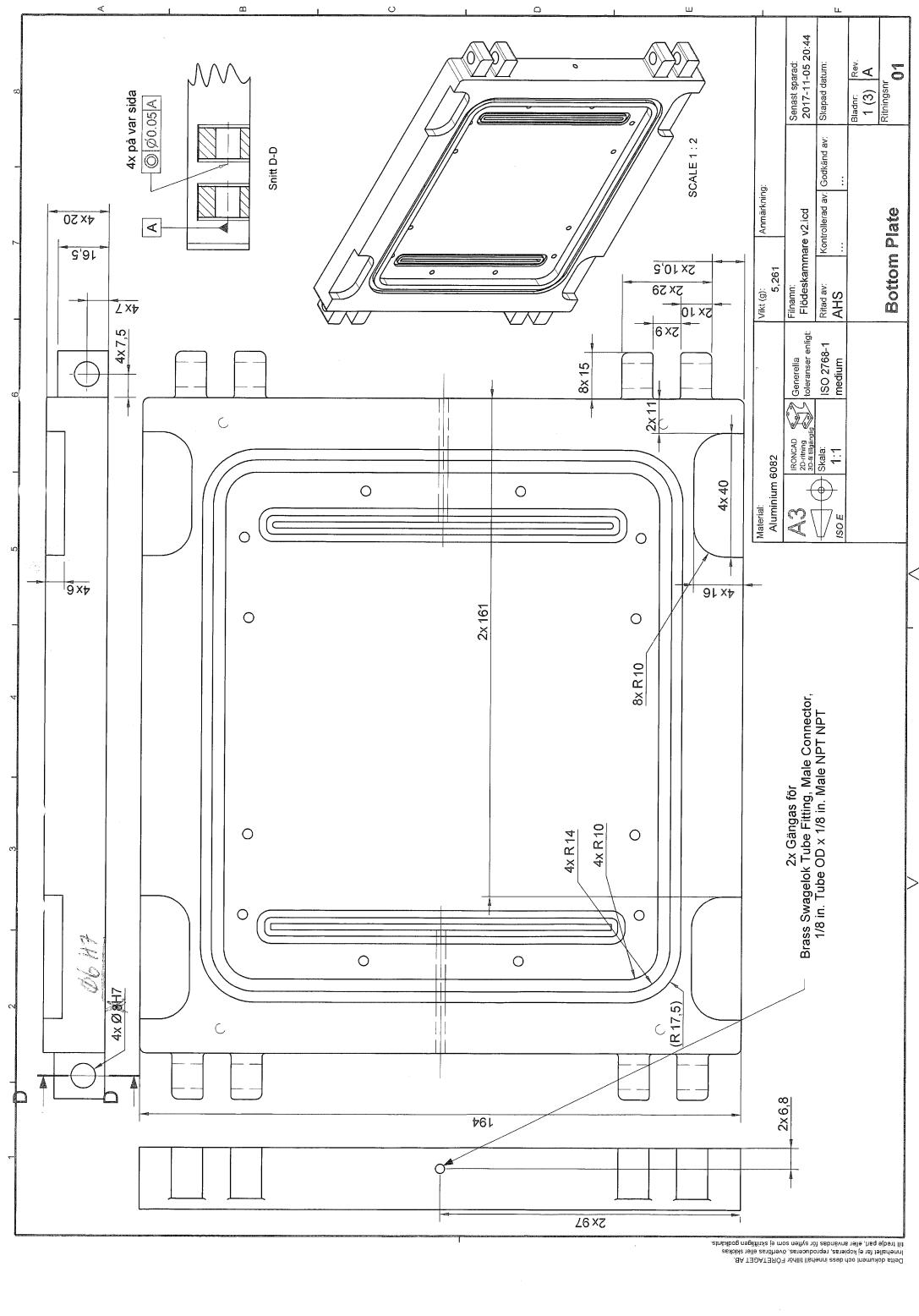


Figure S14: Technical drawing 1 (of 3) of the SVA chamber body. Distances are given in mm.

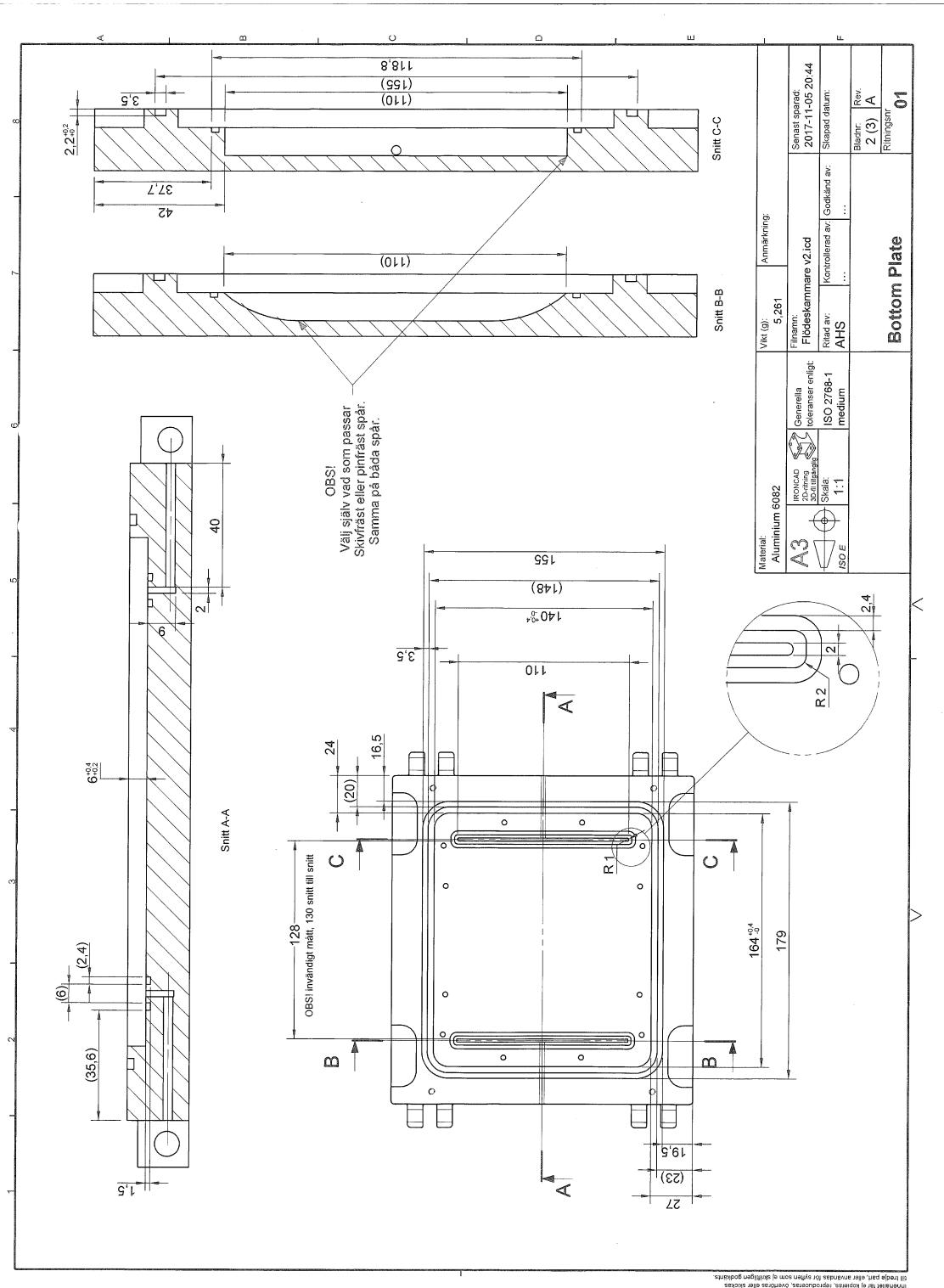


Figure S15: Technical drawing 2 (of 3) of the SVA chamber body. Distances are given in mm.

