

Appendix

Vortex-Heater

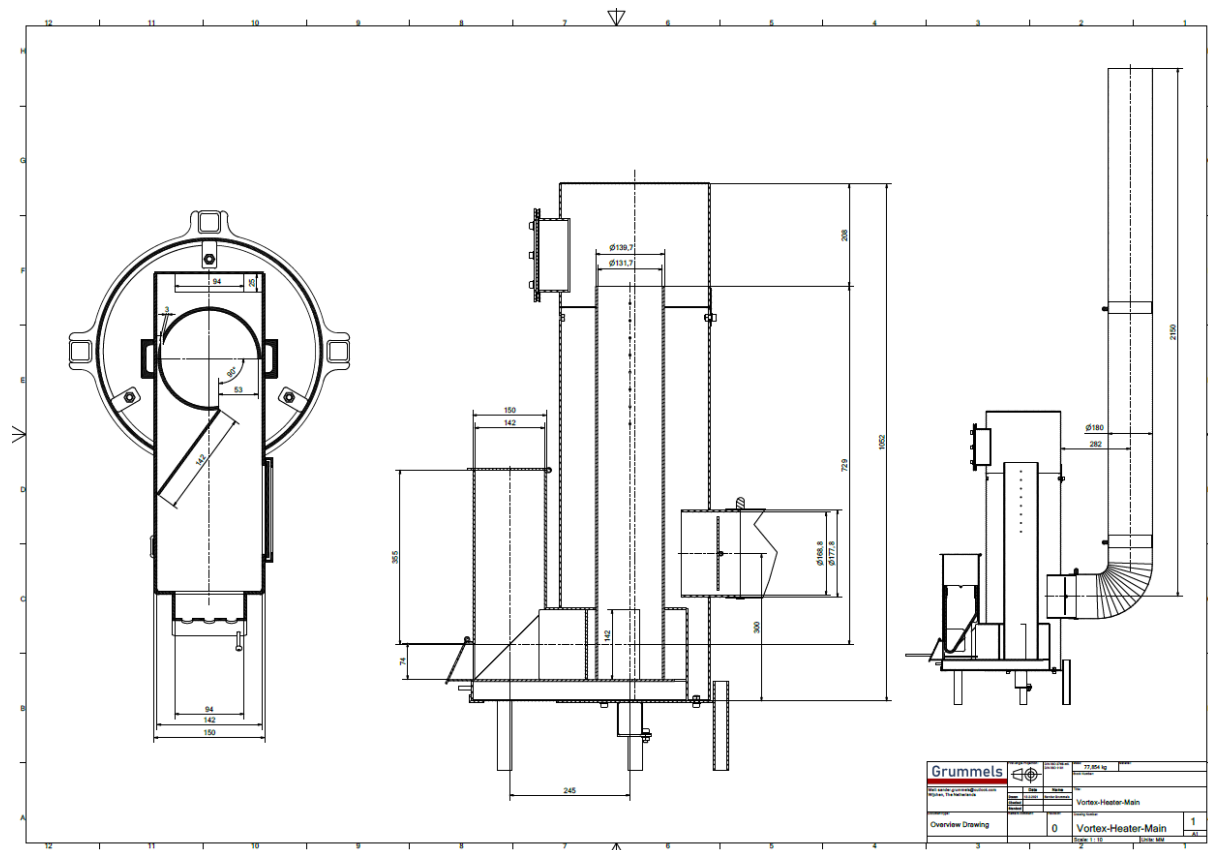
Author: Sander Grummels

Date: 14-4-2021

REV: 0.0

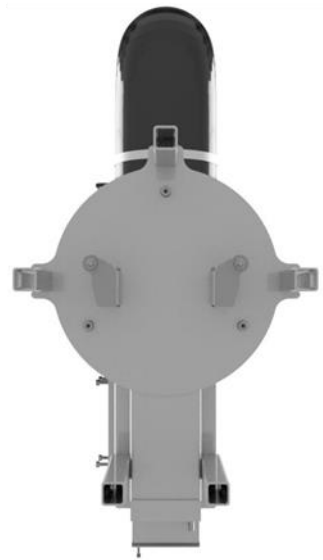
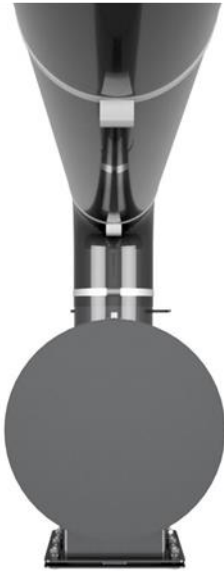
Table of contents

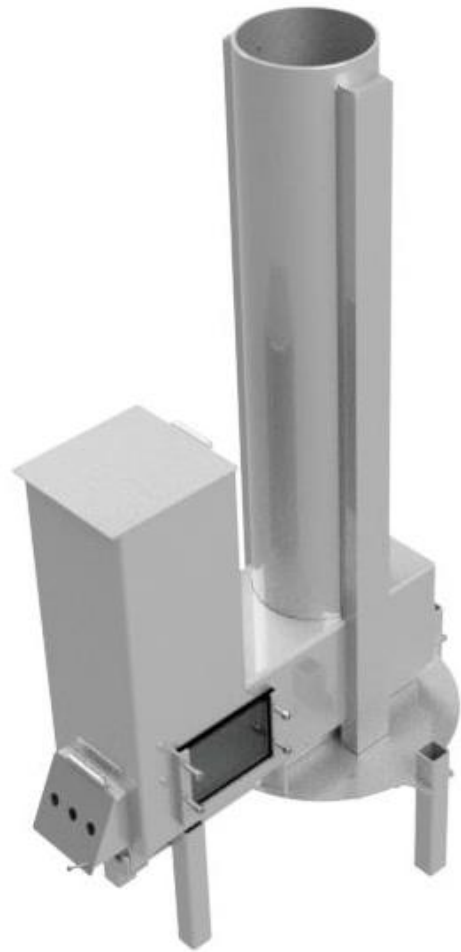
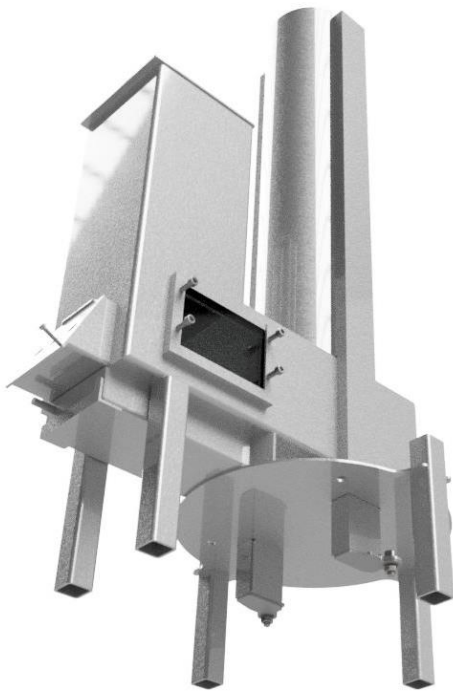
Appendix A	
Appendix A.1: 3D pdf design concept.....	
Appendix A.2: 3D pdf Vortex-Heater design	
Appendix B	
Appendix B.1: 3D renders.....	
Appendix B.2: Building pictures	
Appendix B.3 Pictures & Videos final result	
Appendix C: Air inlet area/factor.....	
Calculation air inlet size:	
Appendix D	
Appendix D.1: 2D-Drawings	
Appendix D.2: Part list	
Appendix D.3: Cut list	
Appendix D.4: STEP files	
Appendix D.5: DXF files	
Appendix E	
Appendix E.1: ROCKET MASS HEATERS:.....	
Appendix E.2: Batchrocket.eu	
Appendix F Internet sources	



Appendix B

Appendix B.1: 3D renders





Appendix B.2: Building pictures



Appendix B.3 Pictures & Videos final result



Appendix C: Air inlet area/factor

The size of the air inlet is a very important factor that will determine if the fire will burn efficient. If the inlet is too large the fire cools down and if the inlet is too small the fire doesn't get enough oxygen.

To determine the size of the air inlet the principle is used that air expands when it heats up. Before the fire the air is much "smaller" than after the combustion when it is a hot gas. With this principle it is possible to not get excess air. In reality when burning the gas after combustion is from a different composition than clean air but it is from little influence.

For the calculation the following things are assumed:

1. The burning temperature amounts 500 °C, even the temperatures can rise higher the fire has to heat up. The assumption is that when the fire has a temperature of 500°C the draft is from adequate level. On the air inlet comes a valve so if the temperature rises the air flow can be reduced.
2. That the fire burns under sea-level conditions at 0 °C. ($p = 101300 \text{ pa}$ $T = 273 \text{ K}$)
3. Mass flow through the stove stays the same unless the combustion.

Calculation air inlet size:

General gas equation:

$$\rho = \frac{p * M}{R * T}$$

$$\rho = \text{airdensity} \left[\frac{\text{kg}}{\text{m}^3} \right]$$

$$p = \text{pressure} [\text{Pa}]$$

$$R = 8,3144 \text{ 72} \left[\frac{\text{J}}{\text{mol} * \text{K}} \right]$$

$$M = 0,02897 \left[\frac{\text{kg}}{\text{mol}} \right]$$

$$T = \text{temperature} [\text{K}]$$

Density at 0 degrees:

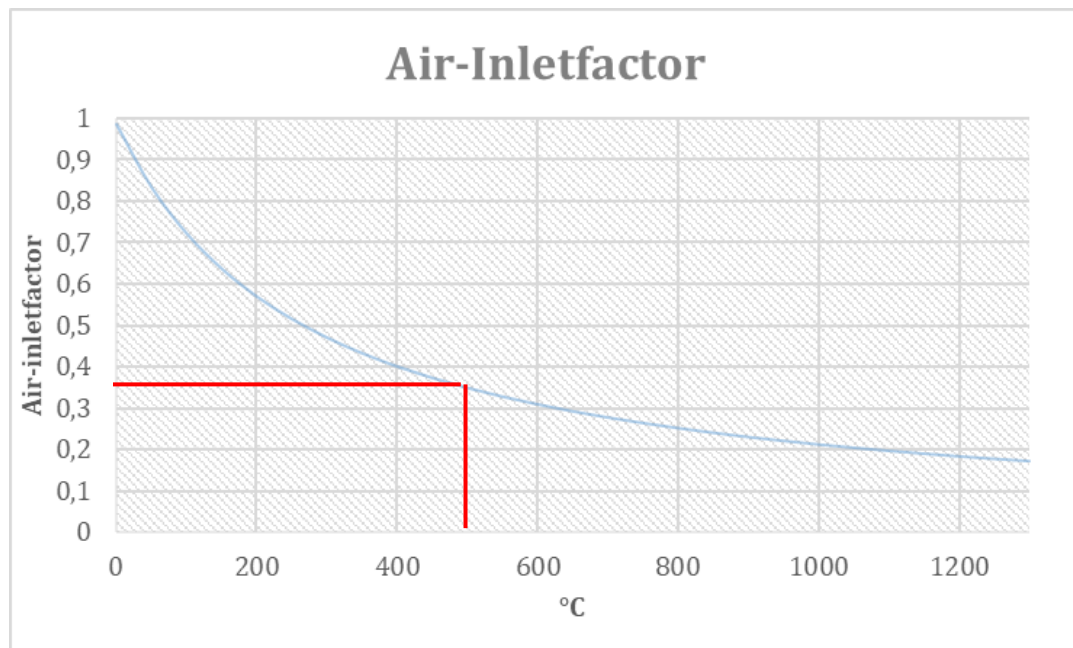
$$\rho = \frac{101300 * 0,02897}{8,314472 * 273} = 1,293 \frac{\text{kg}}{\text{m}^3}$$

Circumscribed formula to calculate inlet factor:

$$AIF = \frac{\frac{p * M}{R * T}}{1,293}$$

What stands out (See chart ?) that when the temperature rises the inlet does require a smaller area.

$$AIF = \frac{\frac{101300 * 0,02897}{8,314472 * 773}}{1,293} = 0,353$$



The inside dimensions of the burn tunnel amount 142x142mm

Required air inlet size:

$$A_{inlet} = I * A_{system} = 0,353 * 142 * 142 = \mathbf{7120 \text{ mm}^2}$$

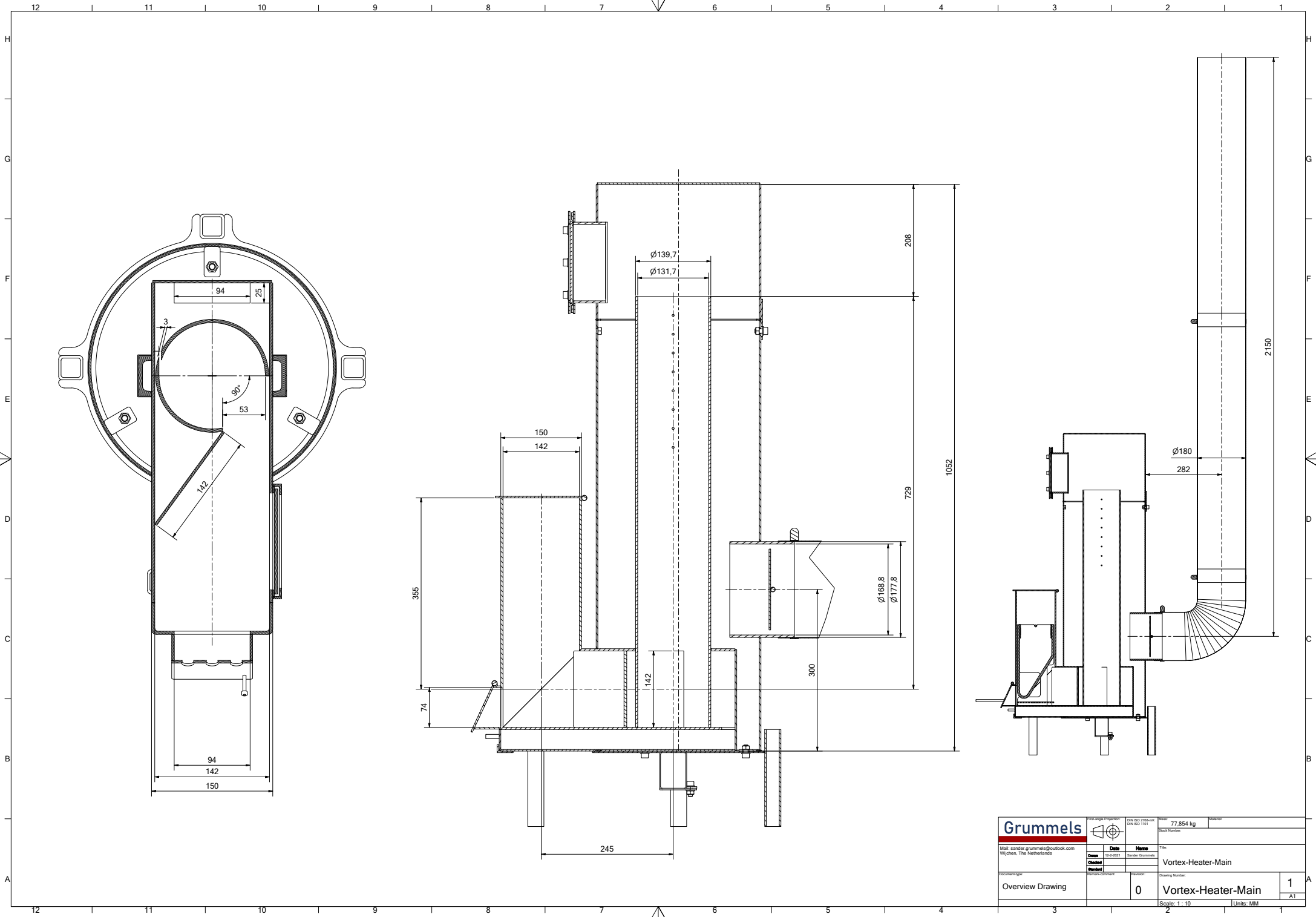
So the air inlet needs to have an area of around **7120 mm²**.