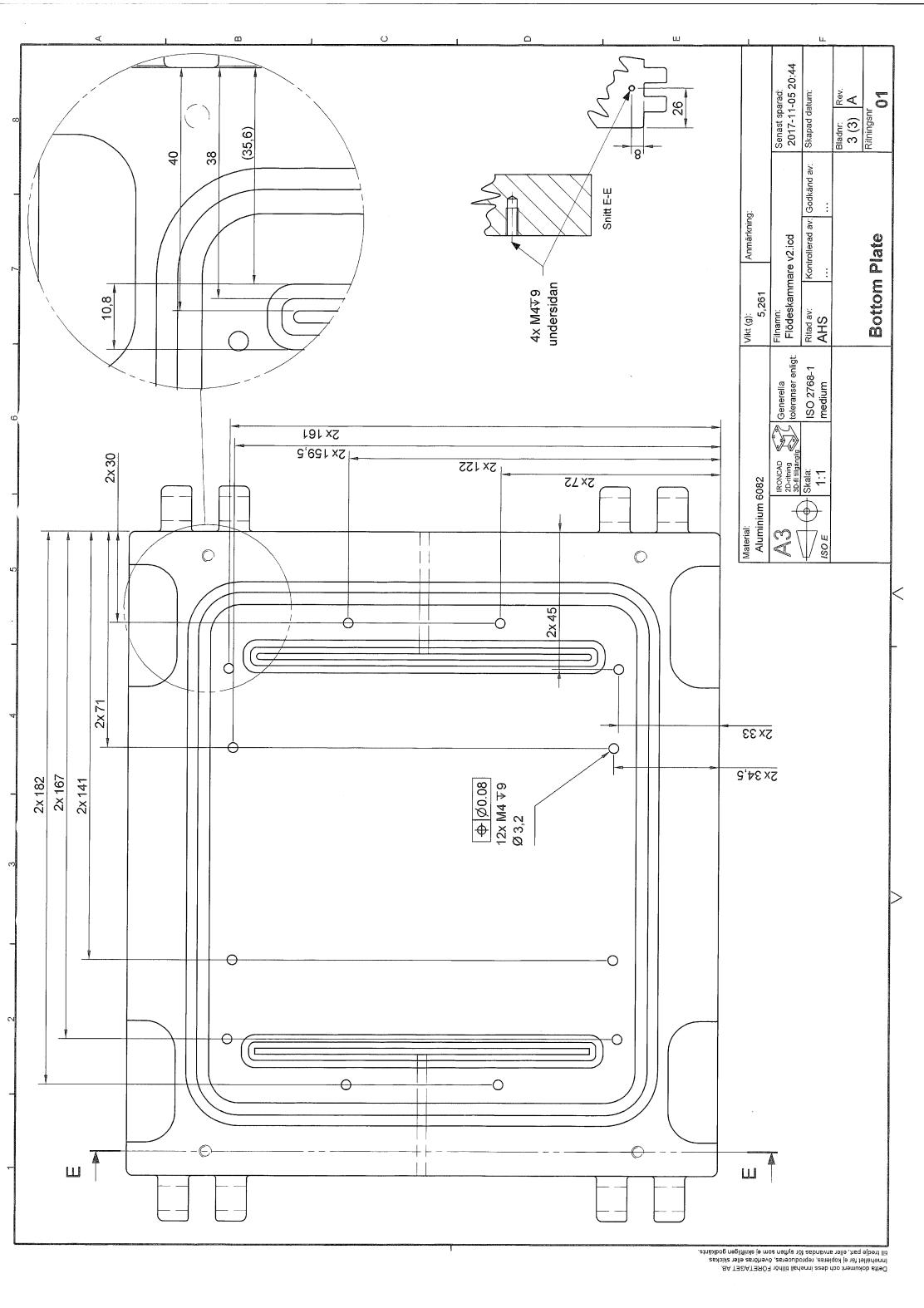


Figure S16: Technical drawing 3 (of 3) of the SVA chamber body. Distances are given in mm.

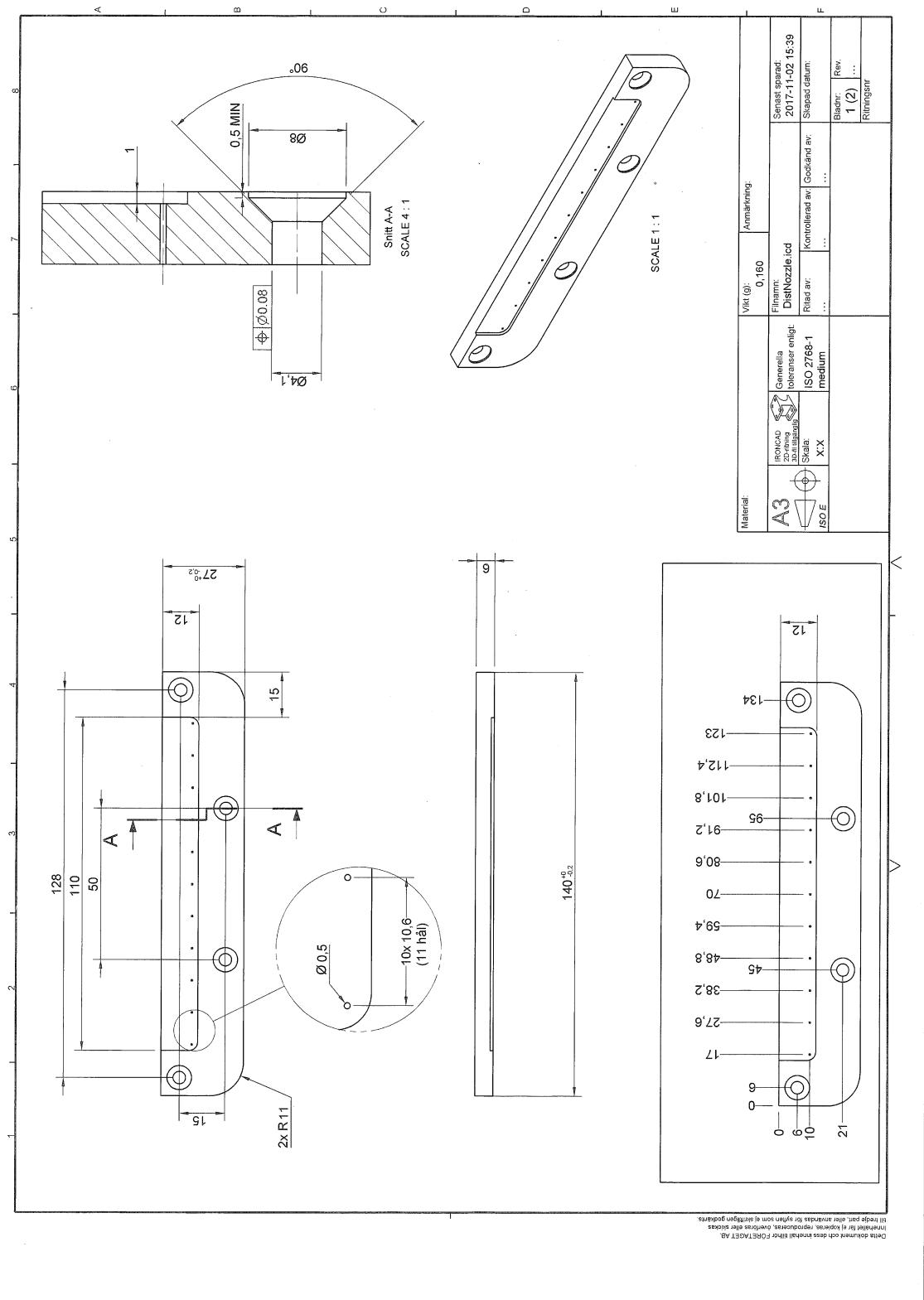


Figure S17: Technical drawing of the gas distribution nozzles. Distances are given in mm.

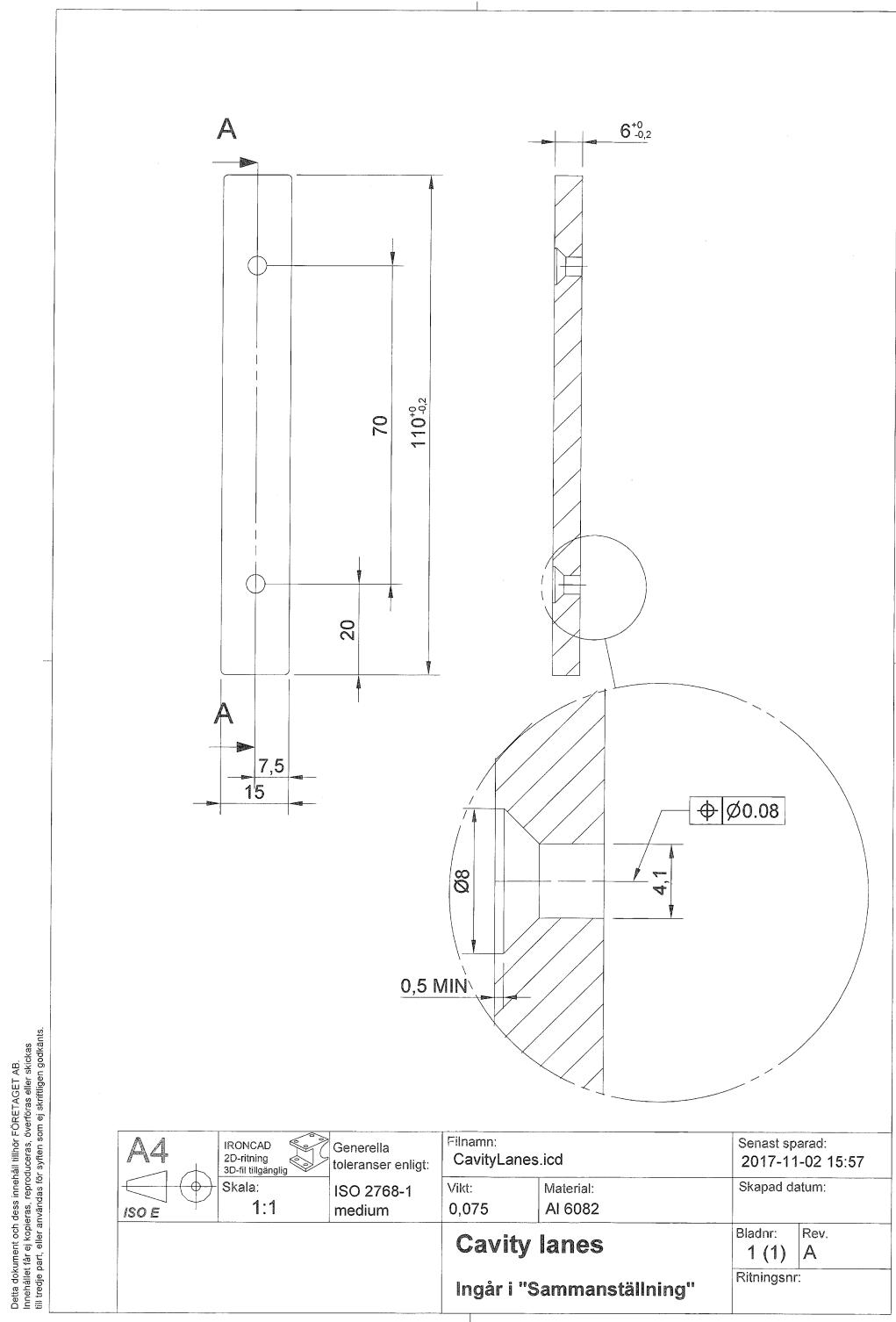


Figure S18: Technical drawing of the cavity lanes. Distances are given in mm.

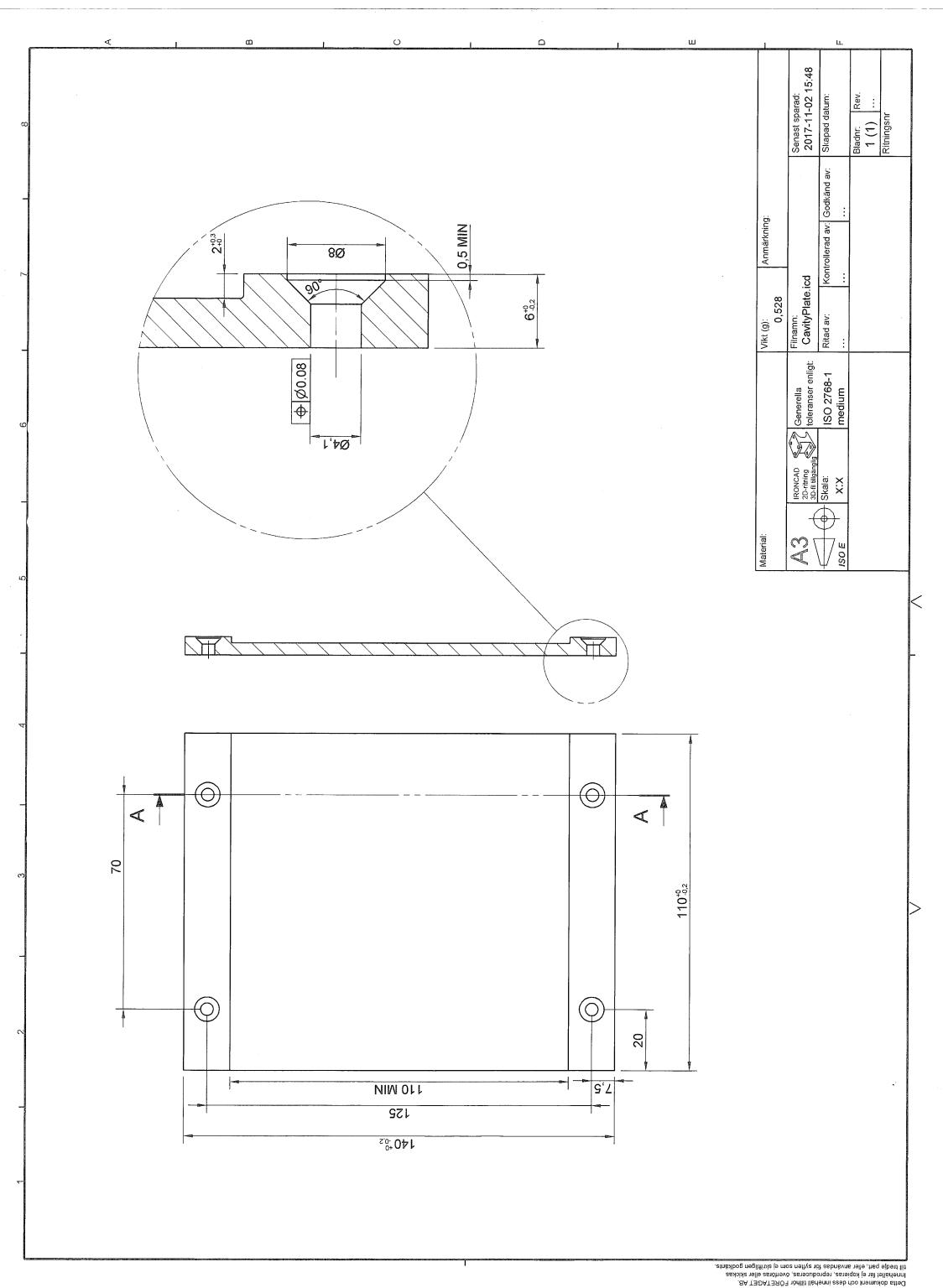


Figure S19: Technical drawing of the cavity insert. Distances are given in mm.