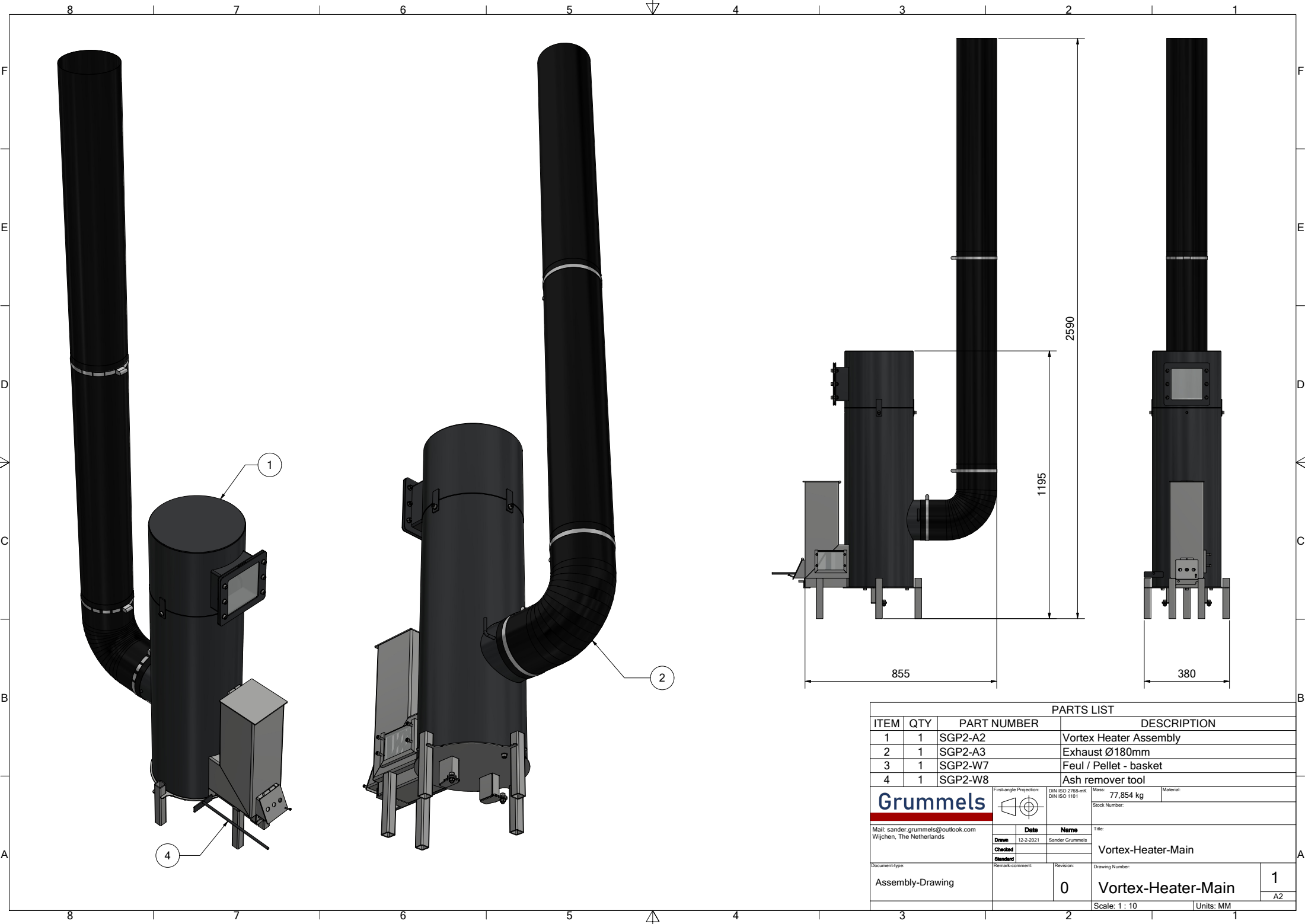
Appendix D



Appendix D.1: 2D-Drawings

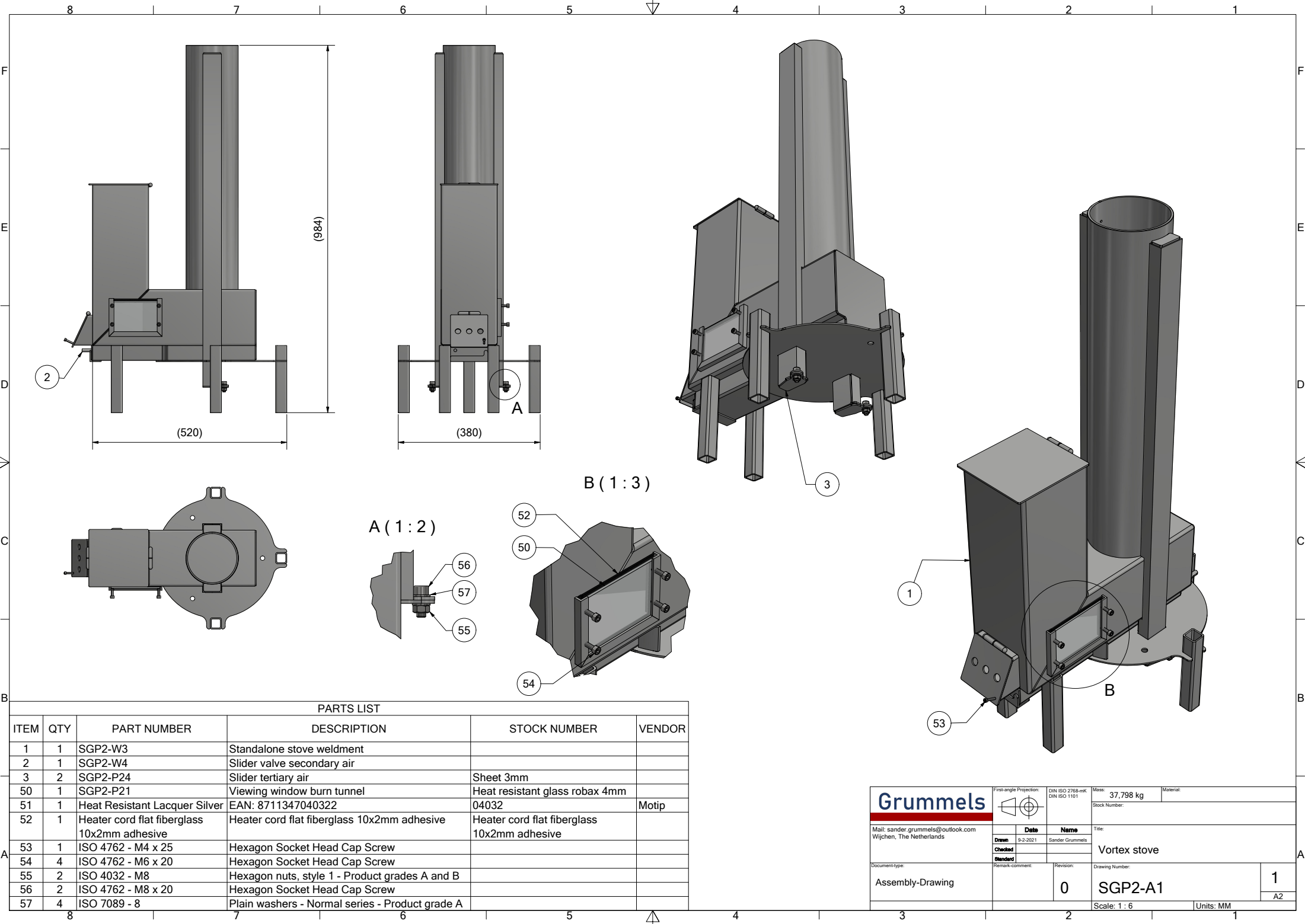
Overview-Drawing-Vortex-Heater	3
Vortex-Heater-Main	4
SGP2-A1	5
SGP2-A2	6
SGP2-A3	7
SGP2-M1	8
SGP2-W1	9
SGP2-W2	10
SGP2-W3	11
SGP2-W4	12
SGP2-W5	13
SGP2-W6	14
SGP2-W7	15
SGP2-W8	16
SGP2-P1	17
SGP2-P2	18
SGP2-P3	19
SGP2-P4	20
SGP2-P5	21
SGP2-P6	22
SGP2-P7	23
SGP2-P8	24
SGP2-P9	25
SGP2-P10	26
SGP2-P11	27
SGP2-P12	28
SGP2-P13	29
SGP2-P14	30
SGP2-P15	31
SGP2-P16	32

SGP2-P17	33
SGP2-P18	34
SGP2-P19	35
SGP2-P20	36
SGP2-P21	37
SGP2-P22	38
SGP2-P23	39
SGP2-P24	40
SGP2-P25	41
SGP2-P27	42
SGP2-P28	43
SGP2-P29	44
SGP2-P30	45
SGP2-P31	46
SGP2-P32	47
SGP2-P33	48
SGP2-P34	49
SGP2-P35	50
SGP2-P36	51
SGP2-P37	52
SGP2-P38	53
SGP2-P39	54
SGP2-P40	55
SGP2-P41	56
SGP2-P42	57
SGP2-P43	58
SGP2-P43_MOLD	59
SGP2-P44	60
SGP2-P45	61





PARTS LIST						
ITEM	QTY	PART NUMBER	DESCRIPTION			
1	1	SGP2-A2	Vortex Heater Assembly			
2	1	SGP2-A3	Exhaust Ø180mm			
3	1	SGP2-W7	Feul / Pellet - basket			
4	1	SGP2-W8	Ash remover tool			
		First-angle Projection:	DIN ISO 2768-mK DIN ISO 1101	Mass: 77,854 kg	Material:	
			Stock Number:			
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title:		
		Drawn Checked Standard	12-2-2021 Sander Grummels	Vortex-Heater-Main		
Document-type: Assembly-Drawing		Remark-comment:	Revision:	Drawing Number:	1	
		0			Vortex-Heater-Main	A2
		Scale: 1 : 10			Units: MM	



PARTS LIST					
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	VENDOR
1	1	SGP2-W3	Standalone stove weldment		
2	1	SGP2-W4	Slider valve secondary air		
3	2	SGP2-P24	Slider tertiary air	Sheet 3mm	
50	1	SGP2-P21	Viewing window burn tunnel	Heat resistant glass robax 4mm	
51	1	Heat Resistant Lacquer Silver	EAN: 8711347040322	04032	Motip
52	1	Heater cord flat fiberglass 10x2mm adhesive	Heater cord flat fiberglass 10x2mm adhesive	Heater cord flat fiberglass 10x2mm adhesive	
53	1	ISO 4762 - M4 x 25	Hexagon Socket Head Cap Screw		
54	4	ISO 4762 - M6 x 20	Hexagon Socket Head Cap Screw		
55	2	ISO 4032 - M8	Hexagon nuts, style 1 - Product grades A and B		
56	2	ISO 4762 - M8 x 20	Hexagon Socket Head Cap Screw		
57	4	ISO 7089 - 8	Plain washers - Normal series - Product grade A		

Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

First-angle Projection:

DIN ISO 2768-mk
DIN ISO 1101

Document-type:
Assembly-Drawing

Revision:
0

Mass: 37.798 kg
Stock Number:

Title:
Vortex stove

Drawing Number:
SGP2-A1

Scale: 1 : 6

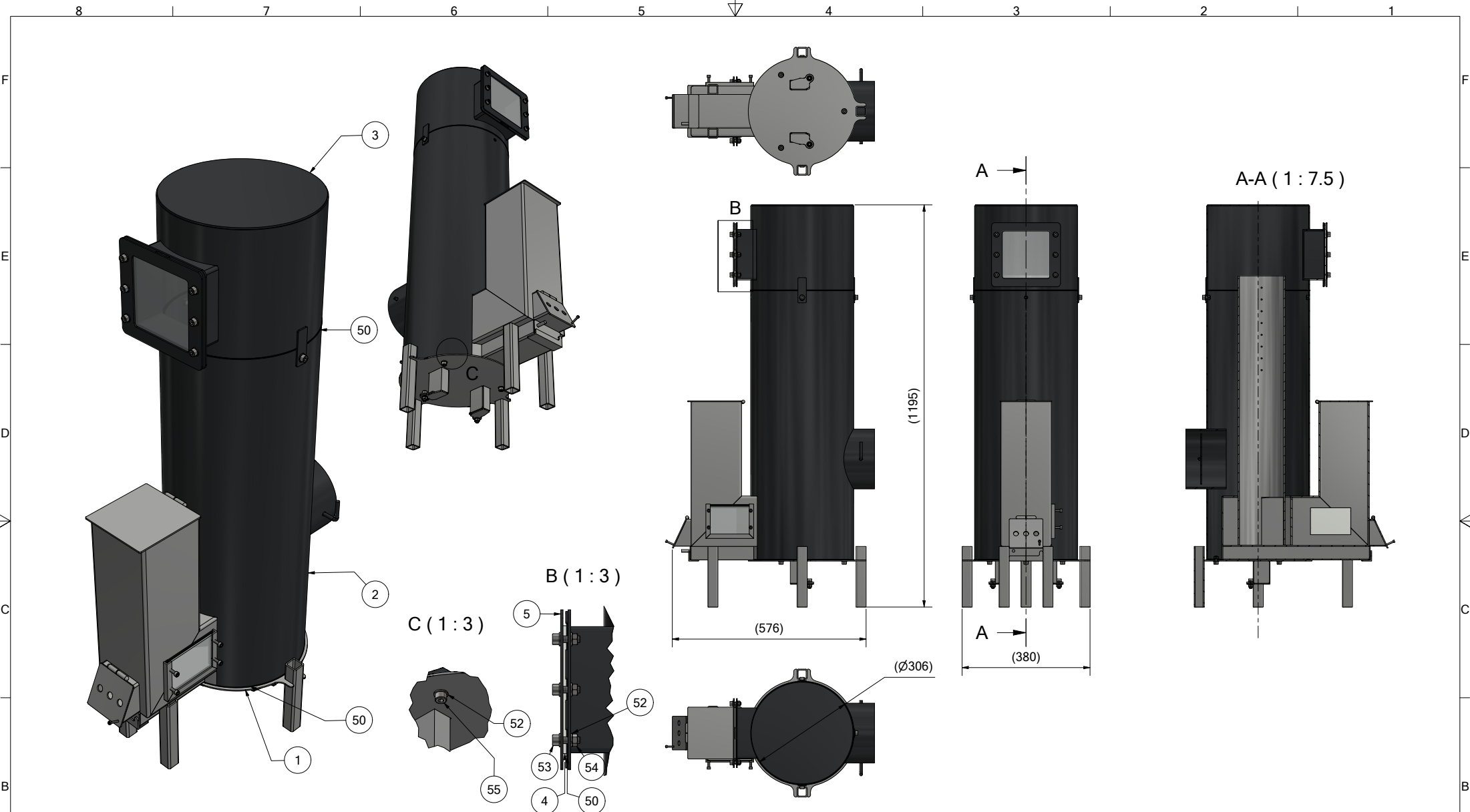
Units: MM

Drawn: 9-2-2021
Checked:
Standard:

Date:
Name: Sander Grummels

1

A2



PARTS LIST				
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER
1	1	SGP2-A1	Vortex stove	
2	1	SGP2-W5	Bottom heat extractor	
3	1	SGP2-W6	Upper heat extractor	
4	1	SGP2-P37	Viewing window top	Heat resistant glass robax 4mm
5	1	SGP2-P38	Seal plate viewing window 2	Sheet 3mm
50	3	Heater cord flat fiberglass 10x2mm adhesive	Heater cord flat fiberglass 10x2mm adhesive	
51	1	Heat Resistant Lacquer Dark Anthracite	EAN: 8711347040308	04030
52	18	ISO 7089 - 8	Plain washers - Normal series - Product grade A	
53	6	ISO 4762 - M8 x 25	Hexagon Socket Head Cap Screw	
54	6	ISO 4032 - M8	Hexagon nuts, style 1 - Product grades A and B	
55	6	ISO 4762 - M8 x 16	Hexagon Socket Head Cap Screw	

Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

First-angle Projection

Drawn

Checked

Standard

Date

11-2-2021

Name

Sander Grummels

Document-type:
Assembly-Drawing

Mass: 67,081 kg

Stock Number:

Title:
Vortex Heater Assembly

Revision:
0

Drawing Number:
SGP2-A2

Scale: 1 : 7.5

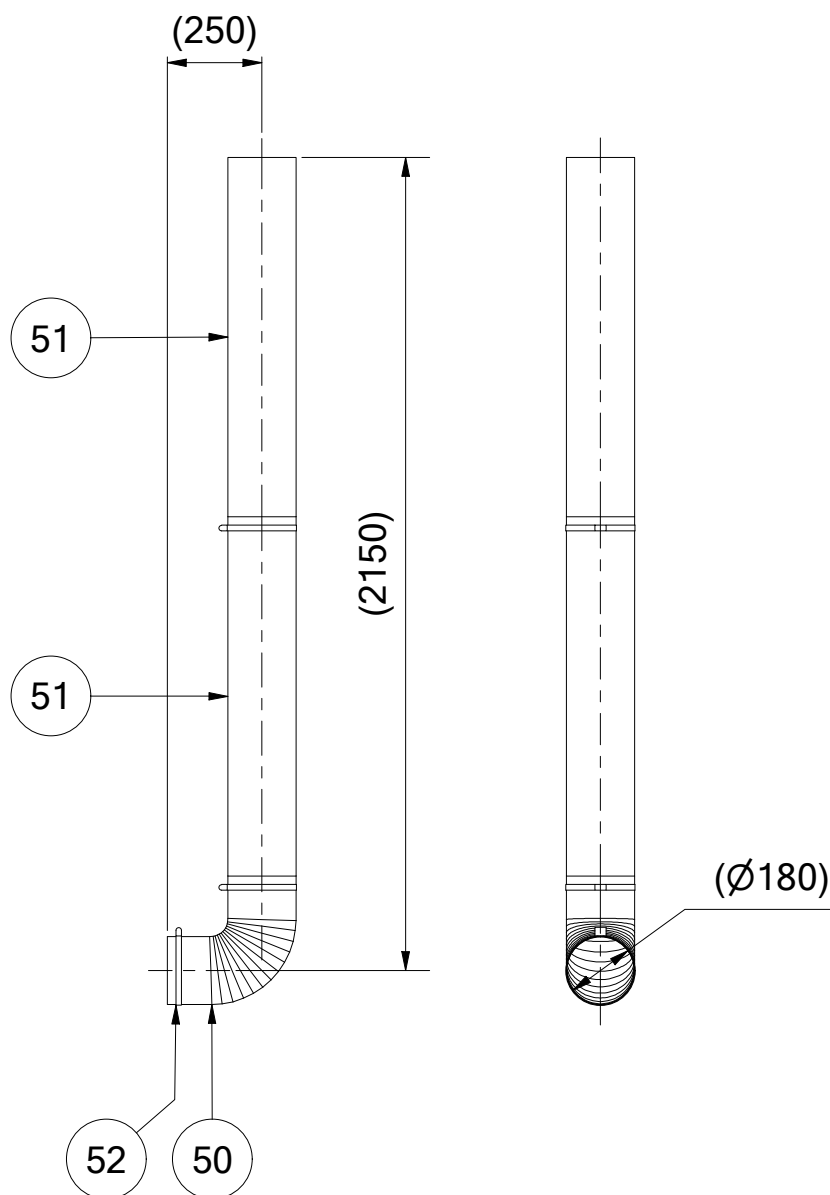
Units: MM

Material:

0

1

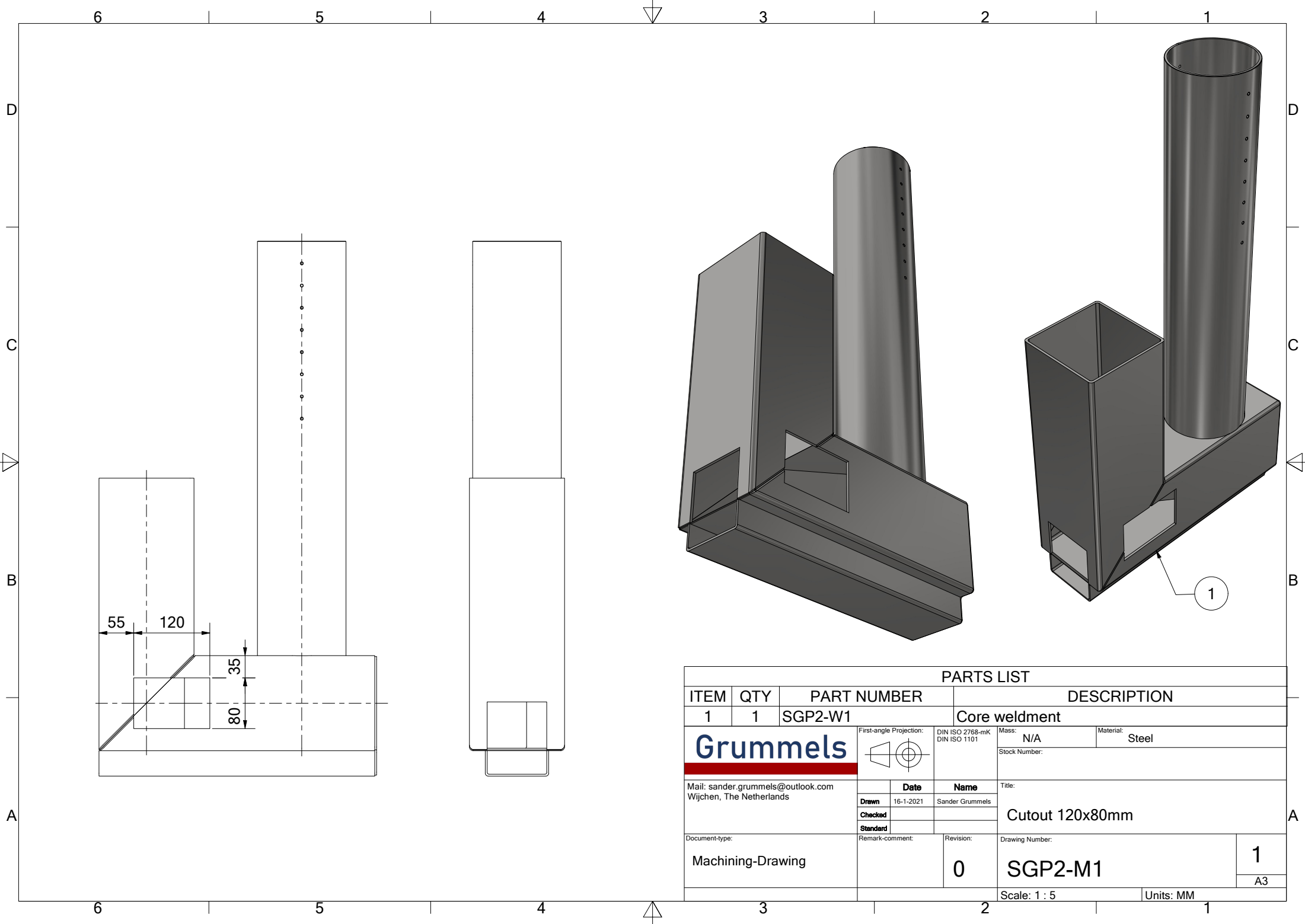
A2

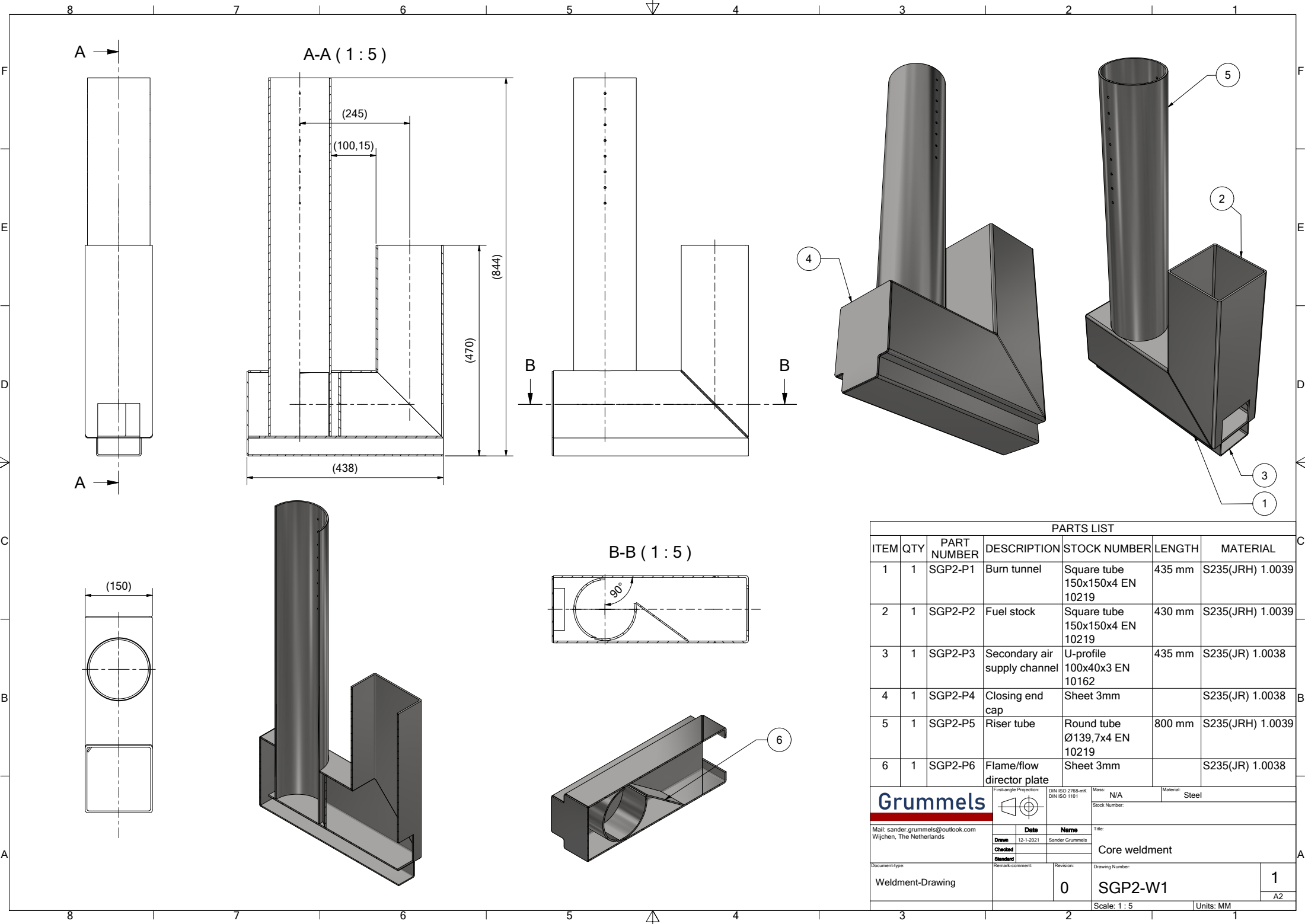


PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
50	1	Stovepipe Ø180mm bend 45 degrees	Ø180x0,6 45 deg L=250x250mm
51	2	Stovepipe Ø180mm 1000mm	Ø180x0,6 L=1000mm
52	3	Clamping band Ø180mm	Ø180x20x0,6 Stainless steel

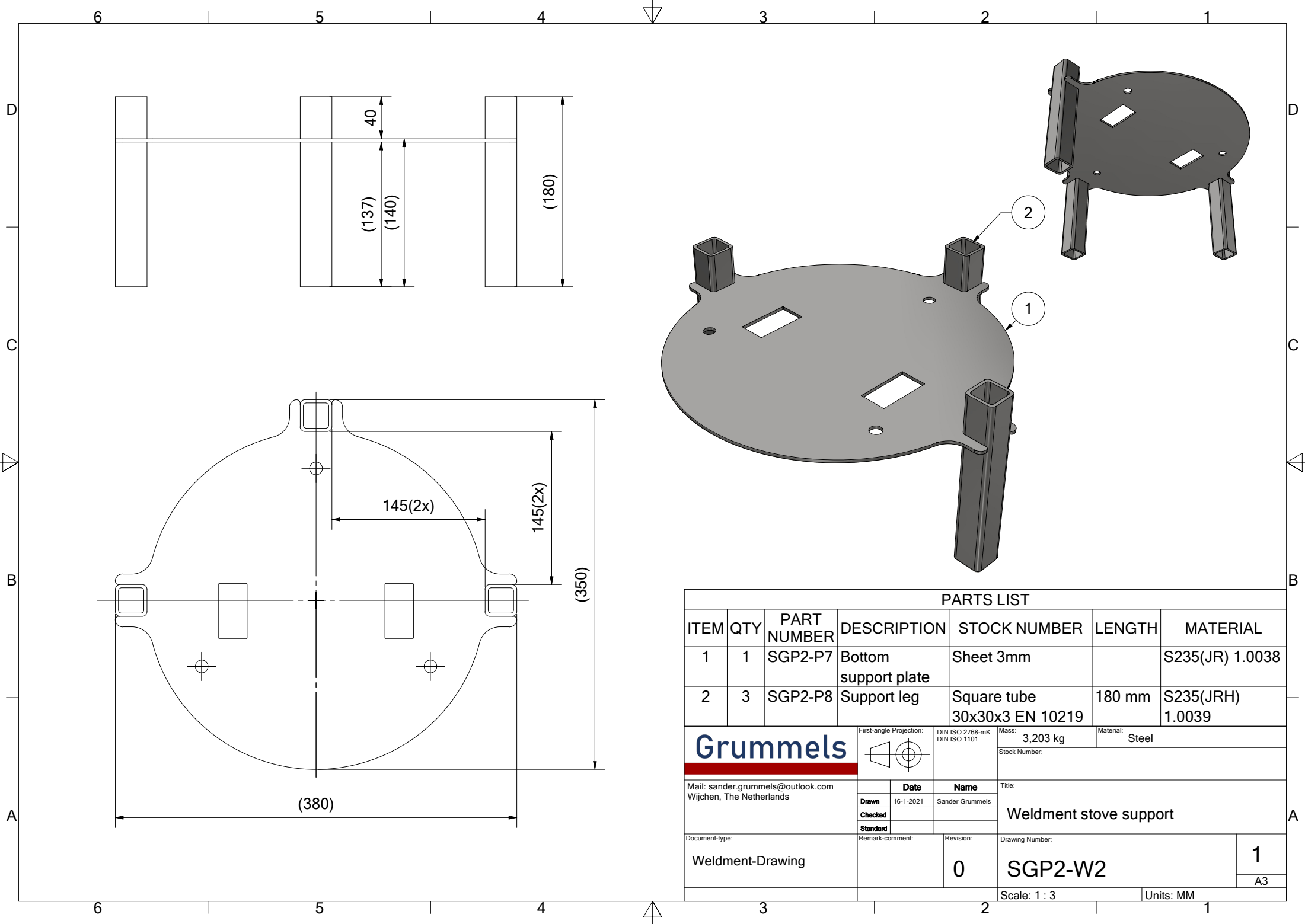
Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands	First-angle Projection:		DIN ISO 2768-mK DIN ISO 1101	Mass: 6,999 kg Stock Number:	Material:
	Drawn: 12-2-2021 Checked: Standard:	Date: 12-2-2021 Name: Sander Grummels	Title: Exhaust Ø180mm		
Document-type: Assembly-Drawing	Remark-comment:		Revision: 0	Drawing Number: SGP2-A3	1 A4
				Scale: 1 : 20	Units: MM

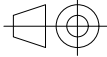


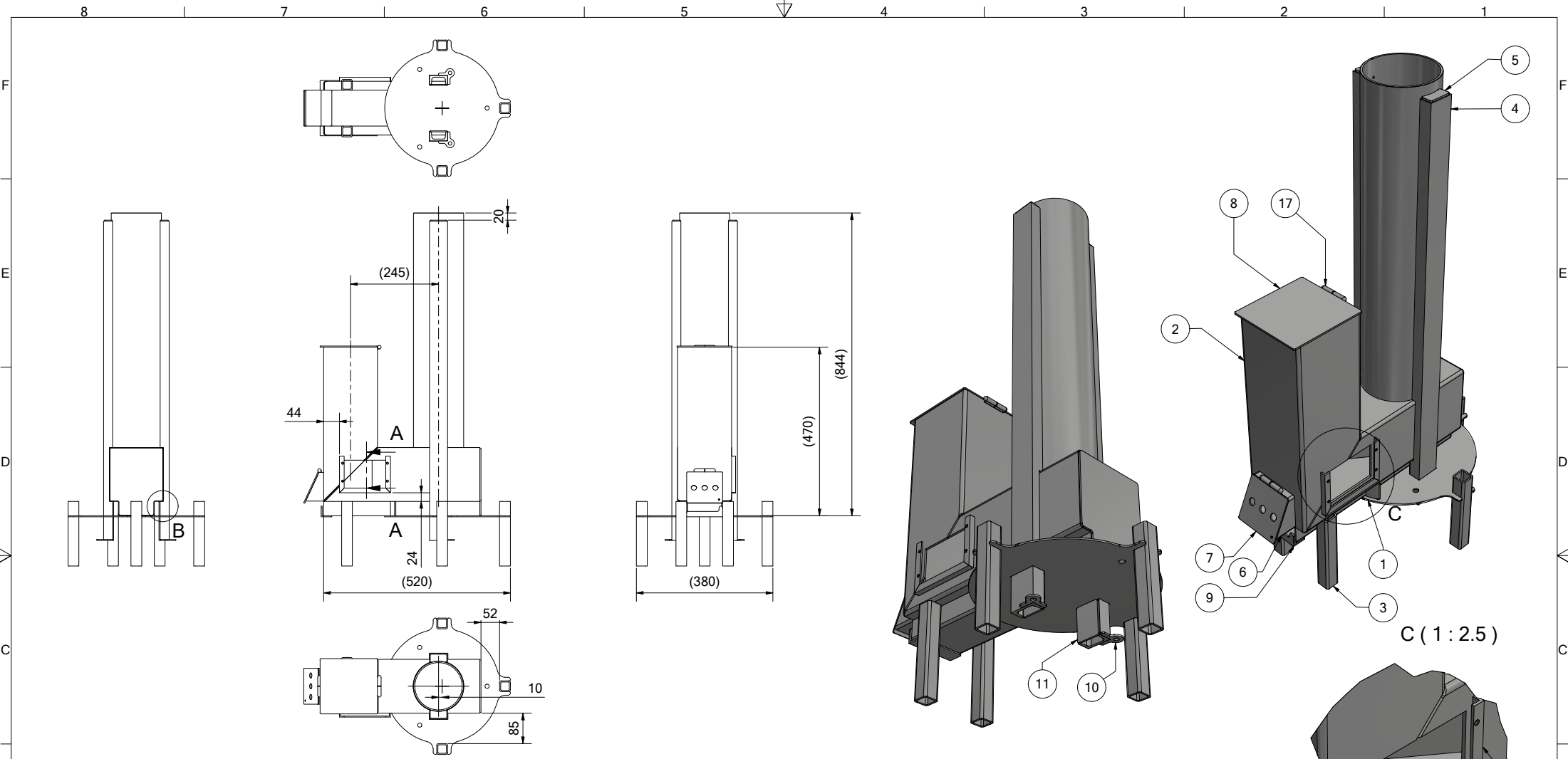


PARTS LIST						
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	LENGTH	MATERIAL
1	1	SGP2-P1	Burn tunnel	Square tube 150x150x4 EN 10219	435 mm	S235(JRH) 1.0039
2	1	SGP2-P2	Fuel stock	Square tube 150x150x4 EN 10219	430 mm	S235(JRH) 1.0039
3	1	SGP2-P3	Secondary air supply channel	U-profile 100x40x3 EN 10162	435 mm	S235(JR) 1.0038
4	1	SGP2-P4	Closing end cap	Sheet 3mm		S235(JR) 1.0038
5	1	SGP2-P5	Riser tube	Round tube Ø139,7x4 EN 10219	800 mm	S235(JRH) 1.0039
6	1	SGP2-P6	Flame/flow director plate	Sheet 3mm		S235(JR) 1.0038

Grummels		First-angle Projection:	DIN ISO 2768-mK DIN ISO 1101	Mass: N/A	Material: Steel
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date: 12-1-2021 Name: Sander Grummels		Title: Core weldment	
Document-type: Weldment-Drawing		Revision: 0		Drawing Number: SGP2-W1	
				Scale: 1 : 5	
				Units: MM	



PARTS LIST						
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	LENGTH	MATERIAL
1	1	SGP2-P7	Bottom support plate	Sheet 3mm		S235(JR) 1.0038
2	3	SGP2-P8	Support leg	Square tube 30x30x3 EN 10219	180 mm	S235(JRH) 1.0039
Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands			First-angle Projection: 	DIN ISO 2768-mK DIN ISO 1101	Mass: 3,203 kg Stock Number:	Material: Steel
			Date	Name	Title:	
			Drawn	16-1-2021	Sander Grummels	
			Checked			
Document-type:			Remark-comment:	Revision:	Drawing Number:	
Weldment-Drawing				0	SGP2-W2	
			Scale: 1 : 3			1 A3
			Units: MM			



PARTS LIST						
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	LENGTH	MATERIAL
1	1	SGP2-W2	Weldment stove support			
2	1	SGP2-M1	Cutout 120x80mm			
3	2	SGP2-P8	Support leg	Square tube 30x30x3 EN 10219	180 mm	S235(JRH) 1.0039
4	2	SGP2-P9	Tertiary air supply channel	UNP 50x25 DIN1026-1		S235(JRH) 1.0039
5	2	SGP2-P10	Cap tertiary air	Sheet 3mm		S235(JR) 1.0038
6	1	SGP2-P11	Inlet tube primary	Rectangular tube 100x40x3 EN 10219	50 mm	S235(JRH) 1.0039
7	1	SGP2-P12	Lid primary air	Sheet 3mm		S235(JR) 1.0038
8	1	SGP2-P13	Lid wood stock	Sheet 3mm		S235(JR) 1.0038
9	1	SGP2-P14	Valve slider	Angle 30x30x3 EN 10025		S235(JR) 1.0038
10	2	SGP2-P15	Sheet 3mm	Connection tertiary air slide		S235(JR) 1.0038
11	2	SGP2-P16	Closing plate tertiary air channel	Sheet 3mm		S235(JR) 1.0038
12	1	SGP2-P17	Window holder horizontal	Angle 30x30x3 EN 10025	142 mm	S235(JR) 1.0038
13	1	SGP2-P18	Window holder vertical left	Angle 30x30x3 EN 10025	102 mm	S235(JR) 1.0038
14	1	SGP2-P19	Window holder vertical right	Angle 30x30x3 EN 10025	102 mm	S235(JR) 1.0038
15	2	SGP2-P20	Closing plate tertiary air channel	Sheet 3mm		S235(JR) 1.0038
16	2	SGP2-P36	Closing plate	Round tube Ø306x3 EN 10217-7		AISI 304 1.4301
17	2	GN 128-60-MS	Welding hinge fixed brass pin 60xØ10mm	GN 128-60-MS		
						Ganter Norm

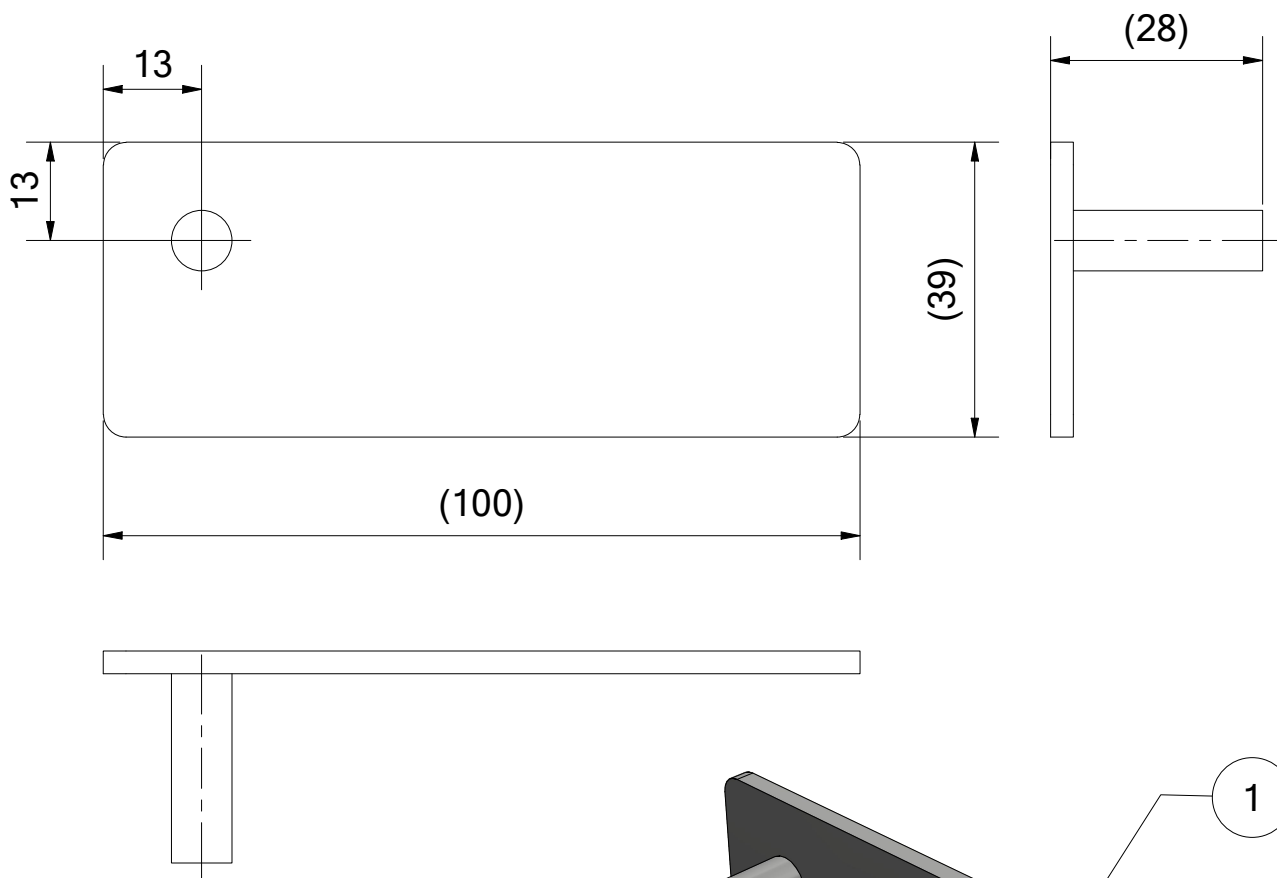
B (1 : 3)

A-A (1 : 7.5)

C (1 : 2.5)

Treatment: Coat with Motip 04032 (Heat Resistant Lacquer Silver)

Grummels	First-angle Projection: DIN ISO 2768-mK DIN ISO 1101	Mass: 37,414 kg Stock Number:	Material: Steel
Mail: sander.grummels@outlook.com Wijchen, The Netherlands	Drawn: 28-1-2021 Checked: Sander Grummels Standard	Title: Standalone stove weldment	
Document-type: Weldment-Drawing	Revision: 0	Drawing Number: SGP2-W3	1
		Scale: 1 : 7.5	Units: MM