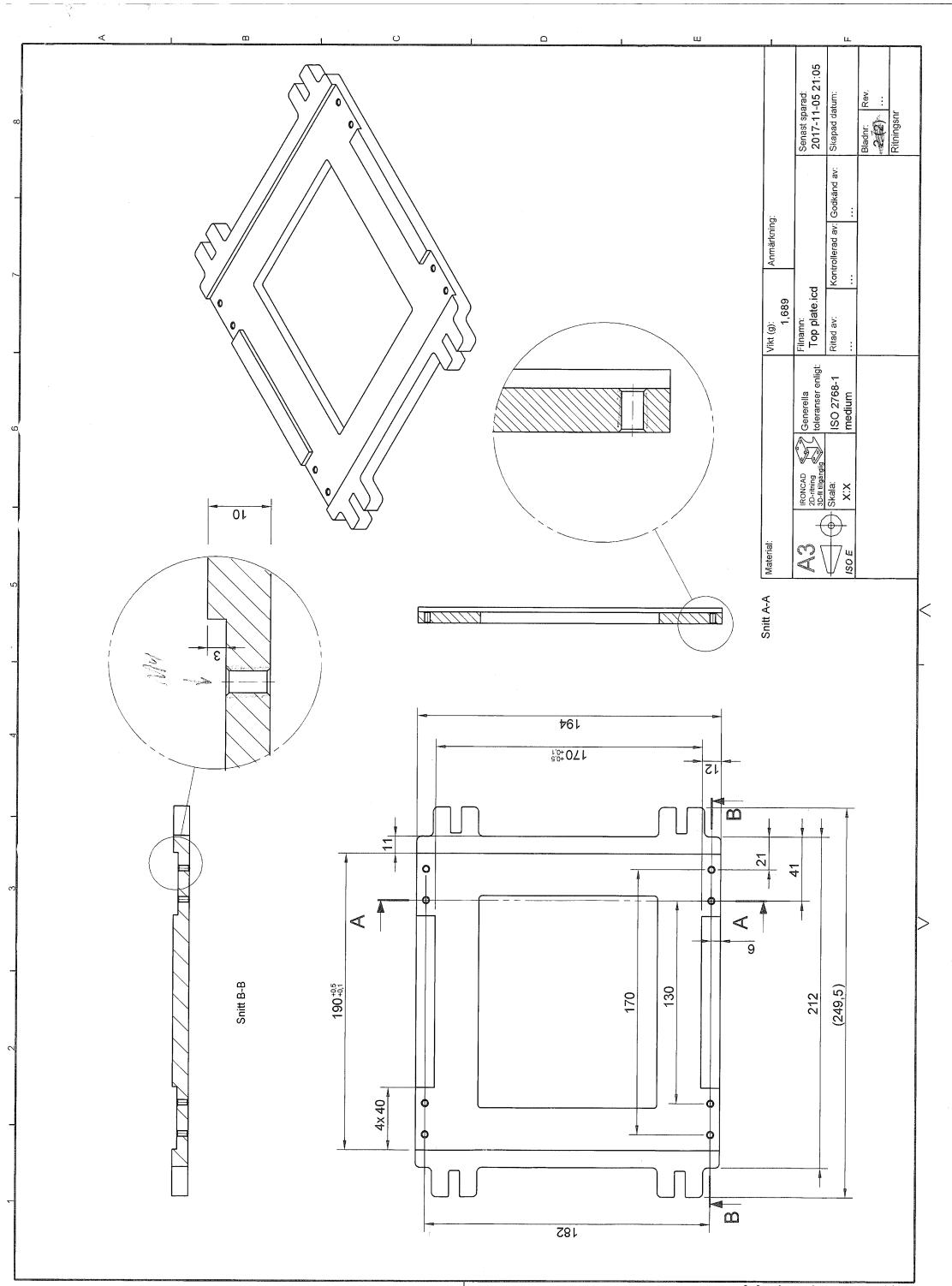


Figure S20: Technical drawing of the lid frame. Distances are given in mm.

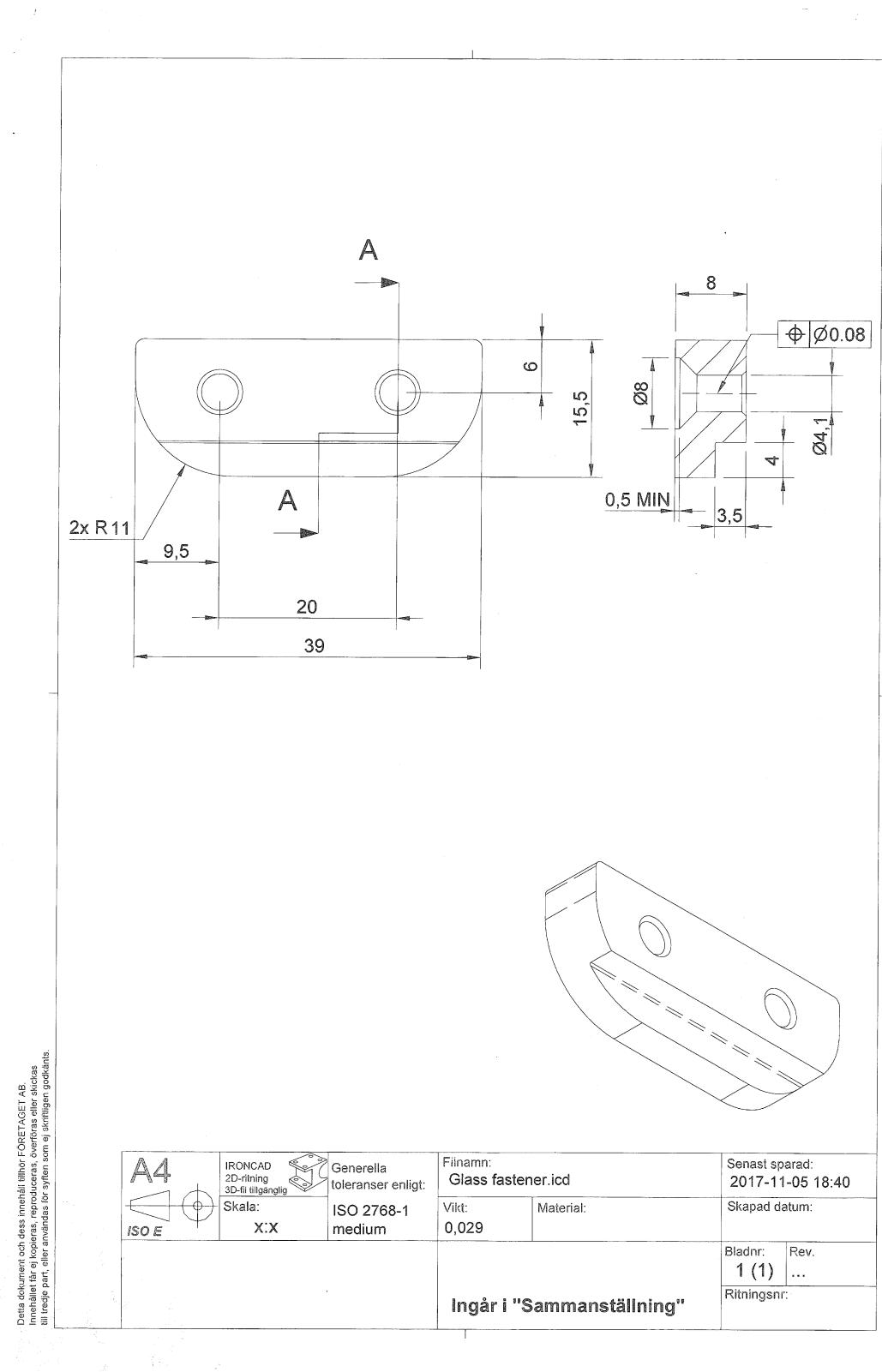


Figure S21: Technical drawing of the glass fasteners for the SVA chamber lid. Distances are given in mm.

### Part III – List of Components

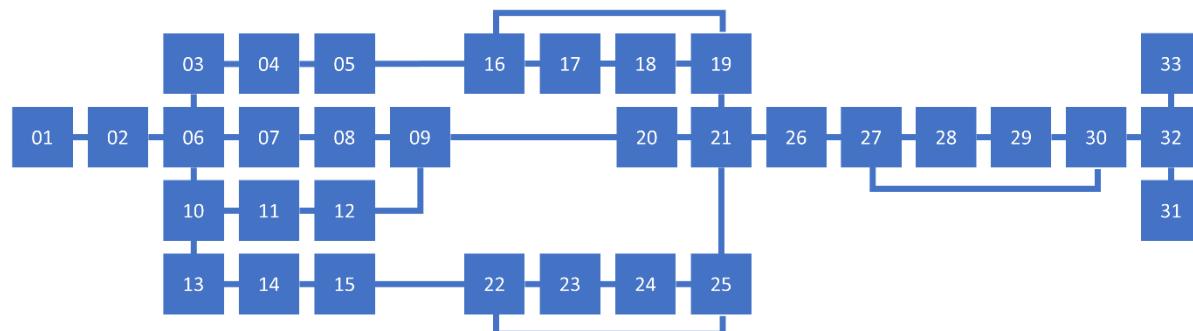


Figure S22: Schematic illustration of *dSVA* setup to describe the relative location of the components of the flow system itemized in Table S1.

**Table S1: Components of the *dSVA* System**

#	Section	Item	Vendor	Art. Nbr.	Comment
1	N <sub>2</sub> Supply Network	N <sub>2</sub> Supply	-	-	
2	"	2-way Valve, Brass, 6 mm Tube Fittings	Swagelok	B-42S6MM	
"	"	6 mm Tube Fitting to Quick Connect (Stem), Brass	Swagelok	B-QC4-S-6M0	
"	"	Quick Connect (Body) to 6 mm Tube Fitting, Brass	Swagelok	B-QC4-B-6M0	
3	"	Union Elbow, Brass, 6 mm Tube Fitting	Swagelok	B-6M0-9	
"	"	6 mm Tube Butt Weld Gland to 1/4" VCR Face Seal Fitting, SS	Swagelok	6LV-4-VCR-3S-6MTB7	
"	"	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR	
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1	
4	MFCs	Tylan FC-2901MEP, 0-100 sccm N <sub>2</sub>	Ebay	-	MFC1
5	N <sub>2</sub> Distribution Network	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR	
"	"	1/4" VCR Face Seal Fitting to 1/4" Tube Adapter, SS	Swagelok	SS-4-VCR-3-4TA	
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1	
"	"	1/4" to 1/8" Tube Fitting Straight Reducing Union, Brass	Swagelok	B-400-6-2	
6	N <sub>2</sub> Supply Network	Union Cross, Brass, 6 mm Tube Fittings	Swagelok	B-6M0-4	
"	"	6 mm Tube Butt Weld Gland to 1/4" VCR Face Seal Fitting, SS	Swagelok	6LV-4-VCR-3S-6MTB7	
"	"	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR	
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1	
7	MFCs	MKS 1159B, 0-1000 sccm N <sub>2</sub>	Ebay	-	MFC4
8	N <sub>2</sub> Distribution Network	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR	
"	"	1/4" VCR Face Seal Fitting to 1/4" Tube Adapter, SS	Swagelok	SS-4-VCR-3-4TA	
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1	
"	"	Union Tee, Brass, 1/4" Tube Fittings	Swagelok	B-400-3	
9	"	1/4" to 1/8" Tube Fitting Straight Reducing Union, Brass	Swagelok	B-400-6-2	

<b>10</b>	N <sub>2</sub> Supply Network	Union Tee, Brass, 6 mm Tube Fittings	Swagelok	B-6M0-3
<b>10</b>	"	6 mm Tube Butt Weld Gland to 1/4" VCR Face Seal Fitting, SS	Swagelok	6LV-4-VCR-3S-6MTB7
"	"	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1
<b>11</b>	MFCs	MKS 1479A, 0-100 sccm N <sub>2</sub>	Ebay	- MFC3
<b>12</b>	N <sub>2</sub> Distribution Network	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR
"	"	1/4" VCR Face Seal Fitting to 1/4" Tube Adapter, SS	Swagelok	SS-4-VCR-3-4TA
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1
"	"	Union Elbow, Brass, 1/4" Tube Fittings	Swagelok	B-400-9
<b>13</b>	N <sub>2</sub> Supply Network	Union Elbow, Brass, 6 mm Tube Fitting	Swagelok	B-6M0-9
"	"	6 mm Tube Butt Weld Gland to 1/4" VCR Face Seal Fitting, SS	Swagelok	6LV-4-VCR-3S-6MTB7
"	"	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1
<b>14</b>	MFCs	Tylan FC-2901MEP, 0-100 sccm N <sub>2</sub>	Ebay	- MFC2
<b>15</b>	N <sub>2</sub> Distribution Network	1/4" Silver Plated Gasket Retainer Assembly, SS	Swagelok	SS-4-VCR-2-GR
"	"	1/4" VCR Face Seal Fitting to 1/4" Tube Adapter, SS	Swagelok	SS-4-VCR-3-4TA
"	"	1/4" VCR Female Nut, SS	Swagelok	SS-4-VCR-1
"	"	1/4" to 1/8" Tube Fitting Straight Reducing Union, Brass	Swagelok	B-400-6-2
<b>16</b>	"	Union Tee, Brass, 1/8" Tube Fittings	Swagelok	B-200-3
<b>17</b>	Bubbler 1	2-Way Valve, Brass, 1/8" Tube Fittings	Swagelok	B-41S2 V2
<b>18</b>	"	Cap to 6 mm Tube Fitting, Brass	Swagelok	B-6M0-C Periscope
"	"	Union Tee, Brass, 6 mm Tube Fittings	Swagelok	B-6M0-3 "
"	"	6 mm Tube Fitting to 1/8" MNPT, SS, Bored-Through	Swagelok	SS-6M0-1-2BT "
"	"	1/8" Tube Fitting to 1/8" MNPT, SS, Bored-Through	Swagelok	SS-200-1-2BT Inlet
"	"	Solvent Inlet Filter, 10 µm, 1/8" Tube Fitting, PCTFE and SS	VWR	554-5761 Gas Diffuser
"	"	1/8" Tube Fitting to 1/8" MNPT, SS	Swagelok	SS-200-1-2 Outlet
"	"	Blind/Blank CF35 Flange, SS, With three 1/8" Female NPT Tapped Bore-Through Holes	MDC Vacuum	- Bored and tapped by Dione AB
"	"	CF35 Oxygen-Free Copper Gasket	MDC Vacuum	-
"	"	CF35 Full Nipple, Length: 25 cm	MDC Vacuum	- CF35 Weld Flanges From MDC Vacuum, Pipe and Welding by Dione AB
"	"	Bolts and Nuts, 6 pcs, A4 SS	Biltema	-
"	"	CF35 Oxygen-Free Copper Gasket	MDC Vacuum	-
"	"	CF35 Blank, SS, With one 1/8" FNPT Tpped Bore-Through Hole	Kurt J. Lesker	F0275XFNPT2
"	"	Bolts and Nuts, 6 pcs, A4 SS	Biltema	-
"	"	3-Way Valve, Brass, 6 mm Tube Fittings	Swagelok	B-42XS6MM Sight Glass, V9
"	"	Plug for 6 mm Tube Fitting, SS	Swagelok	SS-6M0-P Sight Glass
"	"	PFA Tube, OD: 6.0 mm, ID: 3.60 mm	VWR	BOHLS1811-08 "

"	"	Union Tee, SS, 6 mm Tube Fittings	Swagelok	SS-6M0-9	"
18	"	6 mm Tube Fitting to 1/8" MNPT Adapter, SS	Swagelok	SS-6M0-2-2	"
19	Bubbler 1	3-Way Valve, Brass 1/8" Tube Fittings	Swagelok	B-41XS2	V3
20	N <sub>2</sub> Distribution Network	2-Way Valve, Brass 1/8" Tube Fittings	Swagelok	B-41S2	V1
21	Mixing Network	Union Cross, Brass, 1/8" Tube Fittings	Swagelok	B-200-4	
22	N <sub>2</sub> Distribution Network	Union Tee, Brass, 1/8" Tube Fittings	Swagelok	B-200-3	
23	Bubbler 2	2-Way Valve, Brass 1/8" Tube Fittings	Swagelok	B-41S2	V4
24	"	Cap to 6 mm Tube Fitting, Brass	Swagelok	B-6M0-C	Periscope
"	"	Union Tee, Brass, 6 mm Tube Fittings	Swagelok	B-6M0-3	"
"	"	6 mm Tube Fitting to 1/8" MNPT, SS, Bored Through	Swagelok	SS-6M0-1-2BT	"
"	"	1/8" Tube Fitting to 1/8" MNPT, SS, Bored-Through	Swagelok	SS-200-1-2BT	Inlet
"	"	Solvent Inlet Filter, 10 µm, 1/8" Tube Fitting, PCTFE and SS	VWR	554-5761	Gas Diffuser
"	"	1/8" Tube Fitting to 1/8" MNPT, SS	Swagelok	SS-200-1-2	Outlet
"	"	Blind/Blank CF35 Flange, SS, With three 1/8" Female NPT Tapped Bore-Through Holes	MDC Vacuum	-	Bored and tapped by Dione AB
"	"	CF35 Oxygen-Free Copper Gasket	MDC Vacuum	-	
"	"	CF35 Full Nipple, Length: 25 cm	MDC Vacuum	-	CF35 Weld Flanges From MDC Vacuum, Pipe and Weldning by Dione AB
"	"	Bolts and Nuts, 6 pcs, A4 SS	Biltema	-	
"	"	CF35 Oxygen-Free Copper Gasket	MDC Vacuum	-	
"	"	CF35 Blank, SS, With one 1/8" FNPT Tpped Bore-Through Hole	Kurt J. Lesker	F0275XFNPT2	
"	"	Bolts and Nuts, 6 pcs, A4 SS	Biltema	-	
"	"	3-Way Valve, Brass, 6 mm Tube Fittings	Swagelok	B-42XS6MM	Sight Glass, V10
"	"	Plug for 6 mm Tube Fitting, SS	Swagelok	SS-6M0-P	Sight Glass
"	"	PFA Tube, OD: 6.0 mm, ID: 3.60 mm	VWR	BOHLS1811-08	"
"	"	Union Tee, SS, 6 mm Tube Fittings	Swagelok	SS-6M0-9	"
"	"	6 mm Tube Fitting to 1/8" MNPT Adapter, SS	Swagelok	SS-6M0-2-2	"
25	Bubbler 2	3-Way Valve, Brass 1/8" Tube Fittings	Swagelok	B-41XS2	V5
26	Mixing Network	Straight Bulkhead Union, Brass, 1/8" Tube Fittings	Swagelok	B-200-61	
"	"	PFA Tubing; OD: 3.20 mm; ID: 1.60 mm; 0.80 mm	VWR	BOHLS1811-04	
27	Routing Hub	3-Way Valve, Brass, 1/8" Tube Fittings	Swagelok	B-41XS2	V6
28	Chamber Assembly	1/8" Tube Fitting to 1/8" MNPT, Brass	Swagelok	B-200-1-2	Inlet
"	"	Custom-built Chamber	-	-	
"	"	Borofloat 33 Glass Sheet, 190x170x3.3 mm	Glasteknik i Emmaboda AB	-	Inspection Window
"	"	O-rings, EPDM 70, 2 pcs, 75.0x2.0 mm	Lamisa	-	Gas Distribution Nozzle
"	"	O-ring, EPDM 70, 1 pcs, 194.5x3.0 mm	Lamisa	-	Chamber Seal
"	"	O-rings, FKM 75, 2 pcs, 75.0x2.0 mm	Lamisa	-	Gas Distribution Nozzle
"	"	O-ring, FKM 75, 1 pcs, 194.5x3.0 mm	Lamisa	-	Chamber Seal
"	"	Cylindrical Bolt, ISO2341, Hardened, FZB	Wiberger AB	CBH 6X35	Lid Fastening Assembly