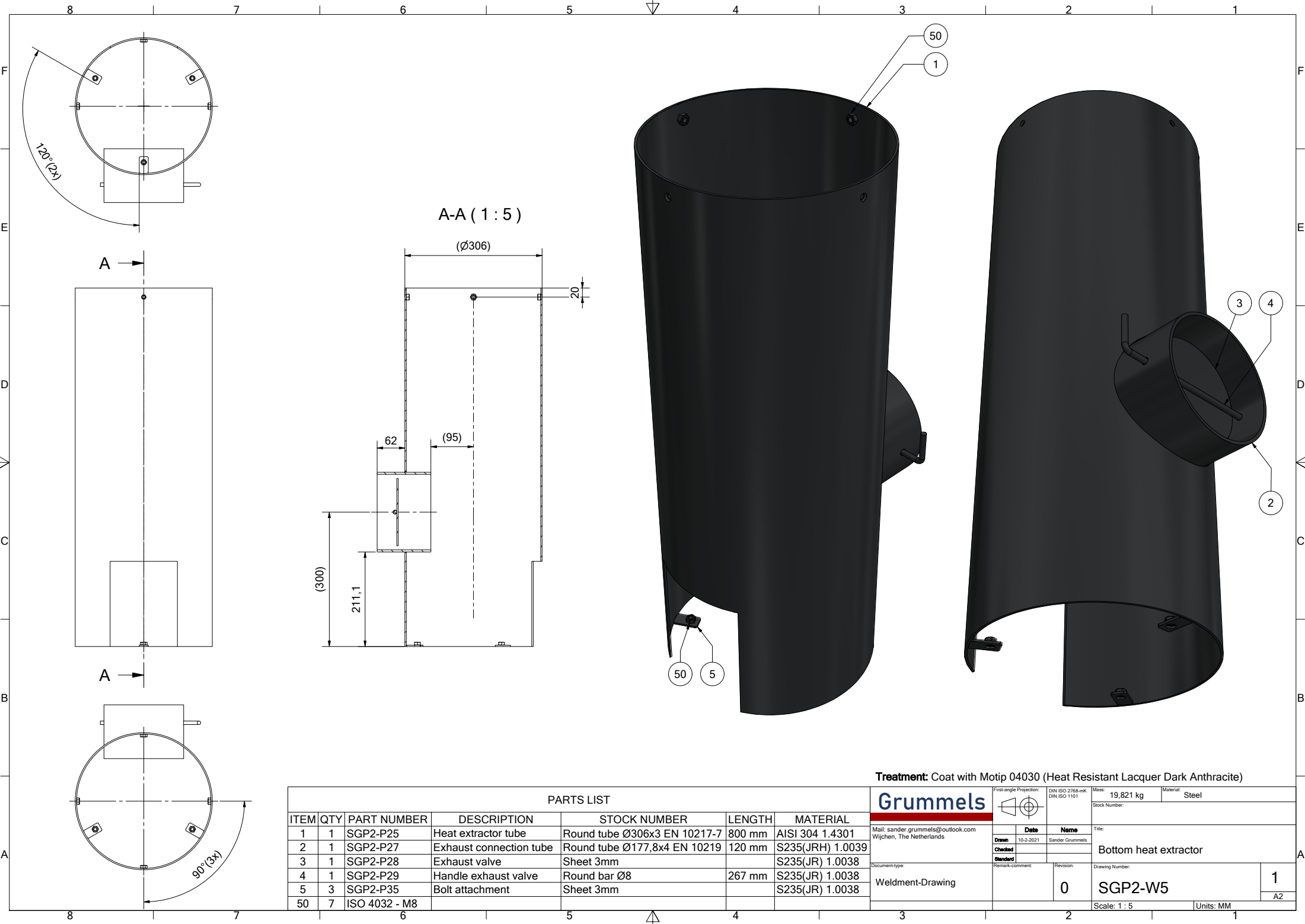


Treatment: Coat with Motip 04032 (Heat Resistant Lacquer Silver)

PARTS LIST


ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	LENGTH	MATERIAL
1	1	SGP2-P22	Inlet slider secondary air	Sheet 3mm		S235(JR) 1.0038
2	1	SGP2-P23	Slider pin	Round bar Ø8	25 mm	S235(JR) 1.0038

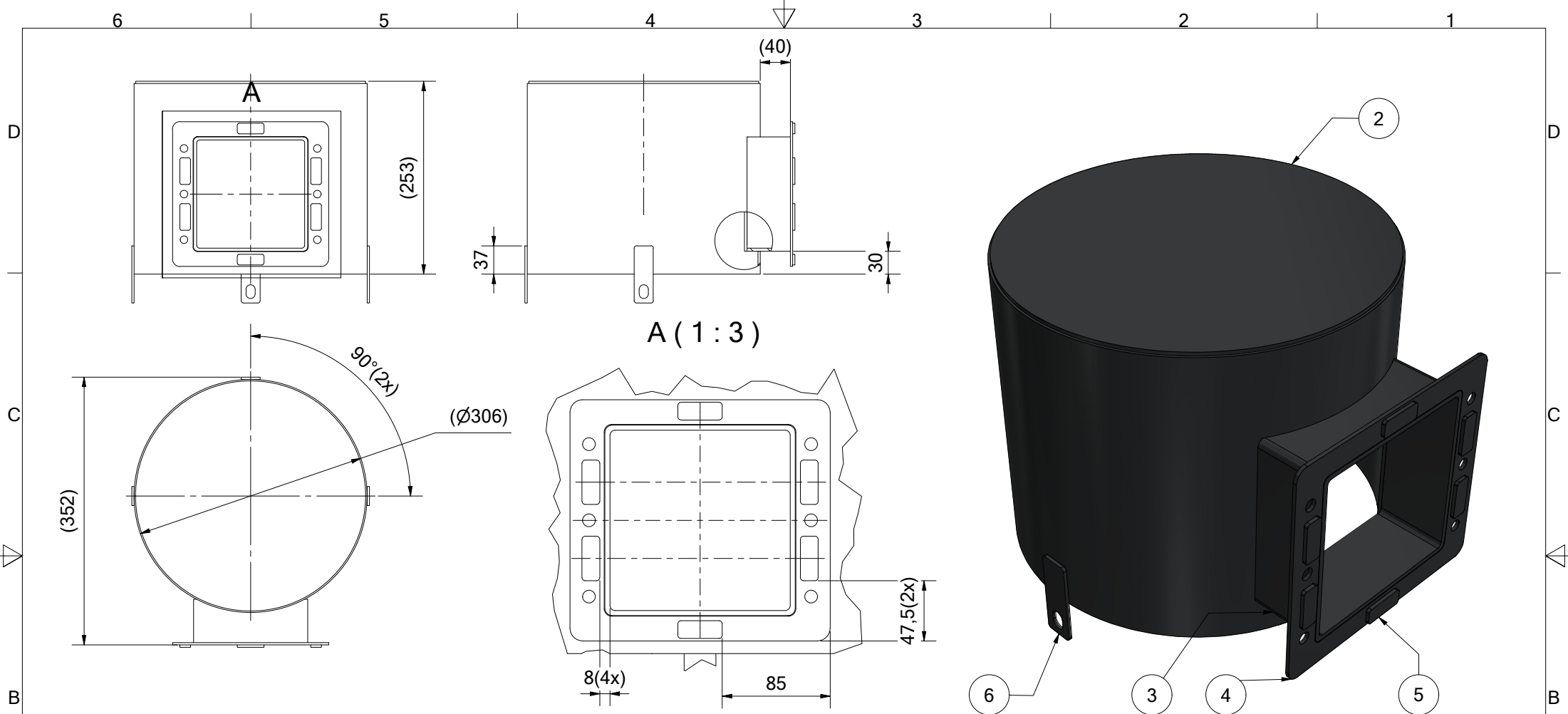
Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands	First-angle Projection:		DIN ISO 2768-mK DIN ISO 1101	Mass: 0,102 kg	Material: Steel
				Stock Number:	
	Drawn	28-1-2021	Sander Grummels	Title: Slider valve secondary air	
	Checked				
Document-type: Weldment-Drawing	Remark-comment:		Revision: 0	Drawing Number: SGP2-W4	1
				Scale: 1 : 1	Units: MM



PARTS LIST					
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	MATERIAL
1	1	SGP2-P25	Heat extractor tube	Round tube Ø306x3 EN 10217-7	800 mm AISI 304 1.4301
2	1	SGP2-P27	Exhaust connection tube	Round tube Ø177,8x4 EN 10219	120 mm S235(JRH) 1.0039
3	1	SGP2-P28	Exhaust valve	Sheet 3mm	S235(JR) 1.0038
4	1	SGP2-P29	Handle exhaust valve	Round bar Ø8	S235(JR) 1.0038
5	3	SGP2-P35	Bolt attachment	Sheet 3mm	S235(JR) 1.0038
50	7	ISO 4032 - M8			

Treatment: Coat with Motip 04030 (Heat Resistant Lacquer Dark Anthracite)

<div>Grummels</div>			First-angle Projection:		DIN ISO 2768-mK		Mass: 19,821 kg		Material: Steel	
			DIN ISO 1101		Stock Number:					
	Mail: sander.grummels@outlook.com		Date		Name		Title:			
	Wijchen, The Netherlands		Drawn 10-2-2021		Sander Grummels		Bottom heat extractor			
		Checked								
		Standard								
Document-type:		Remark-comment:		Revision:		Drawing Number:				
Weldment-Drawing				0		SGP2-W5				
						1				
						A2				
						Scale: 1 : 5				
						Units: MM				



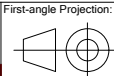
PARTS LIST						
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	LENGTH	MATERIAL
1	1	SGP2-P26	Heat extractor tube top	Round tube Ø306x3 EN 10217-7	250 mm	AISI 304 1.4301
2	1	SGP2-P30	Cover plate upper heat extractor	Sheet 3mm		S235(JR) 1.0038
3	1	SGP2-P31	View tube	Square tube 150x150x4 EN 10219	60 mm	S235(JRH) 1.0039
4	1	SGP2-P32	Seal plate viewing window 1	Sheet 3mm		S235(JR) 1.0038
5	6	SGP2-P33	Space plate 3mm	Sheet 3mm		S235(JR) 1.0038
6	3	SGP2-P34	Connector plate upper heat extractor	Sheet 3mm		S235(JR) 1.0038

Treatment: Coat with Motip 04030 (Heat Resistant Lacquer Dark Anthracite)

Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

Document-type:
Weldment-Drawing



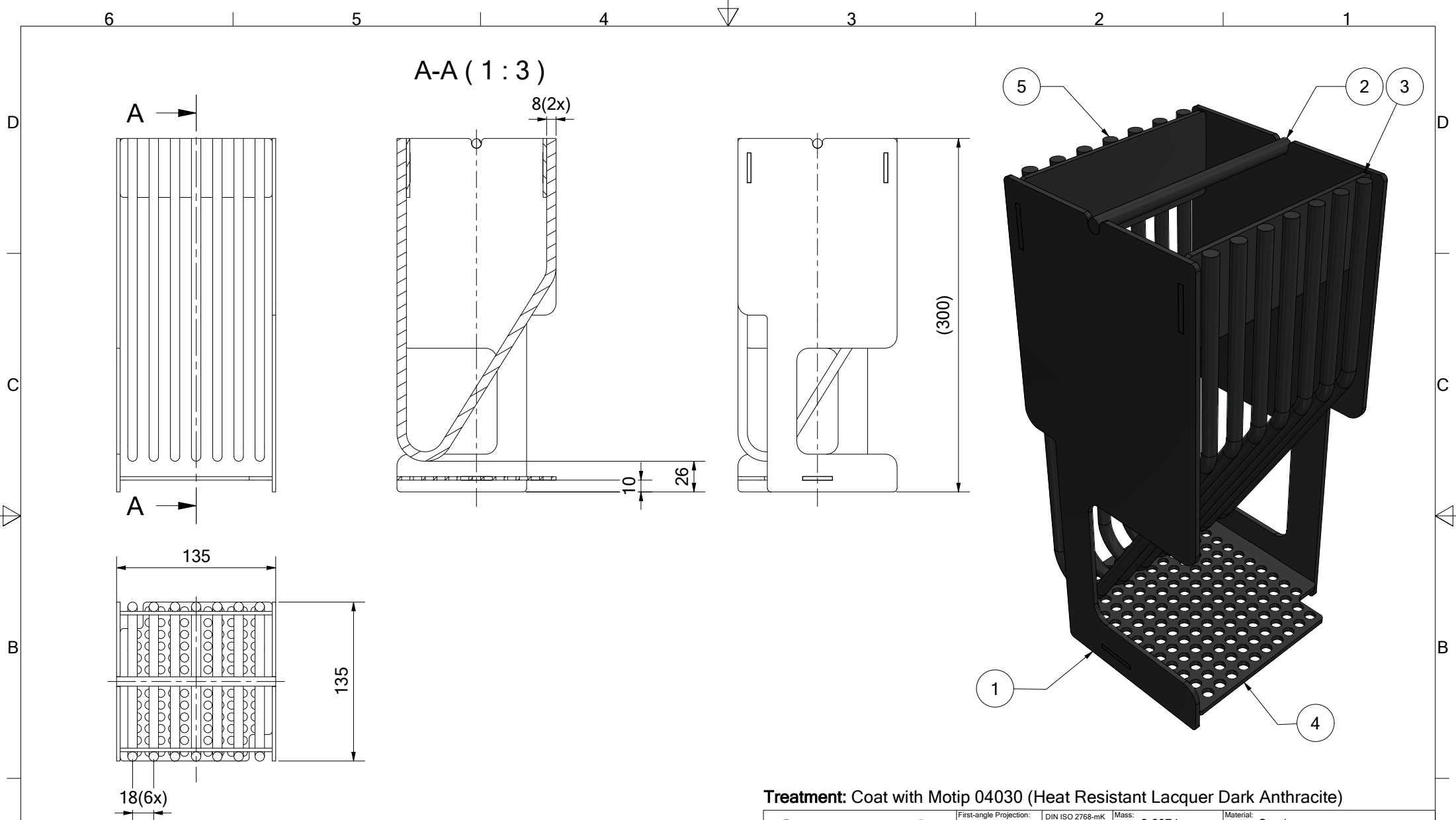
	Date	Name
Drawn	11-2-2021	Sander Grummels
Checked		
Standard		

Remark-comment:		Revision:
		0

Mass: 8,514 kg	Material: Steel
Stock Number:	
Title: Upper heat extractor	
Drawing Number: SGP2-W6	
Scale: 1 : 5	
Units: MM	

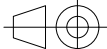
1

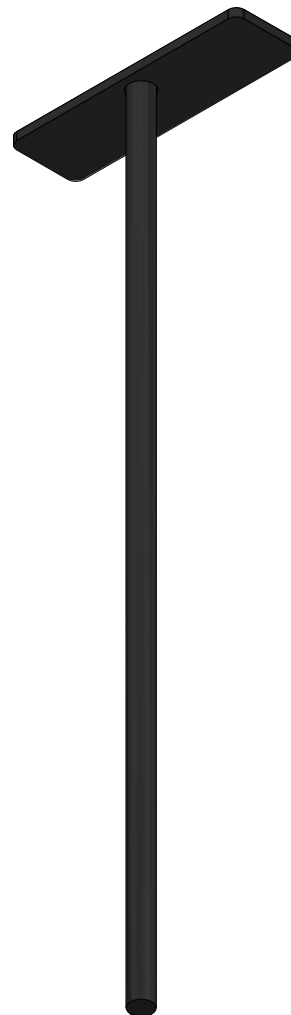
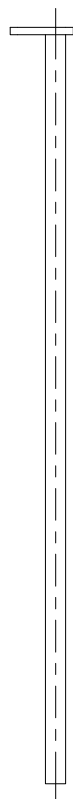
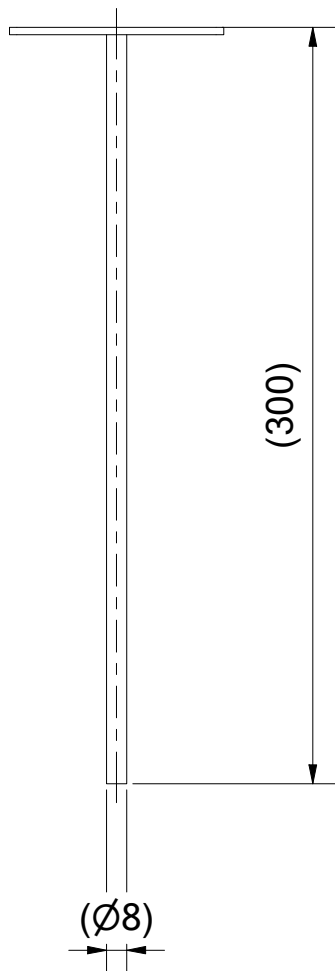
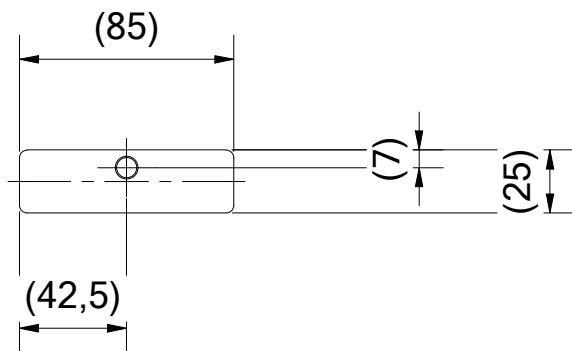
A3



PARTS LIST						
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	LENGTH	MATERIAL
1	2	SGP2-P39	Side plate basket	Sheet 3mm		S235(JR) 1.0038
2	1	SGP2-P40	Connecting bar basket	Round bar Ø8	135 mm	S235(JR) 1.0038
3	2	SGP2-P41	Connecting plate basket	Sheet 3mm		S235(JR) 1.0038
4	1	SGP2-P42	Vent plate basket	Sheet 3mm		S235(JR) 1.0038
5	7	SGP2-P43	Feul holder bar	Round bar Ø8	575 mm	S235(JR) 1.0038

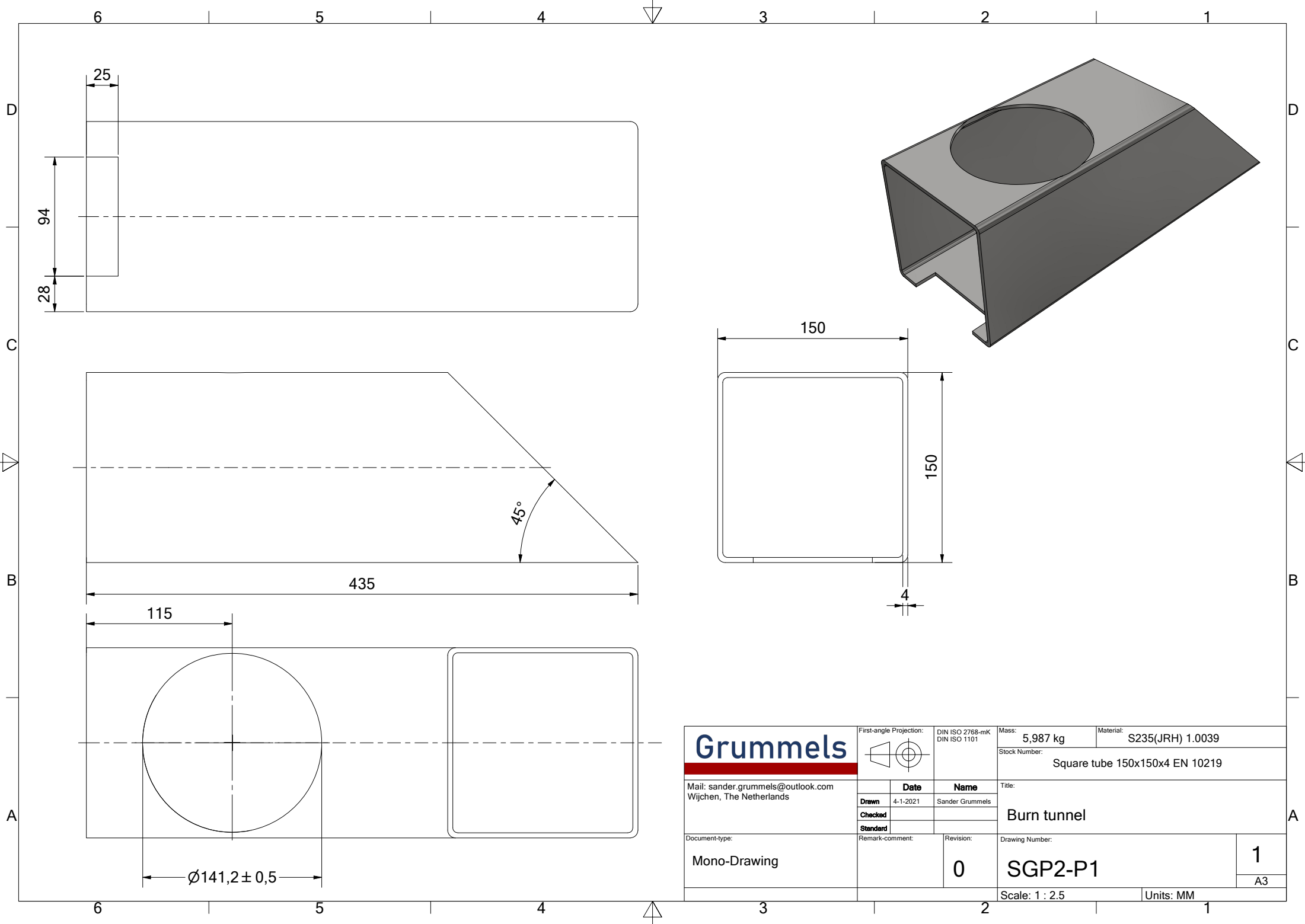
Treatment: Coat with Motip 04030 (Heat Resistant Lacquer Dark Anthracite)