	"	Saxpinne (swe), DIN94, 4 pcs, 1.6x10 mm, A4 SS	Wiberger AB	SP A4 1,6X10	"
28	"	Länkskruv (swe), 4 pcs, M6x60 mm, A4 SS	Wiberger AB	DIN444B A4 M6X60	"
"	"	Bricka (swe), 4 pcs, DIN9021, OD: 18 mm, ID: 6.4 mm, A4 SS	Wiberger AB	DIN9021 A4 6,4	"
"	"	Star Knob, 4 pcs, OD: 40 mm, height: 24 mm, M6, Plastic + A4 SS	Wiberger AB	WN175 DA2 40-M6	"
"	"	Recessed HEX Machine Screw, 12 pcs, DIN7991, M4x12 mm, A4 SS	Wiberger AB	DIN7991 A4 M4X12	For Nozzles and Inserts
"	"	Recessed HEX Machine Screw, 4 pcs, DIN7991, M4x16 mm, A4 SS	Wiberger AB	DIN7991 A4 M4X16	Anchoring Chamber Body
"	"	1/8" Tube Fitting to 1/8" MNPT, Brass	Swagelok	B-200-1-2	Outlet
29	Routing Hub	2-Way Valve, Brass, 1/8" Tube Fittings	Swagelok	B-41S2	V7
30	"	Union Tee, Brass, 1/8" Tube Fittings	Swagelok	B-200-3	
"	"	PFA Tubing; OD: 3.20 mm; ID: 1.60 mm; 0.80 mm	VWR	BOHLS1811-04	
31	Pressurized Air Supply	-	-	-	-
"	Vacuum Pump Assembly	Straight Union, Brass, 6 mm Tube Fittings	Swagelok	B-6M0-6	
"	"	2-Way Ball Valve, Brass, 6 mm Tube Fittings	Swagelok	B-42S6MM	V8
"	"	6 mm Tube Fitting to 1/8" Male ISO Parallel Thread, Brass, Straight Shoulder	Swagelok	B-6M0-1-2RS	
32	"	Norgren Venturi Pump, Al Housing, Brass Constriction, 28 L/min and -0.85 bar @8 bar, G1/8 Female Connectors	RS Sweden	289-5428	Venturi Pump
"	"	1/8" Male ISO Parallel Thread to 1/8" Female NPT, Brass, Straight Shoulder	Swagelok	B-2-A-2RS	
"	"	Elbow Aapter, 1/8" Male NPT to 1/8" Tube Fitting, Brass	Swagelok	B-200-2-2	
"	"	6 mm Tube Fitting to 1/8" Male ISO Parallel Thread, Brass, Straight Shoulder	Swagelok	B-6M0-1-2RS	
"	"	Straight Union, Brass, 6 mm Tube Fittings	Swagelok	B-6M0-6	
"	"	FEP Tube, OD: 6 mm; ID: 4 mm	VWR	BOHLS1815-20	
"	Solvent Exhaust	-	-	-	-
-	SS Pipes	6 mm 316/316L SS Tubing, Wall Thickness: 1 mm	Swagelok	-	N <sub>2</sub> Supply Network, Periscope and Sight Glass
-	"	1/8" 316/316L SS Tubing, Wall Thickness: 0.028"	Swagelok	SS-T2-S-028-20E	From N <sub>2</sub> Distribution Network to Vacuum Pump

#### Part IV – Operational States of the *dSVA* Setup



Figure S23: The *dSVA* control and sight glass valves (V1-V10) with the ports (A, B and C) labelled with reference to the *operational states* listed in

Table S3. For three-way valves, port B is always the common (middle) port.

**Table S2: Operational States – Valve Lever Positions**

Operational State	Valves								MFCs				
	V0 <sup>a</sup>	V1 <sup>a</sup>	V2 <sup>a</sup>	V3 <sup>b</sup>	V4 <sup>b</sup>	V5 <sup>a</sup>	V6 <sup>b</sup>	V7 <sup>a</sup>	V8 <sup>a</sup>	MFC 1 [sccm]	MFC 2 [sccm]	MFC 3 [sccm]	MFC 4 [sccm]
Offline	⊥ <sup>a</sup>	←	←	→	←	→	→	→	←	OFF	OFF	OFF	OFF
Pure N <sub>2</sub>	N <sub>2</sub> Purge	<sup>a</sup>	↓	←	→	←	→	var.	var.	←	-	-	1000
	B1 Bypass		←	←	↑	←	→	var.	var.	←	var.	-	-
	B2 Bypass		←	←	→	↑	→	var.	var.	←	-	var.	-
	MFC3		↓	←	→	←	→	var.	var.	←	-	-	var.
	MFC4		↓	←	→	←	→	var.	var.	←	-	-	var.
	B1 Bypass + B2 Bypass		←	←	↑	↑	→	var.	var.	←	var.	var.	-
	B1 Bypass + MCF3		↓	←	↑	←	→	var.	var.	←	var.	-	-
	B1 Bypass + MCF4		↓	←	↑	←	→	var.	var.	←	var.	-	var.
	B1 Bypass + MCF3 + MFC4		↓	←	↑	←	→	var.	var.	←	var.	var.	var.
	B2 Bypass + MCF3		↓	←	→	↑	→	var.	var.	←	-	var.	-
Single Bubbler, Low dilution dSVA	B2 Bypass + MCF4		↓	←	→	↑	→	var.	var.	←	-	var.	-
	B2 Bypass + MCF3 + MFC4		↓	←	↑	↑	→	var.	var.	←	var.	var.	var.
	B1 dSVA		←	↓	↓	←	→	var.	var.	←	var.	-	-
	B2 dSVA		←	←	→	↓	↑	var.	var.	←	-	var.	-
	B1 dSVA + B2 Bypass		←	↓	↓	↑	→	var.	var.	←	var.	var.	-
	B2 dSVA + B1 Bypass		←	←	↑	↓	↑	var.	var.	←	var.	var.	-
Single Bubbler, High dilution dSVA	B1 dSVA + MFC3		↓	↓	↓	↓	←	→	var.	var.	←	var.	-
	B2 dSVA + MFC3		↓	←	→	↓	↑	var.	var.	←	-	var.	-
	B1 dSVA + B2 SVA		↓	↓	↓	↓	↑	var.	var.	←	var.	var.	-
	B1 dSVA + B2 SVA + MFC3		↓	↓	↓	↓	↑	var.	var.	←	var.	var.	-
	B1 dSVA + B2 SVA + MFC3 + MFC4		↓	↓	↓	↓	↑	var.	var.	←	var.	var.	var.
	B2 dSVA + B1 SVA + MFC3 + MFC4		↓	↓	←	↑	↓	↑	var.	var.	←	var.	var.
Two Bubbler dSVA	B1 dSVA + B2 dSVA		↓	↓	↓	↓	↑	var.	var.	←	var.	var.	-
	B1 dSVA + B2 dSVA + MFC3		↓	↓	↓	↓	↑	var.	var.	←	var.	var.	-
	B1 dSVA + B2 dSVA + MFC3 + MFC4		↓	↓	↓	↓	↑	var.	var.	←	var.	var.	var.
	B1 dSVA + B2 dSVA + MFC3 + MFC4 + MFC5		↓	↓	↓	↓	↑	var.	var.	←	var.	var.	var.
Flow Routing, Vacuum	Chamber Bypass (sSVA)		var.	var.	var.	var.	var.	→	↓	←	var.	var.	var.
	Into Chamber		var.	var.	var.	var.	var.	←	→	←	var.	var.	var.
	Vacuum Quench		←	←	→	←	→	↓	→	↑	-	-	-
Operational State	V0 <sup>a</sup>	V1 <sup>a</sup>	V2 <sup>a</sup>	V3 <sup>b</sup>	V4 <sup>b</sup>	V5 <sup>a</sup>	V6 <sup>b</sup>	V7 <sup>a</sup>	V8 <sup>a</sup>	Comment			
Filling / Emptying Sight Glass	Filling/Emptying B1	⊥	←	←	↓	-	→	↓	-	Filling/Emptying B1 via V9			
	Filling/Emptying B2	⊥	←	←	-	↓	→	-	↓	Filling/Emptying B2 via V10			
	Sight Glass B1	⊥	var.	var.	var.	var.	var.	↑	var.	Activate B1 Sight Glass			
	Sight Glass B2	⊥	var.	var.	var.	var.	var.	var.	↑	Activate B2 Sight Glass			
	Filling/Emptying B1	⊥	←	←	↓	-	→	↑	-	Filling/Emptying B1 via 'periscope'			
	Filling/Emptying B2	⊥	←	←	-	↓	→	-	↑	Filling/Emptying B2 via 'periscope'			

**Comment:** Meaningful operational states available. Arrows indicate the valve lever positions. <sup>a</sup> Two-way valve.

<sup>b</sup> Three-way valve. <sup>c</sup> Valve lever perpendicular (⊥) or parallel (||) to the gas line.

**Table S3: Operational States – Connected Ports**

Operational State	Valves										MFCs			
	V0 <sup>a</sup>	V1 <sup>a</sup>	V2 <sup>a</sup>	V3 <sup>b</sup>	V4 <sup>b</sup>	V5 <sup>a</sup>	V6 <sup>b</sup>	V7 <sup>a</sup>	V8 <sup>a</sup>	MFC 1 [sccm]	MFC 2 [sccm]	MFC 3 [sccm]	MFC 4 [sccm]	
Offline	A B	A B	A B	A B C	A B C	A B	A B-C	A-B	A B	OFF	OFF	OFF	OFF	
Pure N <sub>2</sub>	N <sub>2</sub> Purge	A-B	A-B	A B	A B C	A B C	A B C	A B	var.	A B	-	-	-	1000
	B1 Bypass	A-B	A B	A B	A-B C	A B C	A B C	A B	var.	A B	var.	-	-	-
	B2 Bypass	A-B	A B	A B	A B C	A B C	A B C	A B	var.	A B	-	var.	-	-
	MFC3	A-B	A-B	A B	A B C	A B C	A B C	A B	var.	A B	-	-	var.	-
	MFC4	A-B	A-B	A B	A B C	A B C	A B C	A B	var.	A B	-	-	-	var.
	B1 Bypass + B2 Bypass	A-B	A B	A B	A-B C	A-B C	A-B C	A B	var.	A B	var.	var.	-	-
	B1 Bypass + MCF3	A-B	A-B	A B	A-B C	A B C	A B C	A B	var.	A B	var.	-	var.	-
	B1 Bypass + MCF4	A-B	A-B	A B	A-B C	A B C	A B C	A B	var.	A B	var.	-	-	var.
	B1 Bypass + MFC3 + MFC4	A-B	A-B	A B	A B C	A B C	A B C	A B	var.	A B	var.	-	var.	var.
	B2 Bypass + MCF3	A-B	A-B	A B	A B C	A B C	A-B C	A B	var.	A B	-	var.	var.	-
	B2 Bypass + MCF4	A-B	A-B	A B	A B C	A B C	A-B C	A B	var.	A B	-	var.	-	var.
	B2 Bypass + MFC3 + MFC4	A-B	A-B	A B	A B C	A B C	A-B C	A B	var.	A B	-	var.	var.	var.
	B1 Bypass + B2 Bypass + MFC3	A-B	A-B	A B	A-B C	A-B C	A B C	A B	var.	A B	var.	var.	var.	-
	B1 Bypass + B2 Bypass + MFC3 + MFC4	A-B	A-B	A B	A-B C	A-B C	A B C	A B	var.	A B	var.	var.	var.	var.
Single Bubbler, Low dilution dSVA	B1 dSVA	A-B	A B	A-B	A B-C	A B C	A B C	A B	var.	A B	var.	-	-	-
	B2 dSVA	A-B	A B	A B	A B C	A B C	A B-C	A-B	var.	A B	-	var.	-	-
	B1 dSVA + B2 Bypass	A-B	A B	A-B	A B-C	A-B C	A B C	A B	var.	A B	var.	var.	-	-
	B2 dSVA + B1 Bypass	A-B	A B	A B	A-B C	A B C	A B-C	A-B	var.	A B	var.	var.	-	-
	B1 dSVA + MFC3	A-B	A-B	A-B	A B-C	A B C	A B C	A B	var.	A B	var.	-	var.	-
	B2 dSVA + MFC3	A-B	A-B	A B	A B C	A B C	A B-C	A-B	var.	A B	-	var.	var.	-
Single Bubbler, High dilution dSVA	B1 dSVA + B2 Bypass + MFC3	A-B	A-B	A-B	A B-C	A-B C	A B C	A B	var.	A B	var.	var.	var.	-
	B1 dSVA + B2 Bypass + MFC3 + MFC4	A-B	A-B	A-B	A B-C	A-B C	A B C	A B	var.	A B	var.	var.	var.	var.
	B2 dSVA + B1 Bypass + MFC3	A-B	A-B	A B	A-B C	A B C	A B-C	A-B	var.	A B	var.	var.	var.	-
	B2 dSVA + B1 Bypass + MFC3 + MFC4	A-B	A-B	A B	A-B C	A B C	A B-C	A-B	var.	A B	var.	var.	var.	var.
	B1 dSVA + B2 dSVA	A-B	A B	A-B	A B-C	A B C	A B-C	A-B	var.	A B	var.	var.	-	-
	B1 dSVA + B2 dSVA + MFC 3	A-B	A-B	A-B	A B-C	A B C	A B-C	A-B	var.	A B	var.	var.	var.	-
Two Bubbler, dSVA	B1 dSVA + B2 dSVA + MFC3 + MFC4	A-B	A-B	A-B	A B-C	A B C	A B-C	A-B	var.	A B	var.	var.	var.	var.
	Chamber Bypass (sSVA)	A-B	var.	var.	var.	var.	var.	A B-C	A B	A B	var.	var.	var.	var.
	Into Chamber	A-B	var.	var.	var.	var.	var.	A-B C	A-B	A B	var.	var.	var.	var.
	Vacuum Quench	A-B	A B	A B	A B C	A B C	A B C	A B	A-B	A-B	-	-	-	-
	Operational State	V0 <sup>a</sup>	V1 <sup>a</sup>	V2 <sup>a</sup>	V3 <sup>b</sup>	V4 <sup>b</sup>	V5 <sup>a</sup>	V9 <sup>b</sup>	V10 <sup>b</sup>	Comment				
	Filling/Emptying B1	A B	A B	A B	A B-C	-	A B	A B-C	-	Filling/Emptying B1 via V9				
Sight Glass	Filling/Emptying B2	A B	A B	A B	-	A B-C	A B	-	A B-C	Filling/Emptying B2 via V10				
	Sight Glass B1	A B	var.	var.	var.	var.	var.	A-B C	var.	Activate B1 Sight Glass				
	Sight Glass B2	A B	var.	var.	var.	var.	var.	A-B C	var.	Activate B2 Sight Glass				
	Filling/Emptying B1	A B	A B	A B	A B-C	-	A B	A-B C	-	Filling/Emptying B1 via 'periscope'				
	Filling/Emptying B2	A B	A B	A B	-	A B-C	A B	-	A B-C	Filling/Emptying B2 via 'periscope'				

**Comment:** Meaningful operational states available. 'A', 'B' and 'C' represents the ports indicated in Figure S22. <sup>a</sup> Two-way valve.

<sup>b</sup> Three-way valve.

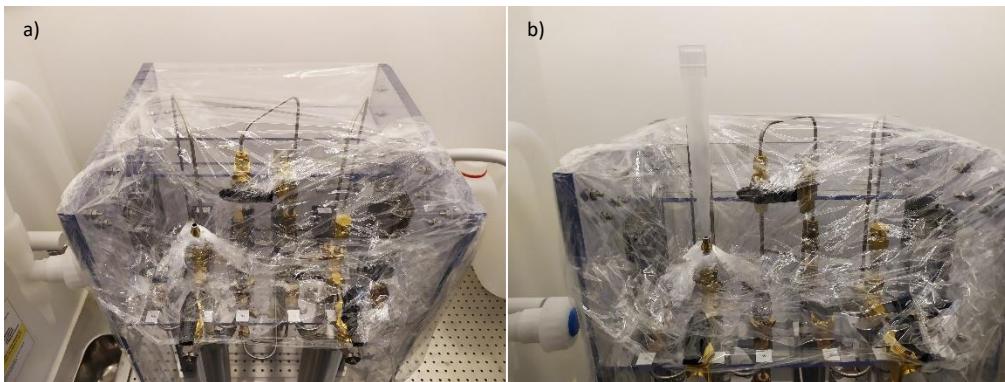


Figure S24: *Module 1*, inside a solvent fume hood, wrapped in 'cling film' and with the 'periscope' port of B1 opened (a) and with a micropipette inserted for use as a funnel during filling (b).