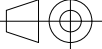
Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands	First-angle Projection: 		DIN ISO 2768-mk DIN ISO 1101	Mass: 3,607 kg	Material: Steel
	Date		Name	Title:	
	Drawn 11-2-2021		Sander Grummels	Feul / Pellet - basket	
	Checked			Stock Number:	
Document-type: Weldment-Drawing		Remark-comment:		Revision: 0	Drawing Number: SGP2-W7
				Scale: 1 : 3	Units: MM

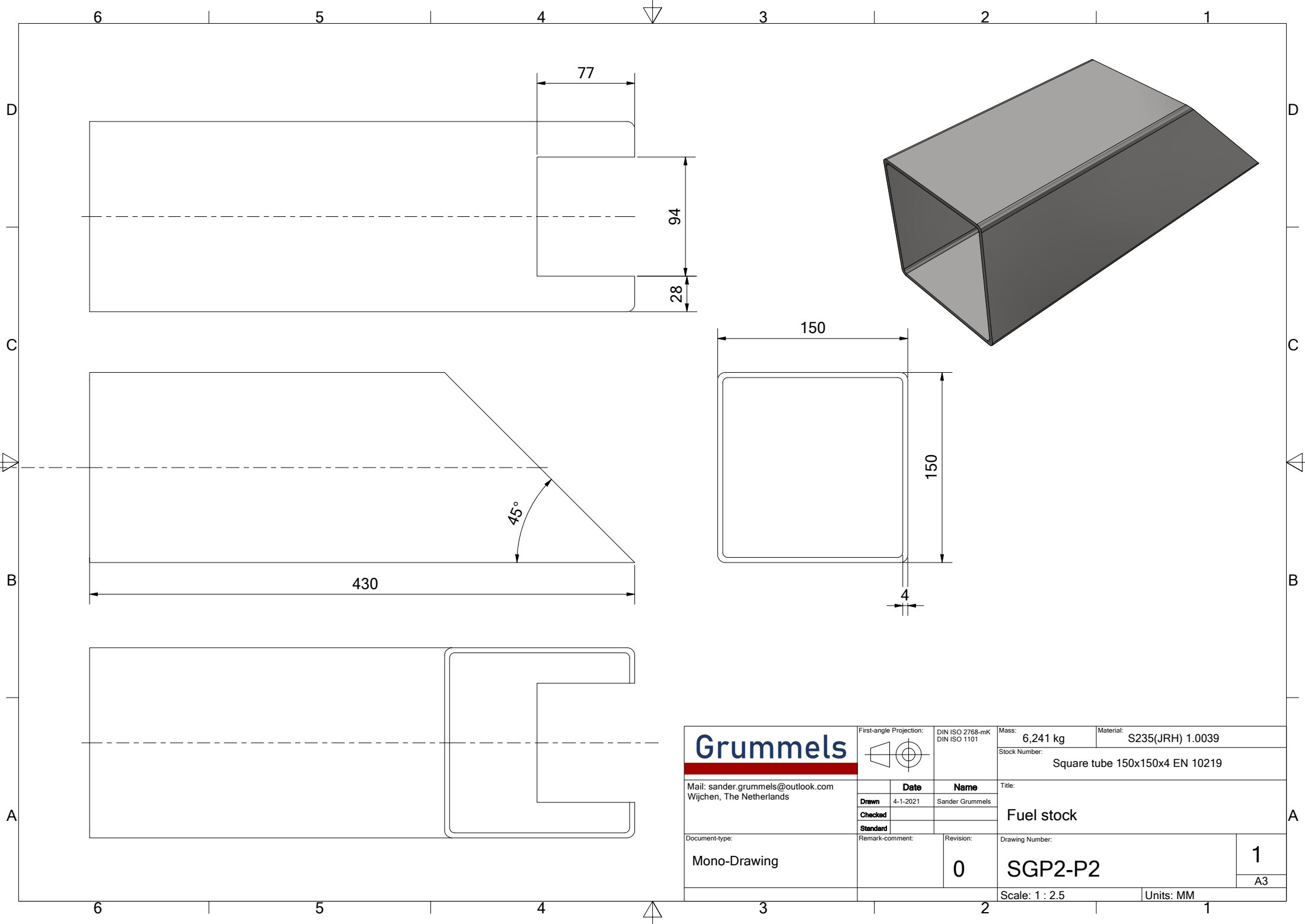



Treatment: Coat with Motip 04030 (Heat Resistant Lacquer Dark Anthracite)

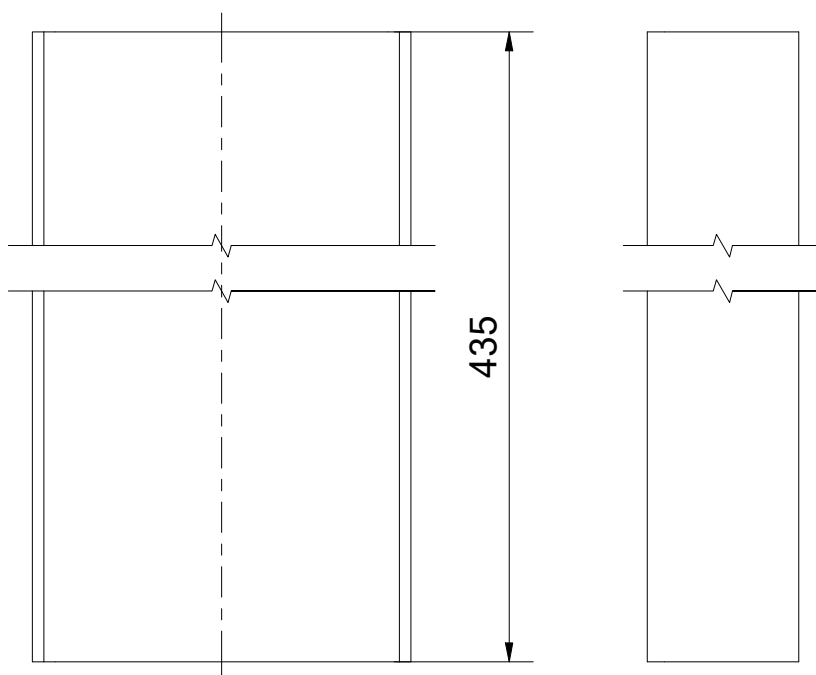
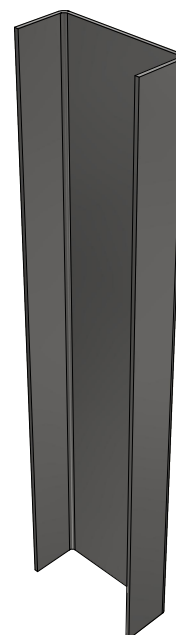
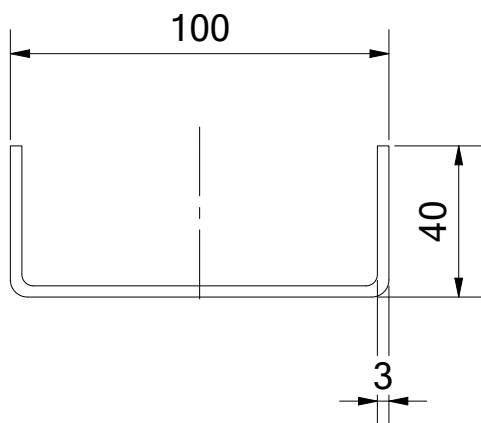
Grummels	First-angle Projection:		DIN ISO 2768-mK DIN ISO 1101	Mass: 0,167 kg	Material: Steel
				Stock Number:	
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Ash remover tool	
	Drawn	11-2-2021	Sander Grummels		
	Checked				
Document-type: Weldment-Drawing	Standard			Drawing Number: SGP2-W8	
	Remark-comment:		Revision:		
			0	Scale: 1 : 3	
				Units: MM	1 A4



Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands	First-angle Projection: 		DIN ISO 2768-mk DIN ISO 1101	Mass: 5,987 kg	Material: S235(JRH) 1.0039
				Stock Number: Square tube 150x150x4 EN 10219	
		Date	Name	Title: Burn tunnel	
	Drawn	4-1-2021	Sander Grummels		
Document-type: Mono-Drawing		Remark-comment:		Revision: 0	Drawing Number: SGP2-P1
				Scale: 1 : 2.5	Units: MM
					1 A3



Grummels	First-angle Projection: 		DIN ISO 2768-mk DIN ISO 1101	Mass: 6,241 kg	Material: S235(JRH) 1.0039
				Stock Number: Square tube 150x150x4 EN 10219	
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title:	
	Drawn	4-1-2021	Sander Grummels	Fuel stock	
	Checked				
	Standard				
Document-type: Mono-Drawing	Remark-comment:		Revision:	Drawing Number:	1 A3
			0	SGP2-P2	
				Scale: 1 : 2.5	Units: MM



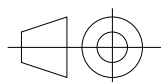
Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

Document-type:

Mono-Drawing

First-angle Projection:



DIN ISO 2768-mK
DIN ISO 1101

Mass: 1,766 kg

Material: S235(JR) 1.0038

Stock Number:

U-profile 100x40x3 EN 10162

	Date	Name
Drawn	4-1-2021	Sander Grummels
Checked		
Standard		

Title:

Secondary air supply channel

Remark-comment:

Revision:

0

Drawing Number:

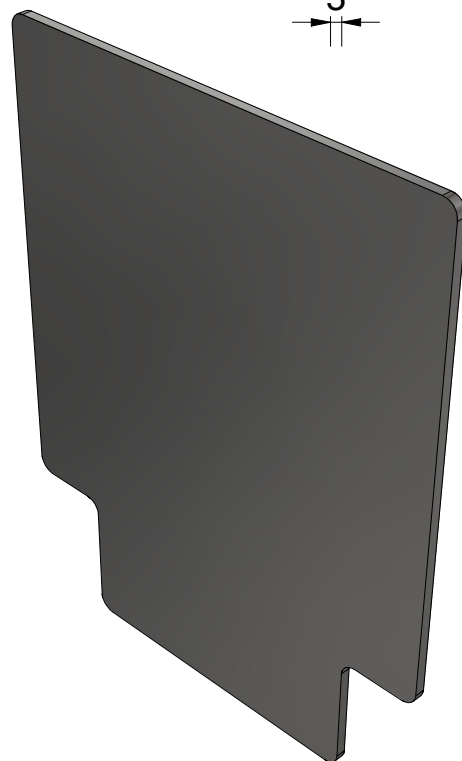
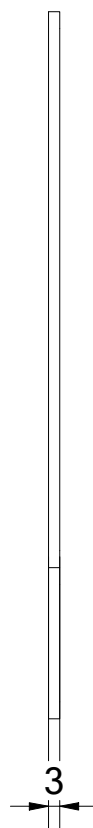
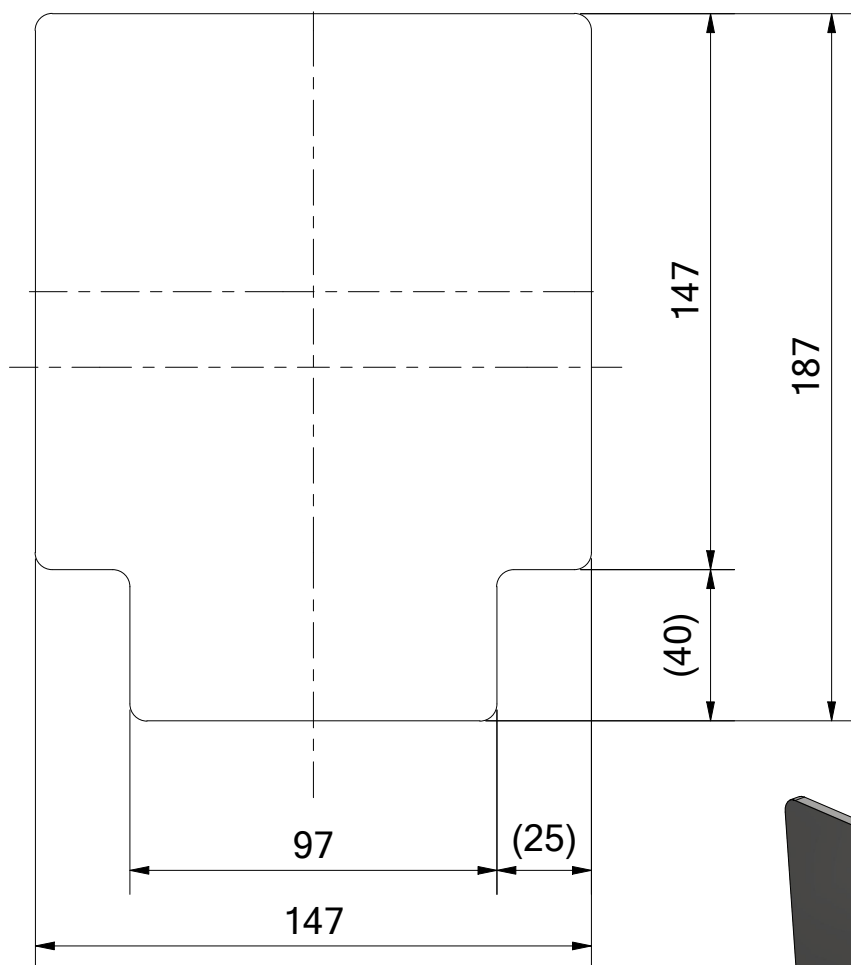
SGP2-P3

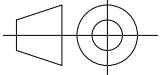
1

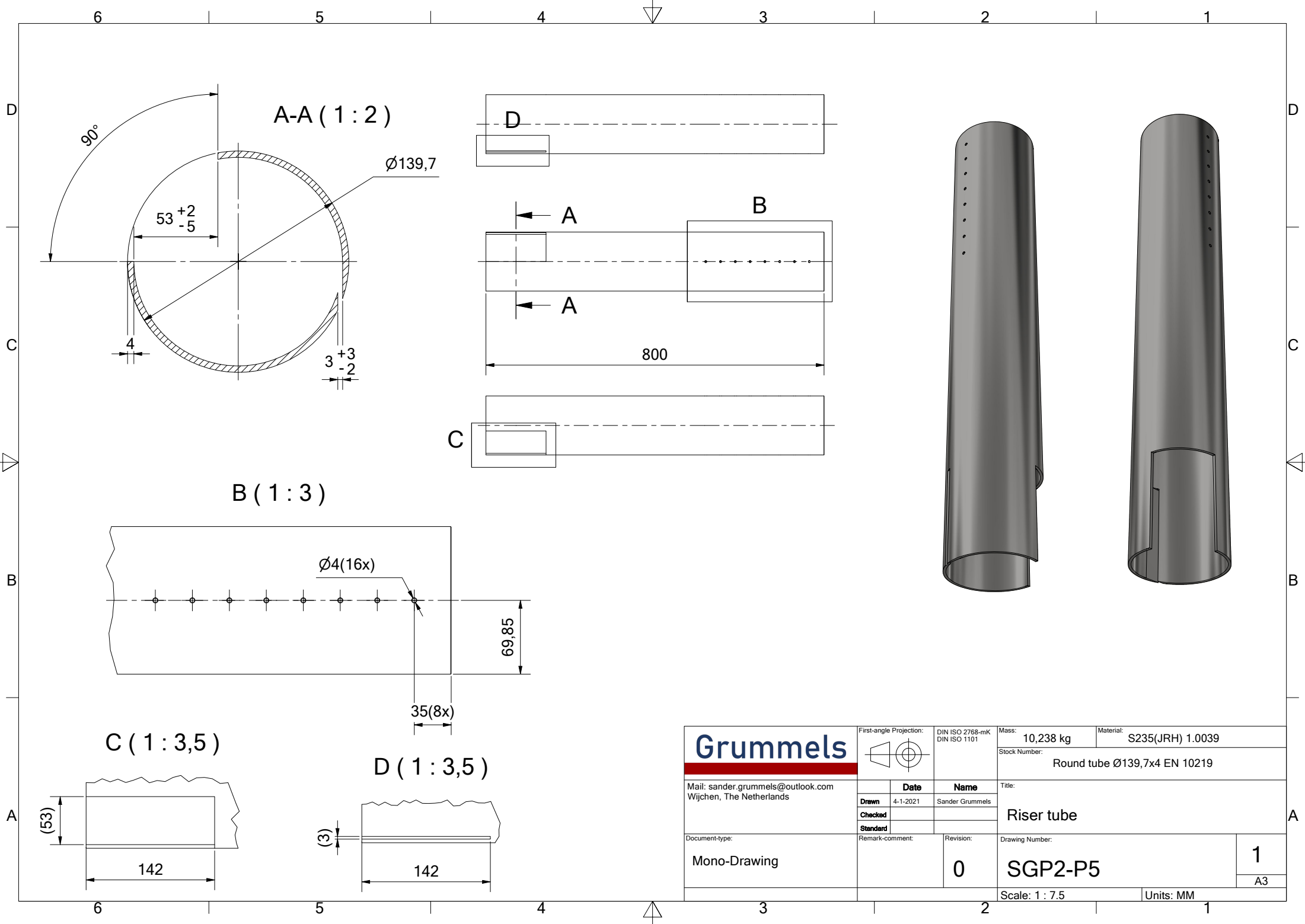
A4

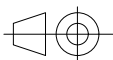
Scale: 1 : 2

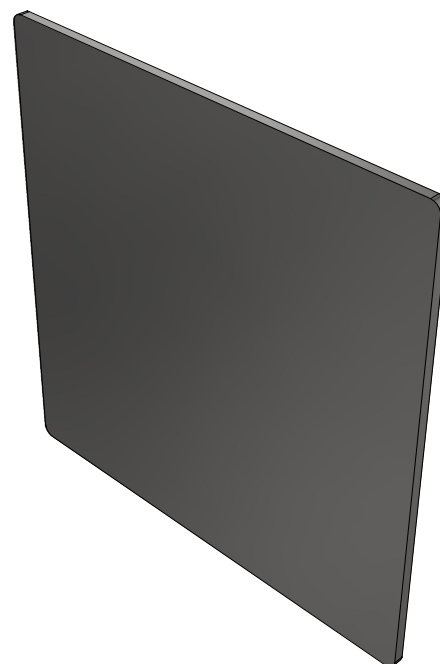
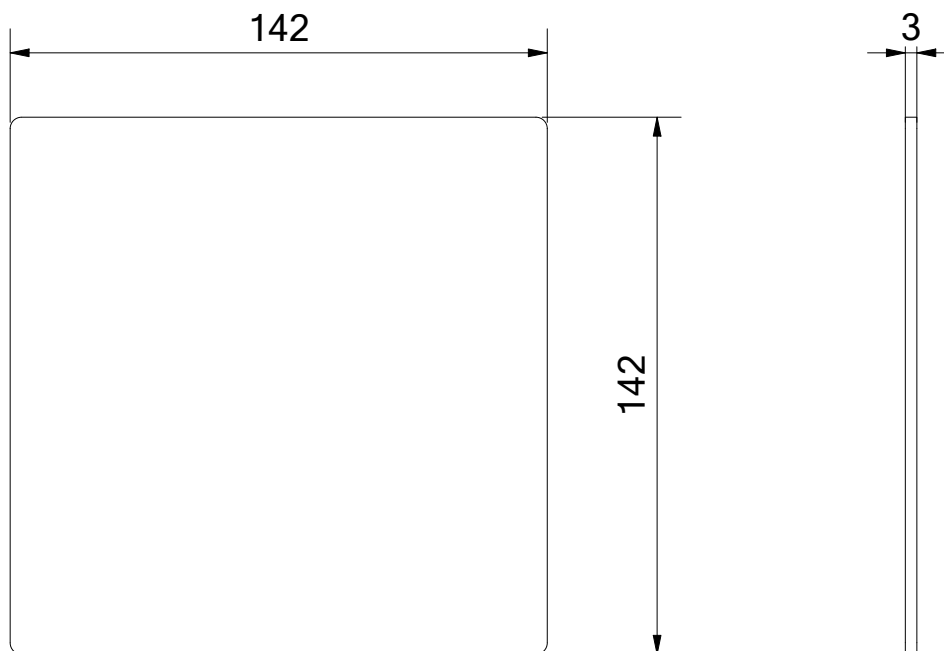
Units: MM

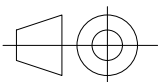


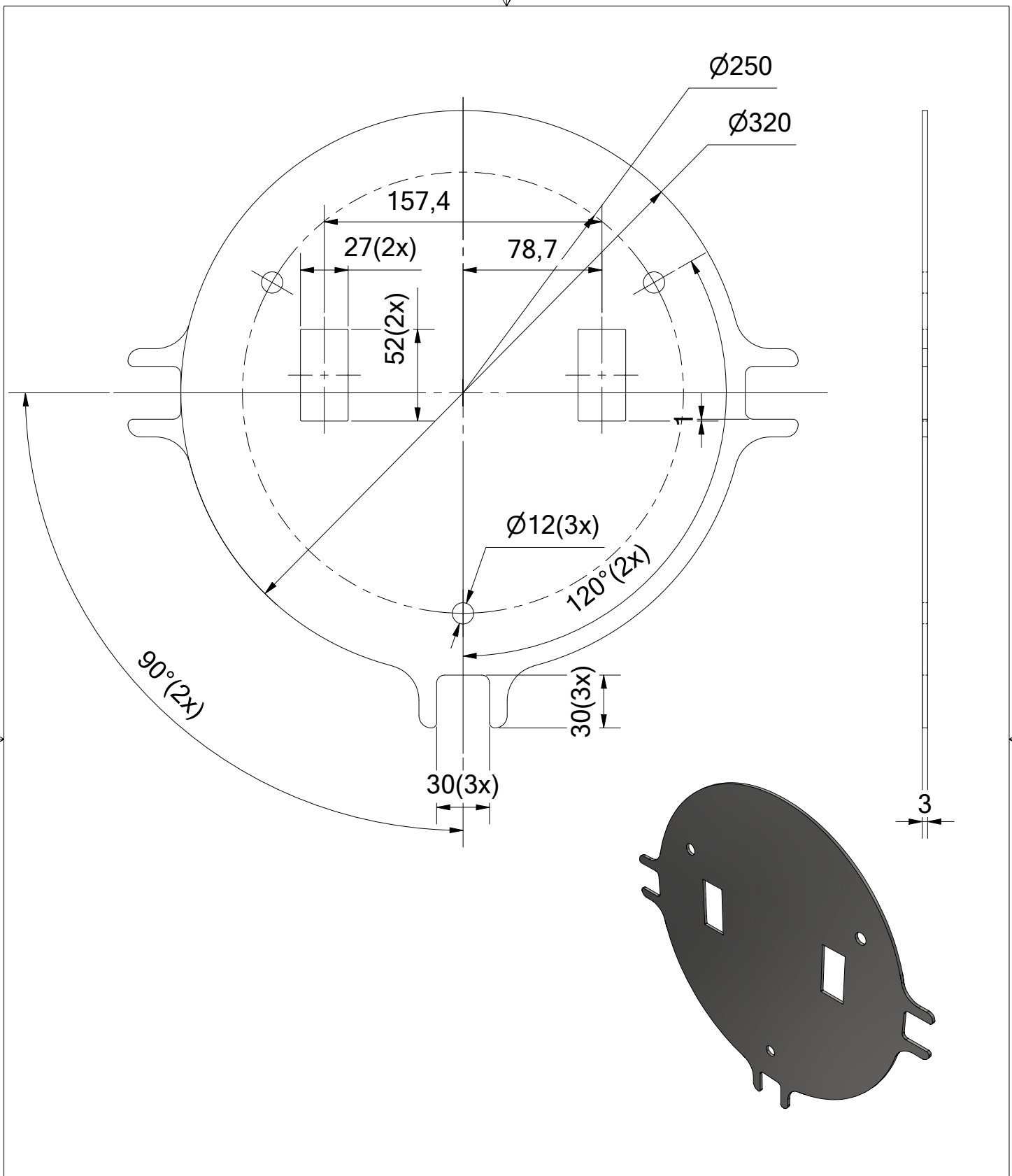
Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands	First-angle Projection: 		DIN ISO 2768-mK DIN ISO 1101	Mass: 0,600 kg Stock Number:	Material: S235(JR) 1.0038 Sheet 3mm
	Drawn: 12-1-2021 Checked: Standard:	Date: 12-1-2021 Name: Sander Grummels	Title: Closing end cap	Drawing Number: SGP2-P4	1 A4
Document-type: Mono-Sheetmetal-Drawing	Remark-comment:	Revision: 0	Scale: 1 : 2	Units: MM	



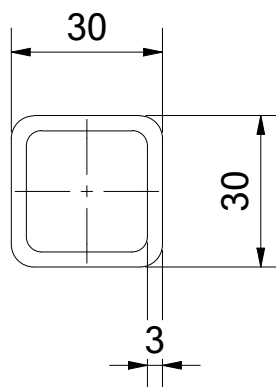
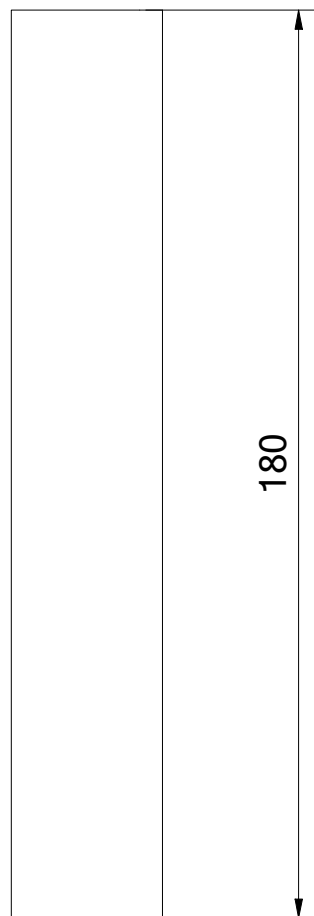
Grummels	<div>First-angle Projection:</div> 	DIN ISO 2768-mk DIN ISO 1101	Mass: 10,238 kg	Material: S235(JRH) 1.0039	
			Stock Number: Round tube Ø139,7x4 EN 10219		
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Riser tube	
	Drawn	4-1-2021	Sander Grummels		
	Checked				
	Standard				
Document-type: Mono-Drawing	Remark-comment:		Revision: 0	Drawing Number:	
				SGP2-P5	
				1	
				A3	
			Scale: 1 : 7.5		Units: MM



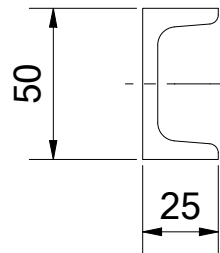
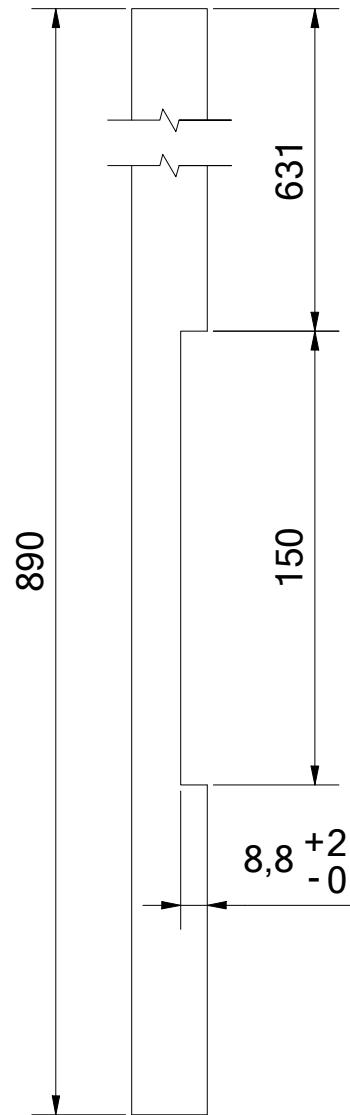
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>Mass:</div> <div>0,475 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>	
			<div>Stock Number:</div> <div>Sheet 3mm</div>			
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Flame/flow director plate</div>	
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>		<div>Drawing Number:</div> <div>SGP2-P6</div>	
					<div>1</div>	
					<div>A4</div>	
	<div>Scale: 1 : 2</div>			<div>Units: MM</div>		




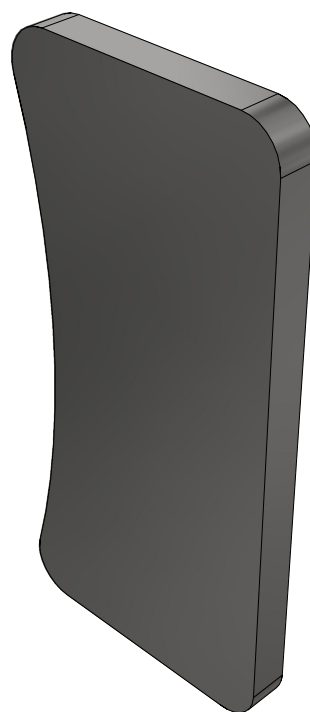
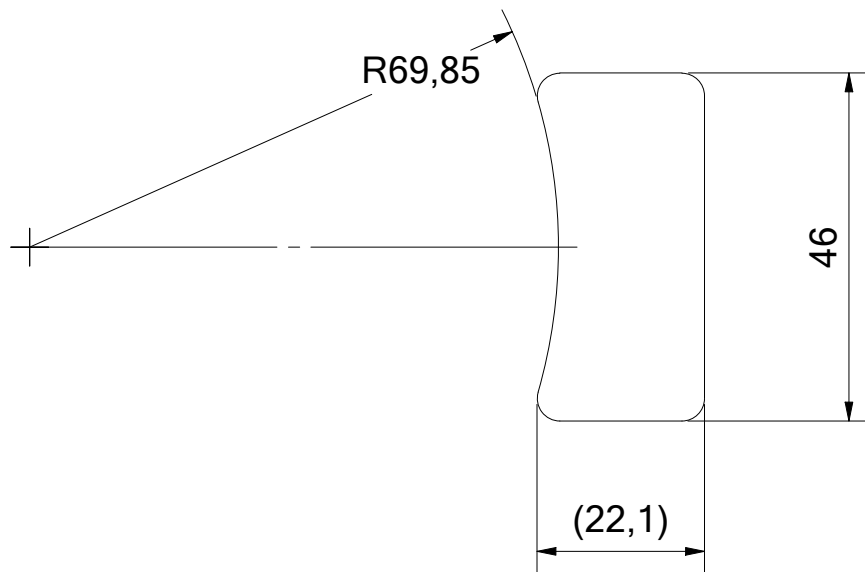
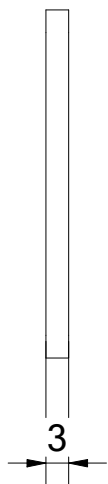
Grummels	First-angle Projection:		DIN ISO 2768-mK DIN ISO 1101	Mass: 1,871 kg	Material: S235(JR) 1.0038
				Stock Number: Sheet 3mm	
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Bottom support plate	
	Drawn	4-1-2021	Sander Grummels		
	Checked				
Document-type: Mono-Sheetmetal-Drawing	Remark-comment:		Revision:	Drawing Number:	
			0	SGP2-P7	
	Scale: 1 : 3			Units: MM	
					1 A4

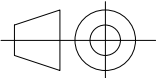


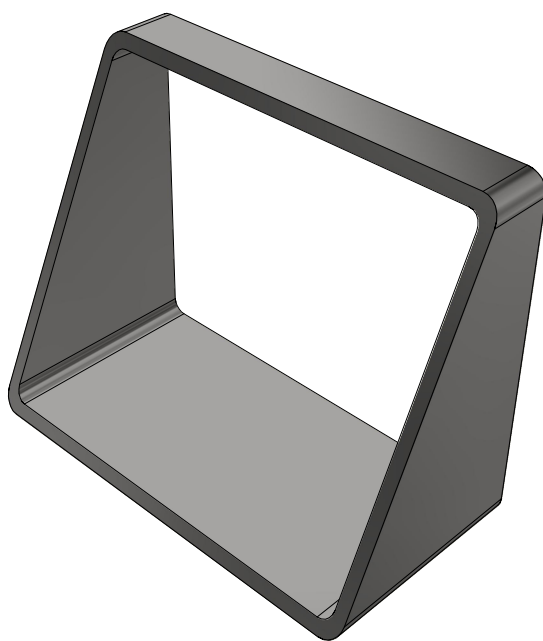
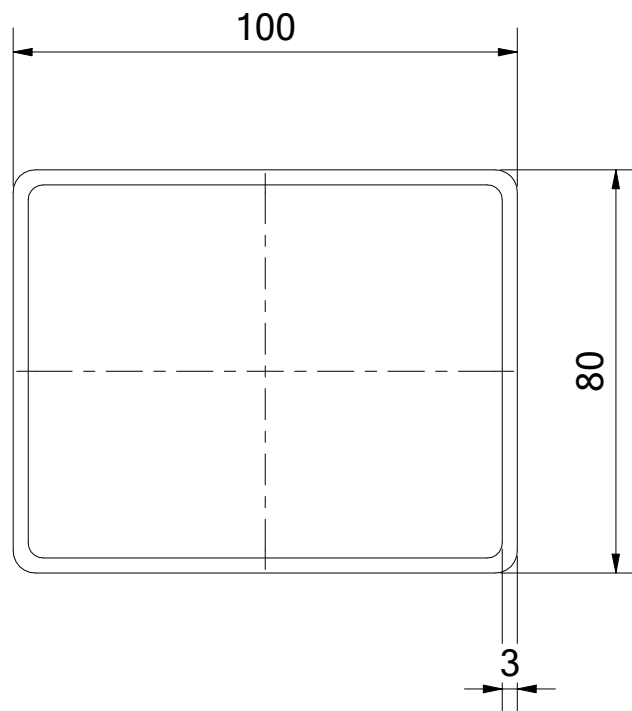
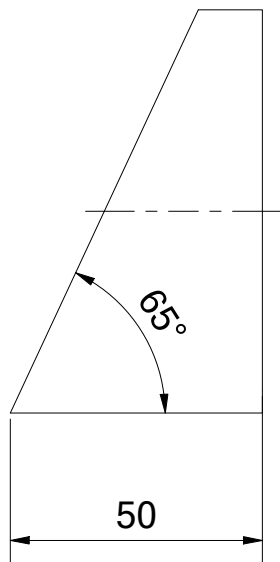
Grummels	First-angle Projection: 		DIN ISO 2768-mK DIN ISO 1101	Mass: 0,444 kg	Material: S235(JRH) 1.0039
				Stock Number: Square tube 30x30x3 EN 10219	
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Support leg	
	Drawn	4-1-2021	Sander Grummels		
	Checked				
	Standard				
Document-type: Mono-Drawing	Remark-comment:		Revision: 0	Drawing Number: SGP2-P8	1
				Scale: 1 : 1.5	Units: MM A4



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>3,327 kg</div>	<div>Material:</div> <div>S235(JRH) 1.0039</div>
					<div>Stock Number:</div> <div>UNP 50x25 DIN1026-1</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Tertiary air supply channel</div>		
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P9</div>	<div>1</div> <div>A4</div>	
				<div>Scale: 1 : 2.5</div>	<div>Units: MM</div>	



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>	<div>Mass:</div> <div>0,022 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
				<div>Stock Number:</div> <div>Sheet 3mm</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Cap tertiary air</div>	
	<div>Drawn</div>	<div>17-1-2021</div>	<div>Sander Grummels</div>		
	<div>Checked</div>				
	<div>Standard</div>				
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P10</div>	<div>1</div> <div>A4</div>
				<div>Scale: 1 : 1</div>	<div>Units: MM</div>



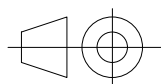
Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

Document-type:

Mono-Drawing

First-angle Projection:



DIN ISO 2768-mK
DIN ISO 1101

Mass: 0,255 kg

Material: S235(JRH) 1.0039

Stock Number:

Rectangular tube 100x40x3 EN 10219

	Date	Name
Drawn	4-1-2021	Sander Grummels
Checked		
Standard		

Title:

Inlet tube primary

Remark-comment:

Revision:

0

Drawing Number:

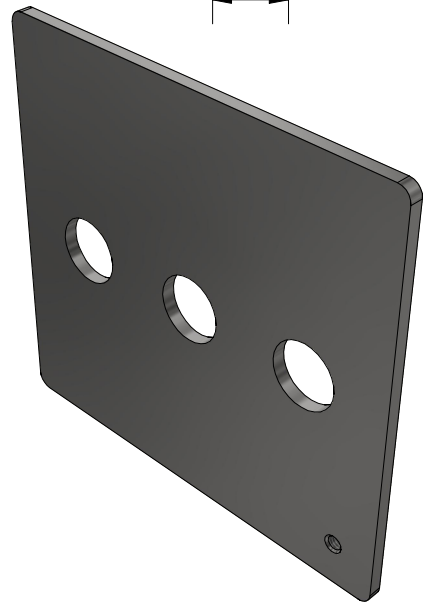
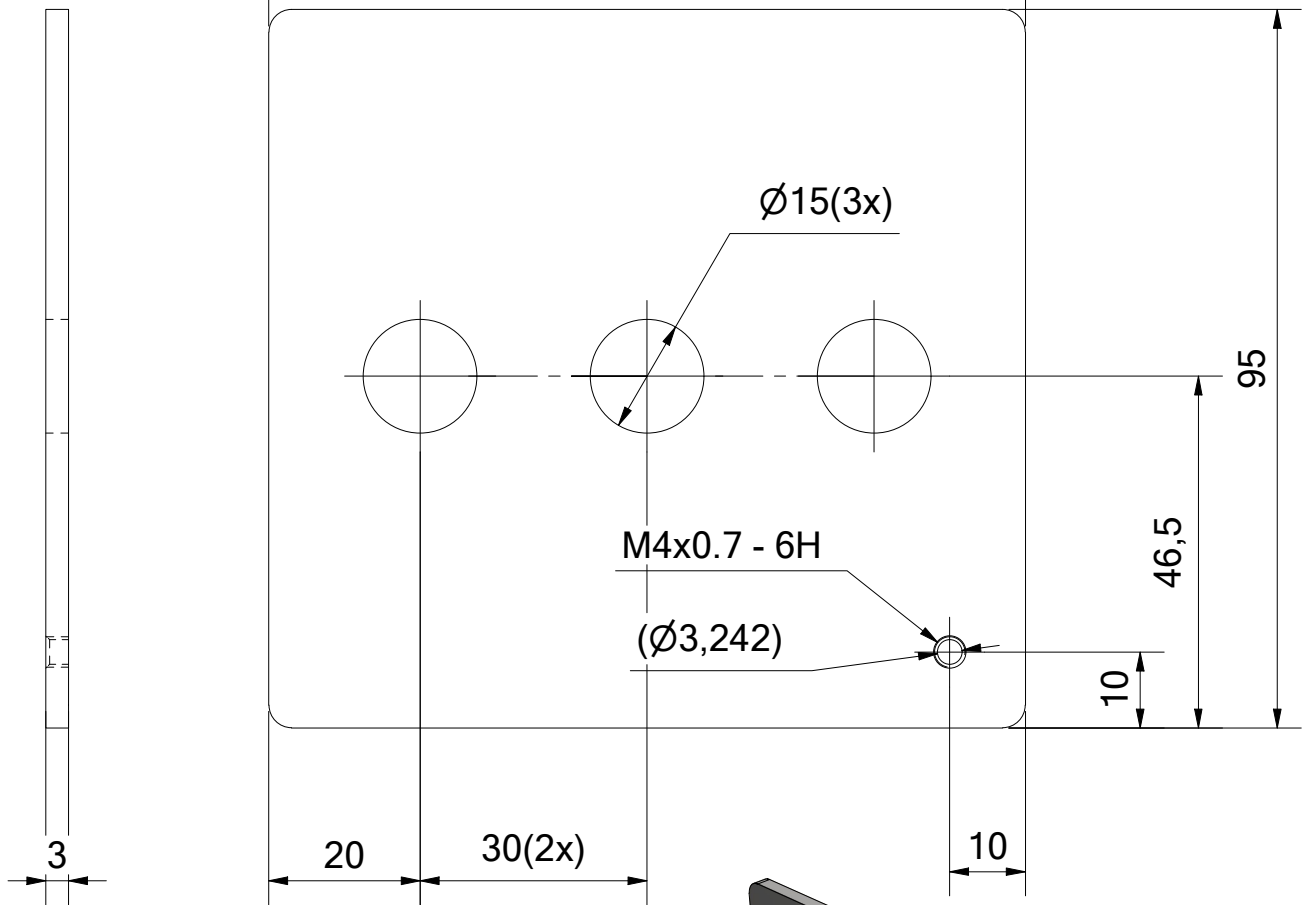
SGP2-P11

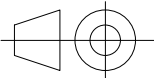
1

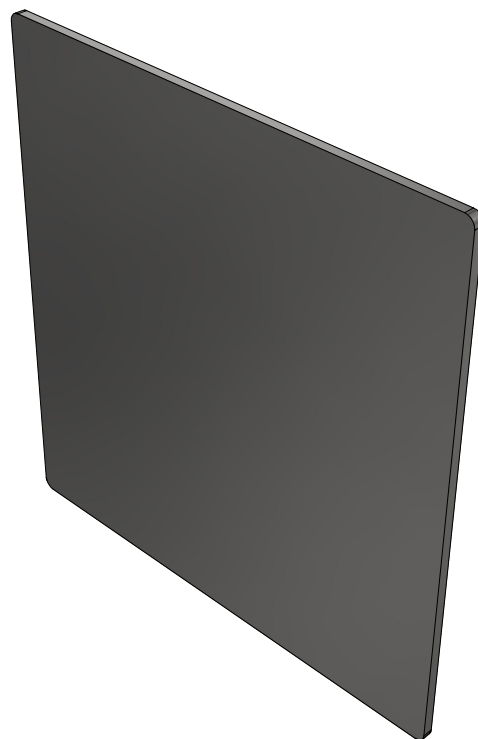
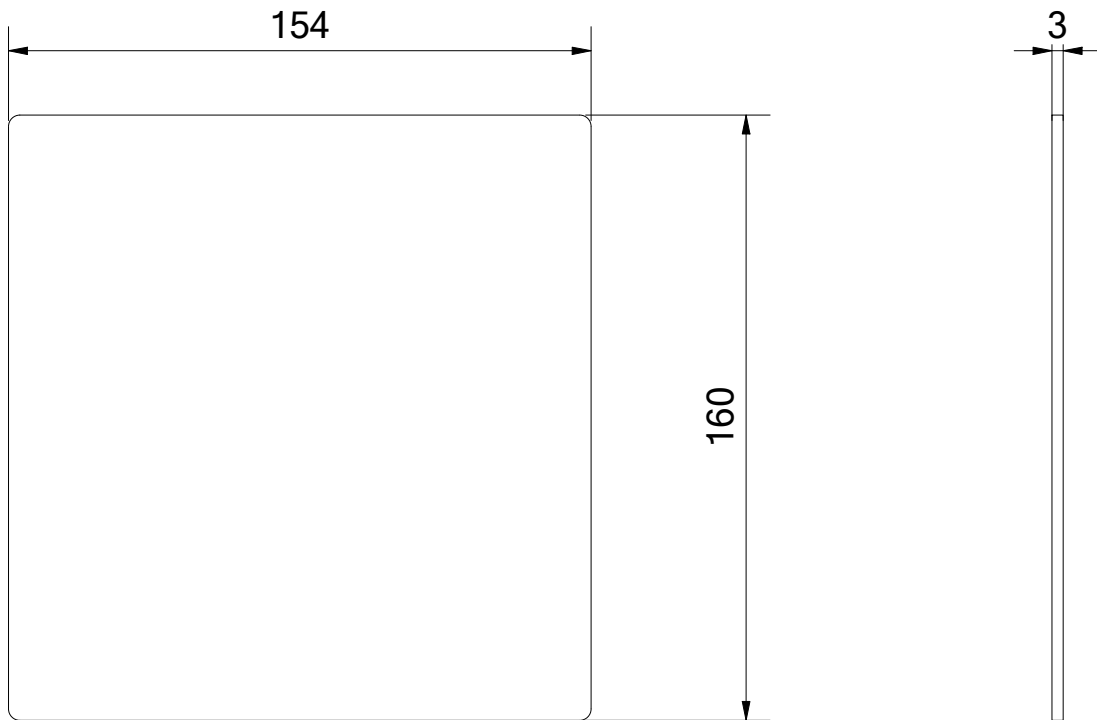
A4

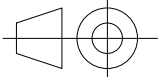
Scale: 1 : 1.5

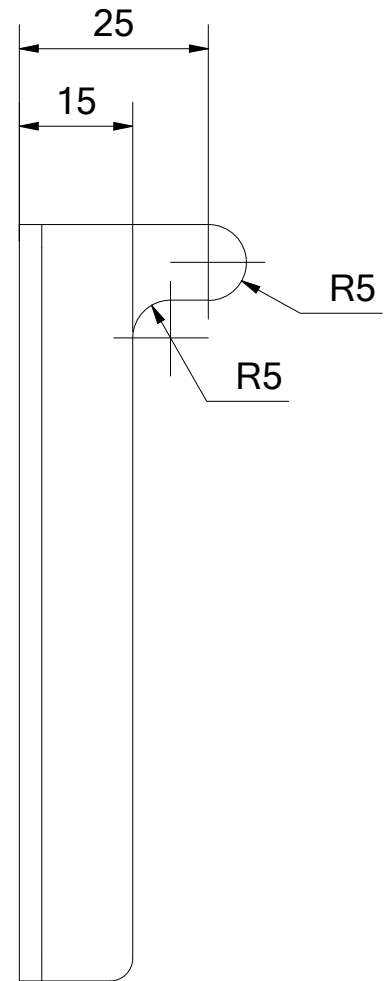
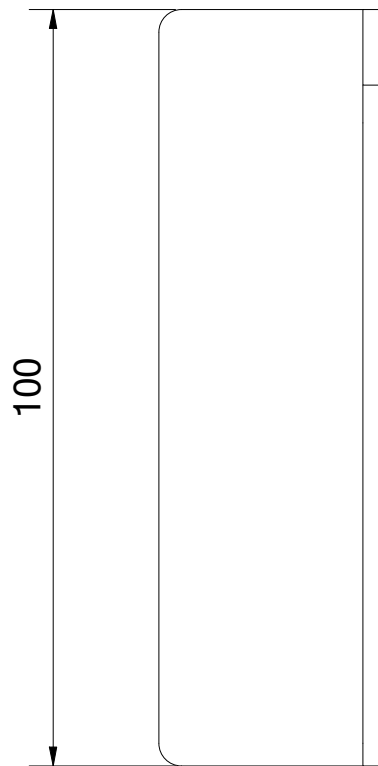
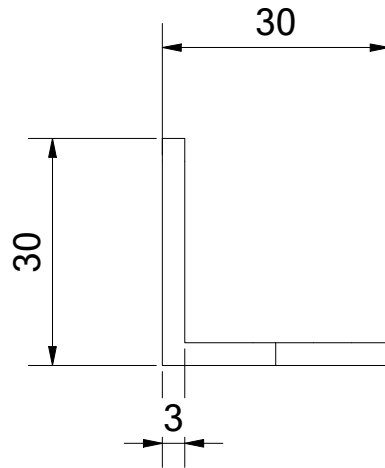
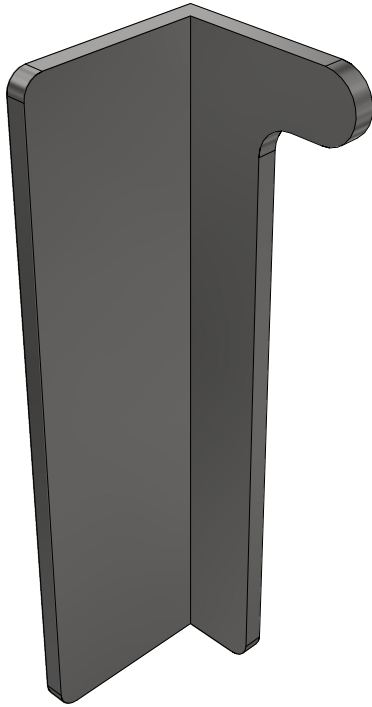
Units: MM



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,211 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
					<div>Stock Number:</div> <div>Sheet 3mm</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Lid primary air</div>		
	<div>Drawn</div>	<div>17-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P12</div>		<div>1</div>
						<div>A4</div>
				<div>Scale: 1 : 1</div>		<div>Units: MM</div>



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div> <div>DIN ISO 2768-mK DIN ISO 1101</div>		Mass:	0,580 kg	Material:	S235(JR) 1.0038	
			Stock Number:				Sheet 3mm
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Lid wood stock			
	Drawn	4-1-2021	Sander Grummels				
	Checked						
	Standard						
Document-type:	Remark-comment:		Revision:	Drawing Number:			1
Mono-Sheetmetal-Drawing			0	SGP2-P13			A4
				Scale: 1 : 2		Units: MM	



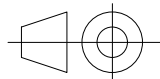
Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

Document-type:

Mono-Drawing

First-angle Projection:



DIN ISO 2768-mK
DIN ISO 1101

Mass: 0,102 kg

Material: S235(JR) 1.0038

Stock Number:

Angle 30x30x3 EN 10025

	Date	Name
Drawn	4-1-2021	Sander Grummels
Checked		
Standard		

Title:

Valve slider

Remark-comment:

Revision:

0

Drawing Number:

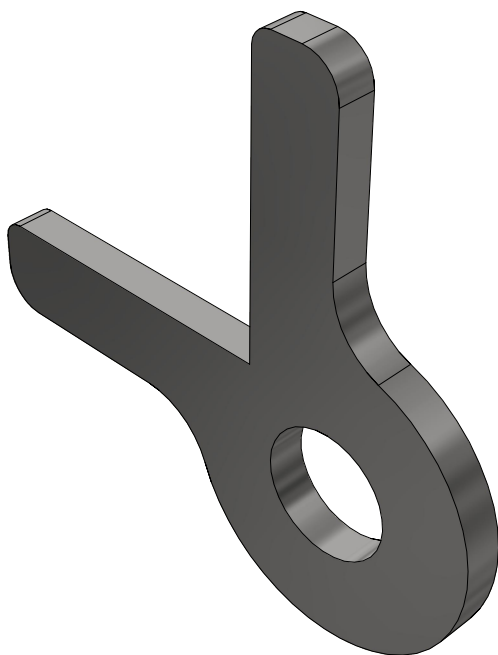
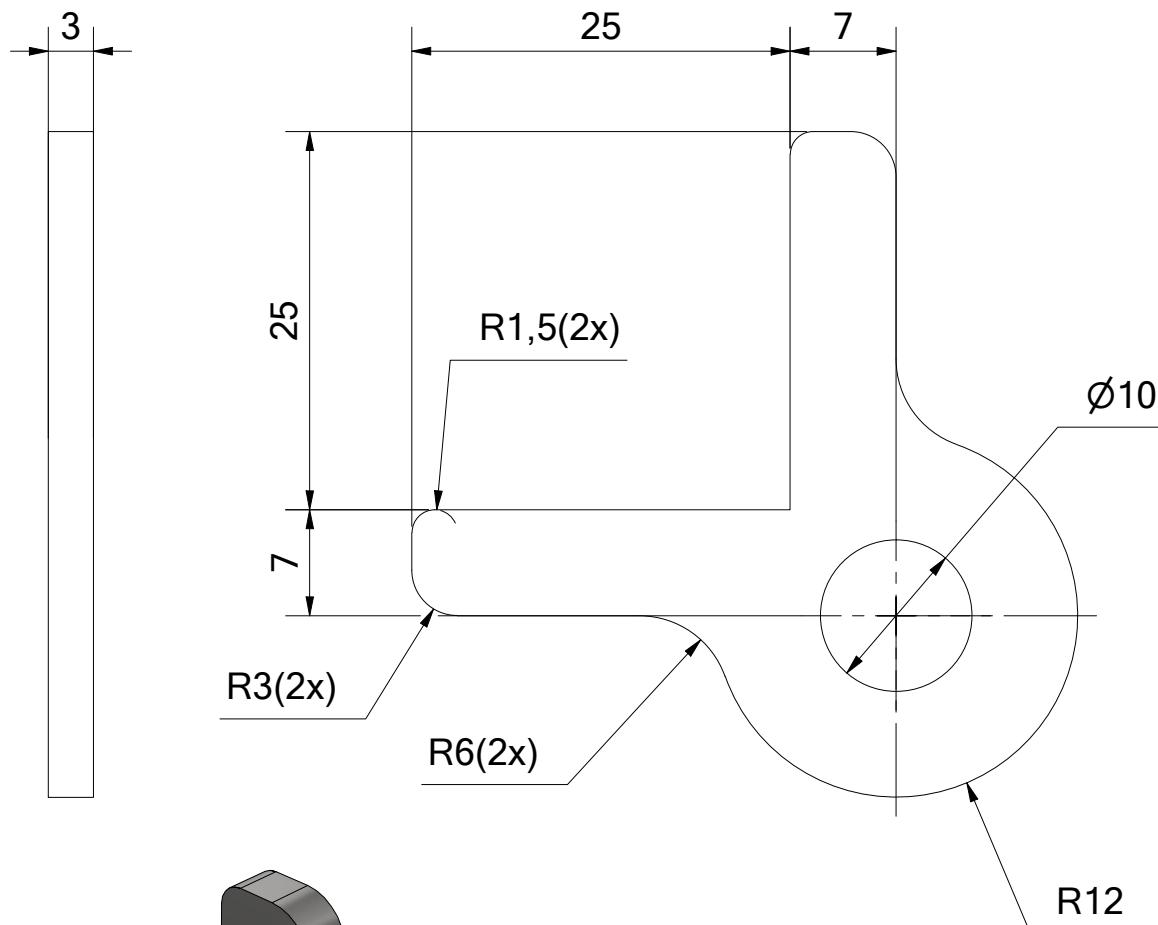
SGP2-P14

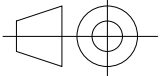
1

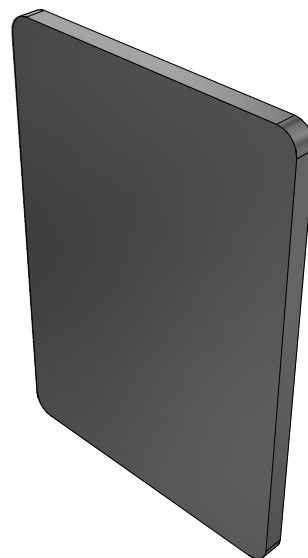
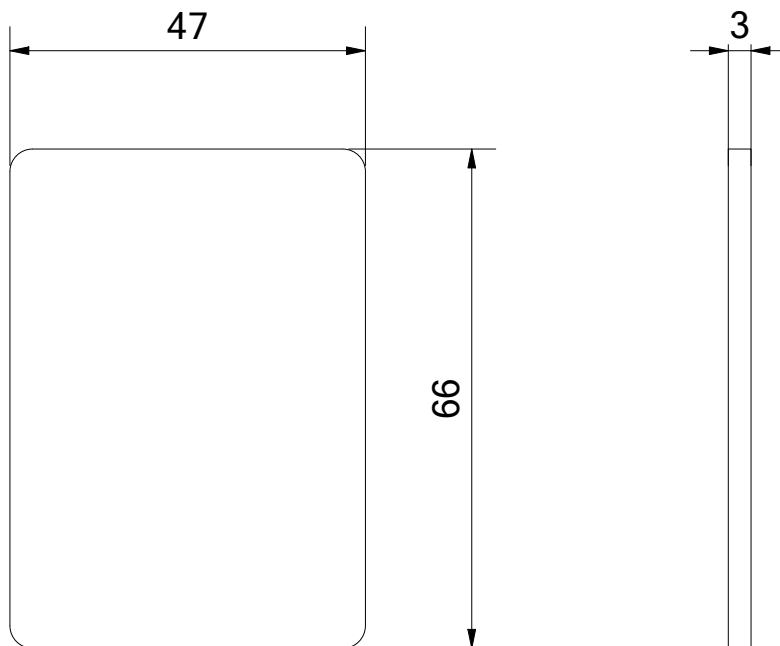
A4

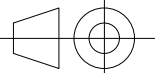
Scale: 1 : 1

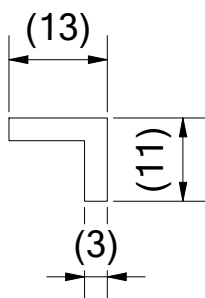
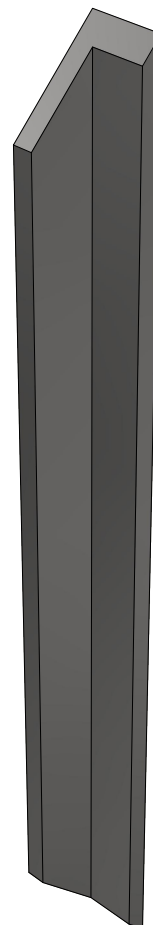
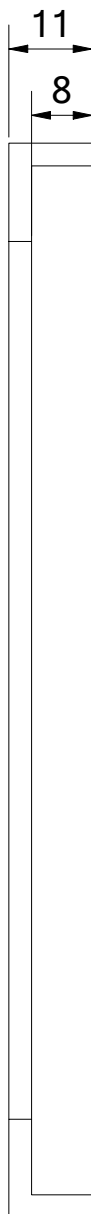
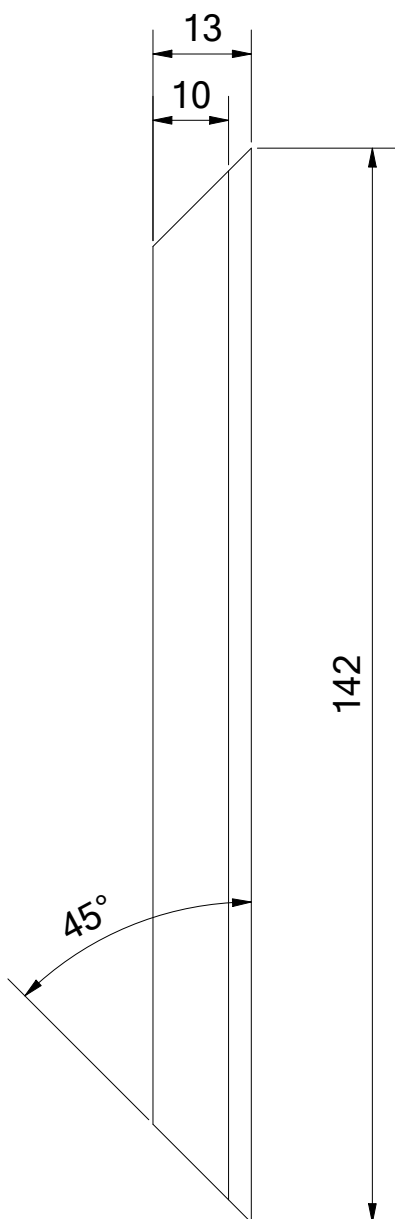
Units: MM