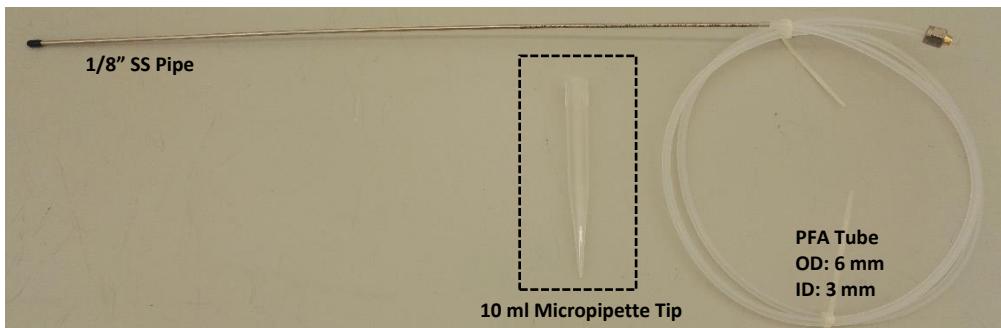


Figure S25: Photo of bubbler siphoning tool and micropipette tip used as a funnel to fill the bubblers via the 'periscopes'.

## Part V – Scripts

### 4.1 AutoHotkey Script

Script to periodically initiate and record measurements from the K-MAC ST4000-DLX spectroscopic reflectometer. It operates by simulating keyboard commands periodically to access software functions. AutoHotkey is a free open-source scripting language for automation and the required software is available from <https://autohotkey.com/>.

```
SampleName := "S1801xx" ; Sample Identifier
F_Nbr := 2 ; Number of files with M_Nbr of measurements per file
M_Nbr := 10 ; Number of measurements per file (max 200)
M_Interval := 2000 ; Sets interval between measurements in milliseconds
FilePath := "C:\Users\KmacUsers\
Documents\BjörnLW\" ; Location of saved files
FileCreateDir, C:\Users\KmacUsers\
Documents\BjörnLW\%SampleName% ; Create a new dir for sample files

^!b:: ; To initiate measurements: Alt + Crl + b
Sleep, 1000 ; Delay before start of script (to allow for release of initiation keys)

k := 1 ; Enumerator (Counts up the Nbr of files)
Loop, %F_Nbr%
{
Send, !RF ; Creates a file to record measurements to (Alt (!) activates the menu bar, R the
"Results" tab and F the "Record File..." option
Sleep, 200 ; Delay for allowing the Save As window to open; otherwise loss of first part of
filename

SendInput, %FilePath%%SampleName%\%SampleName%%k% ; Assigning path and filename
Send, {Enter}
k := k + 1

Loop, %M_Nbr% ; Loops through the Nbr of measurements per file (max 200)
{
Send,{F12} ; Initiates a measurement
Sleep, %M_Interval% ; Sets interval between measurements
}

^!s:: ExitApp ; "Stop" Hotkey Alt + Crl + b stops script prematurely
ExitApp ; Scripts stopes upon completion
Return ; End of program
```

## 4.2 MATLAB Scripts

A few select functions needed to predict solvent consumption and the required settings of the dilution MFC to achieve a setpoint toluene activity level in the *dSVA* chamber.

### Vapor Pressure Approximation – Example: Toluene

```
function vp_Tol = vp_Tol(T)
% Returns the vapor pressure [kPa] at T [C] for Toluene
% Data Source:
https://www.cheric.org/research/kdb/hcprop/showcoef.php?cmpid=652&prop=PVP
% Reportedly valid for T = [178.18, 591.79] K

T = T + 273.15; % Conversion to Absolute temperature, T i.e. from Celsius to Kelvin

% Coefficients for expanded Antonine Eq.
A = -8.795480E+00;
B = -6.918798E+03;
C = 7.413580E+01;
D = 5.754912E-06;

vp_Tol = exp(A.*log(T) + B./T + C + D.*T.^2);
end
```

### Volumetric to Molar Flow Conversion

```
function M = M(Q,rho,MW)
% Returns Molar Flow, M [mol/min]
% Q = Volumetric flow [sccm]
% rho = gas density [g/cm^3]
% MW = Molecular weight [g/mol]

M = (Q.*rho)./MW;
end
```

### Molar to Volumetric Flow Conversion

```
function Q = Q(M,rho,MW)
% Returns volumetric flow, Q [sccm]
% M = Molar flow [mol/min]
% rho = gas density [g/cm^3]
% MW = Molecular weight [g/mol]

Q = (M.*MW)./rho;
end
```

### Molar Flow of Solvent Out of Bubbler

```
function M_sol = M_sol(M_N2,P_sys,vp)
% Returns molar flow of solvent [mol/min] out of bubbler.
% Assumptions:
% i) Saturation of carrier gas
% ii) Inert carrier gas with negligible solubility in solvent

% M_N2 = Molar flow of nitrogen into (and out of) bubbler [mol/min]
% P_sys = (Absolute) pressure in bubbler head/system [e.g. kPa]
% vp = (Saturated) vapor pressure of solvent [e.g. kPa]

M_sol = M_N2.* (vp./(P_sys-vp));
end
```

### Partial Pressure of Solvent From Total Molar Flow

```
function p_part_sol = p_part_sol(P_sys,M_sol_B1,...  
    M_N2_B1,M_sol_B2,M_N2_B2,M_N2_dil)  
% Returns the resultant partial pressure [kPa] of solvent after mixing  
% convergence/mixing of flows.  
  
% P_sys = total pressure in system [kPa]  
% M_sol_B1 = Molar flow of solvent [mol/min] out of B1  
% M_N2_B1 = Molar flow of nitrogen in/out of B1  
% M_sol_B2 = Molar flow of solvent [mol/min] out of B2 (Assuming B1 and B2  
% contains different solvents)  
% M_N2_B2 = Molar flow of nitrogen in/out of B2  
% M_N2_dil = Molar flow of pure nitrogen  
p_part_sol = (P_sys.*M_sol_B1)./. . .  
    (M_sol_B1 + M_N2_B1 + M_sol_B2 + M_N2_B2 + M_N2_dil);  
end
```

### Example: The Required Volumetric Dilution Flow Rate

- to obtain desired activity level of toluene in chamber when using one bubbler

```
function Q_N2_dil_Tol = Q_dil_Tol(T_WB, T_ch, P_sys, Q_N2_B, a_ch)  
% Returns the volumetric dilution flow of N2 required to obtain the desired  
% toluene activity in the process chamber.
```

```
% T_WB = Temperature of bubbler water bath [Celsius]  
% T_ch = Temperature of process chamber [Celsius]  
% P_sys = Absolute pressure in system [kPa]  
% Q_N2_B1 = Volumetric flow rate of N2 through toluene bubbler [sccm]  
% a_ch = desired solvent activity level in chamber NB: Vector Input  
% Possible  
  
p_VP_1 = vp_Tol(T_WB); % Vapor pressure of Toluene at T_WB  
p_VP_2 = vp_Tol(T_ch); % Vapor pressure of Toluene at T_ch  
p_SP = a_ch .* p_VP_2; % Setpoint partial pressure of Toluene in chamber.  
vec = ones(1,length(a_ch)); % 'Vector accommodation'  
  
% Constants: Nitrogen  
rho_N2 = 0.001165 * vec; %[g/cm^3] @ 20C, 101.325 kPa;  
% Source: http://www.engineeringtoolbox.com/gas-density-d\_158.html  
MW_N2 = 28.0134 * vec; %[g/mol]  
  
M_N2_B1 = M(Q_N2_B, rho_N2, MW_N2); % Volumetric to molar N2 flow through bubbler  
M_Tol_B1 = M_sol(M_N2_B1, P_sys, p_VP_1); % Molar flow of toluene out of bubbler  
  
M_N2_dil = ((M_Tol_B1.*P_sys)./p_SP) - M_N2_B1 - M_Tol_B1; % Required dilution N2 molar  
flow  
Q_N2_dil_Tol = Q(M_N2_dil, rho_N2, MW_N2); % Required dilution N2 volumetric flow  
end
```

### Solvent Consumption

```
function V_Tol = V_Tol(T_WB, Q_N2)
% Returns the volume of Toluene consumed per minute, i.e. [ml/min], in bubbler at
temperature T_WB and with Q_N2 volumetric flow of nitrogen through it.

P_sys = 101.3250; % Atmospheric pressure in bubbler unit assumed.

% Constants: Nitrogen
rho_N2 = 0.001165; %[g/cm^3]; Gas density @ 20C, 101.325 kPa.
MW_N2 = 14.0067*2; %[g/mol]; Molecular weight.

% Constants: Nitrogen
rho_l_Tol = 0.87; %[g/cm^3] Liquid density at 20C (Wikipedia)
MW_Tol = 92.14; %[g/mol]; Molecular weight.

M_N2 = M(Q_N2, rho_N2, MW_N2); %[mol/min]; Molar flow of nitrogen.
M_Tol = M_sol(M_N2, P_sys, vp_Tol(T_WB)); %[mol/min]; Molar flow of Toluene
m_Tol = M_Tol*MW_Tol; %[g/min]; Mass of toluene leaving the bubbler per min.
V_Tol = m_Tol/rho_l_Tol; %[ml/min]
```