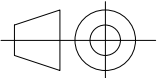


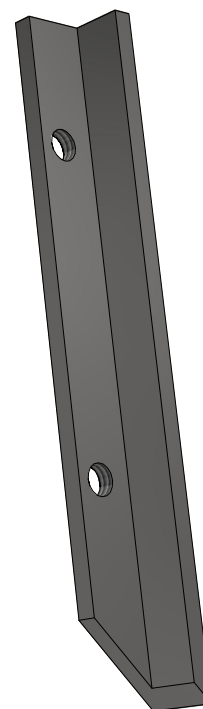
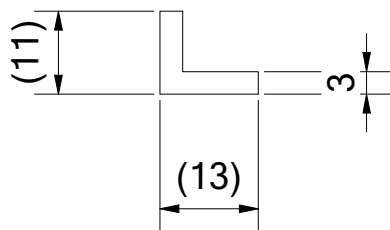
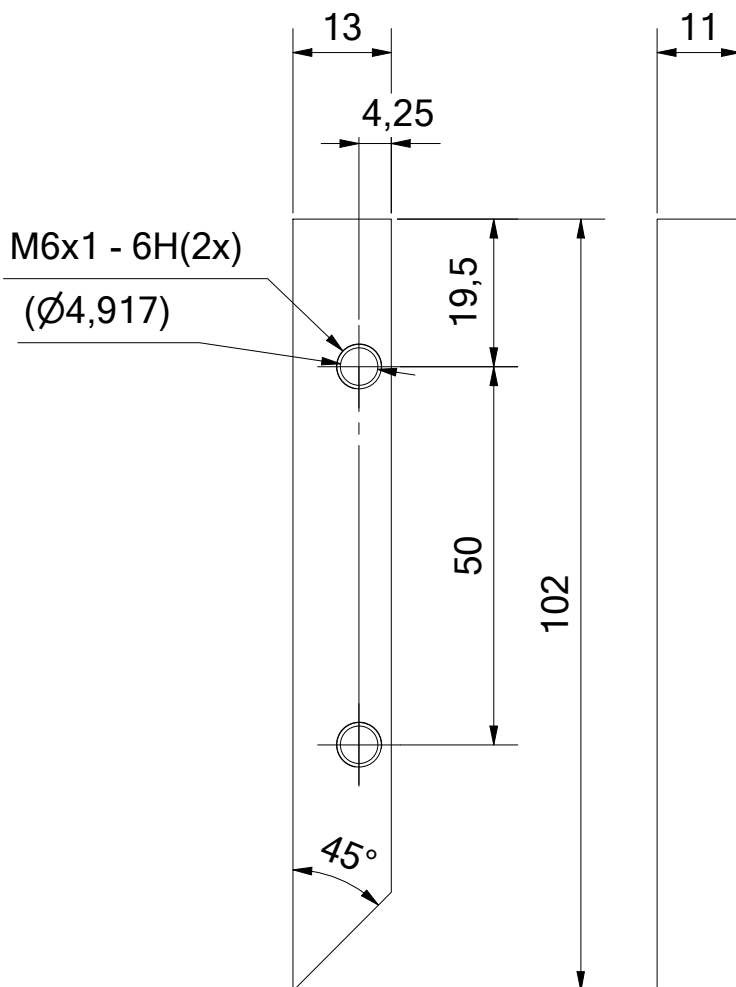
Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands	First-angle Projection: 		DIN ISO 2768-mK DIN ISO 1101	Mass: 0,016 kg Stock Number:	Material: S235(JR) 1.0038 Connection tertiary air slide
	Drawn: 4-1-2021 Checked: Standard:	Date: 4-1-2021 Name: Sander Grummels	Title: Sheet 3mm	Drawing Number: SGP2-P15	1 A4
Document-type: Mono-Sheetmetal-Drawing	Remark-comment:	Revision: 0	Scale: 2 : 1	Units: MM	

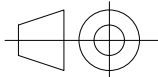


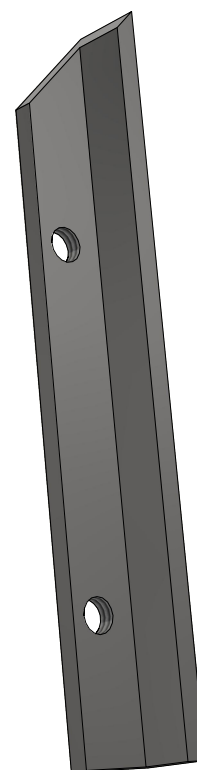
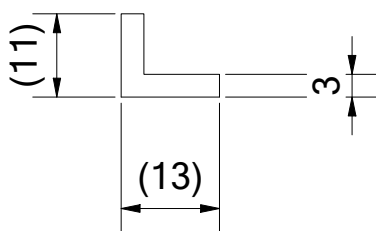
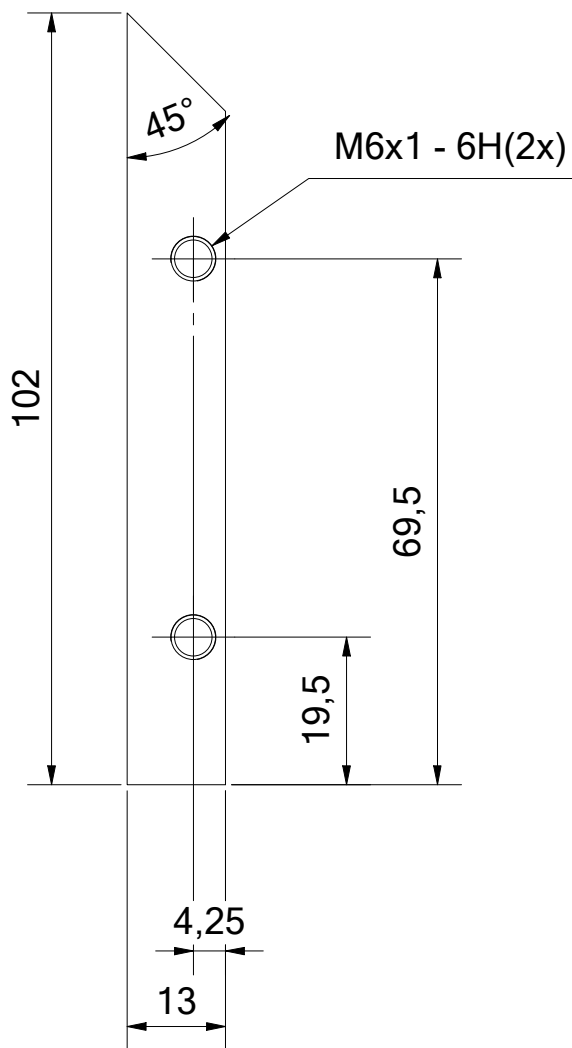
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,073 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>		
					<div>Stock Number:</div> <div>Sheet 3mm</div>				
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Closing plate tertiary air channel</div>				
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>						
	<div>Checked</div>								
	<div>Standard</div>								
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>		<div>Drawing Number:</div> <div>SGP2-P16</div>				<div>1</div>
									<div>A4</div>
				<div>Scale: 1 : 1</div>				<div>Units: MM</div>	

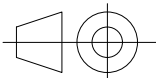


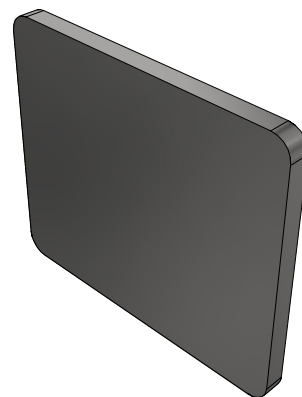
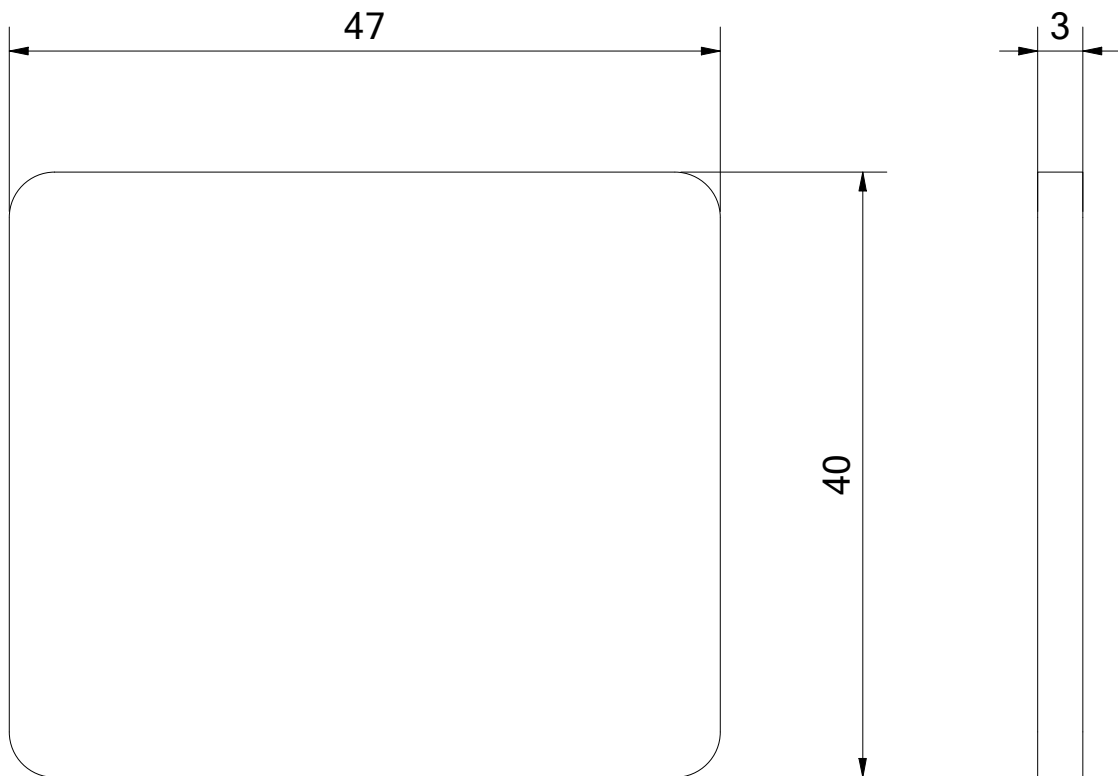
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,066 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>		
					<div>Stock Number:</div> <div>Angle 30x30x3 EN 10025</div>				
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Window holder horizontal</div>				
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>						
	<div>Checked</div>								
	<div>Standard</div>								
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>		<div>Drawing Number:</div> <div>SGP2-P17</div>				<div>1</div>
									<div>A4</div>
				<div>Scale: 1 : 1</div>				<div>Units: MM</div>	

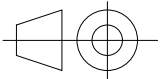


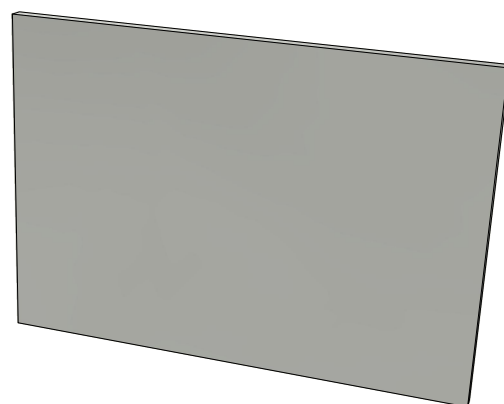
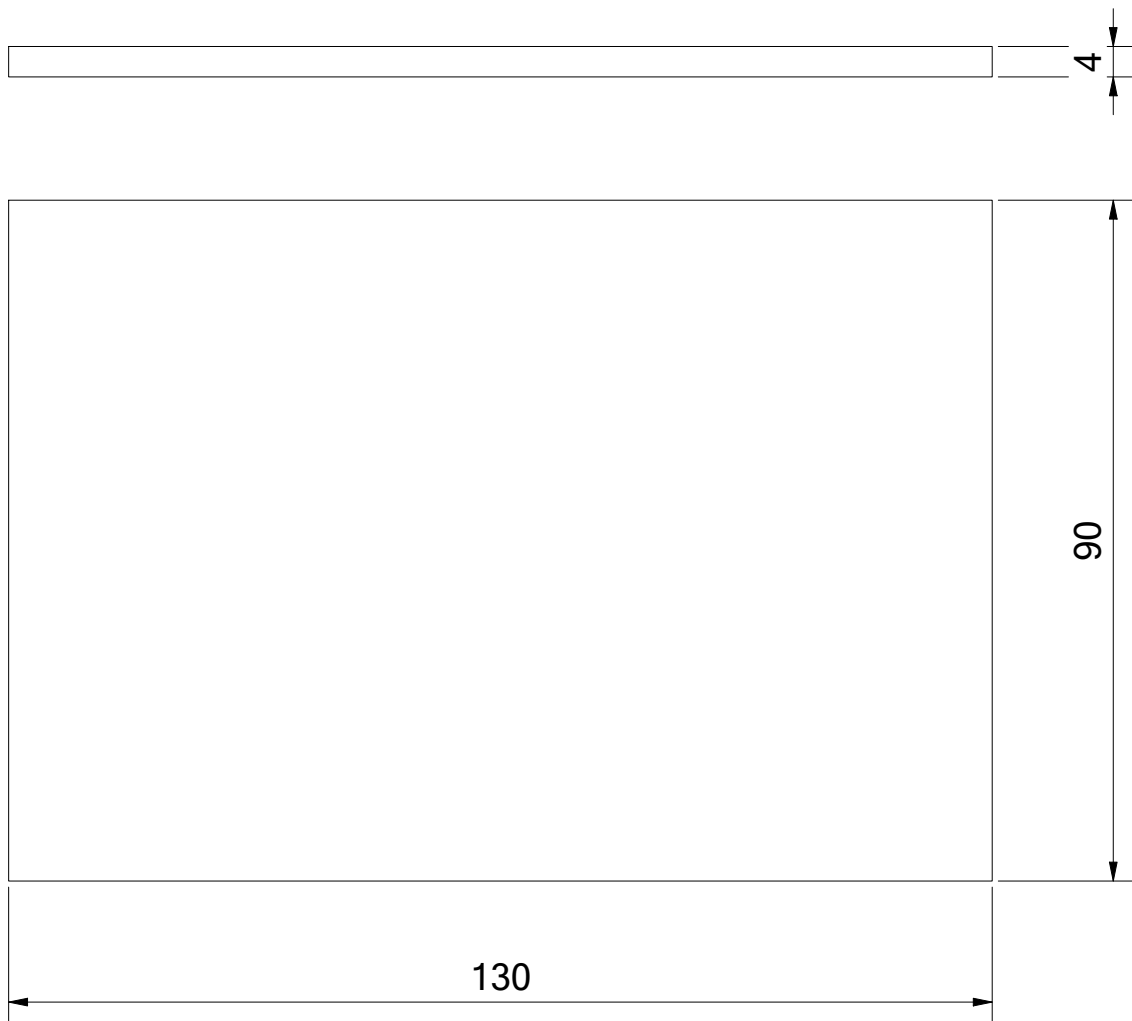
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>Mass:</div> <div>0,047 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>	
			<div>Stock Number:</div> <div>Angle 30x30x3 EN 10025</div>			
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Window holder vertical left</div>	
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P18</div>		
				<div>Scale: 1 : 1</div>		
				<div>Units: MM</div>		

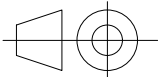


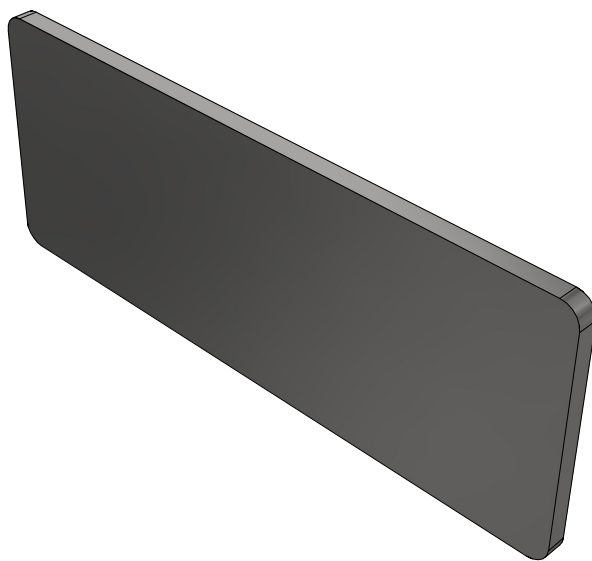
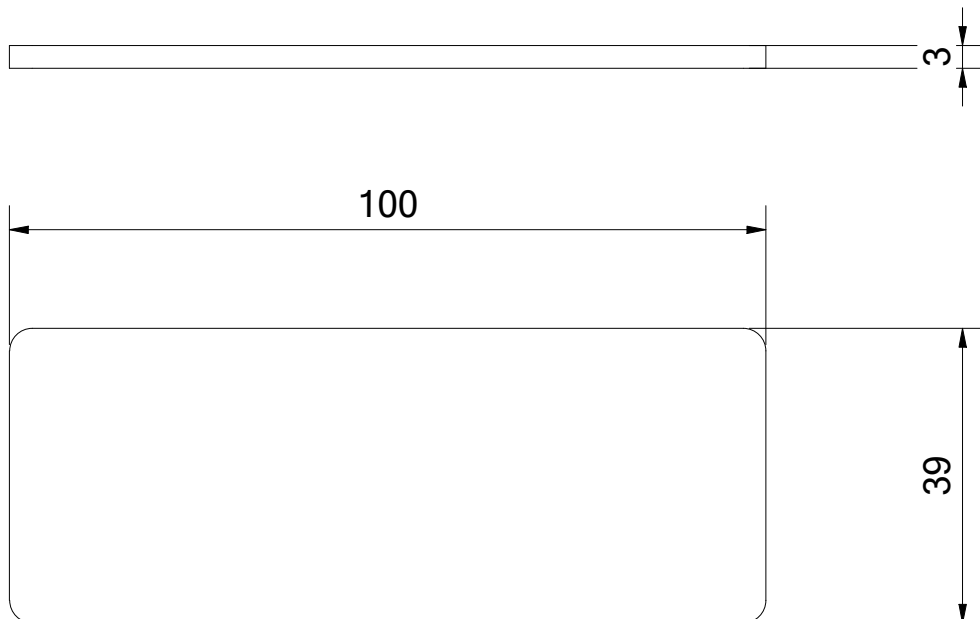
<div>Grummels</div>	<div>First-angle Projection:</div> 		<div>Mass: 0.047 kg</div> <div>Material: S235(JR) 1.0038</div>		
					<div>Stock Number: Angle 30x30x3 EN 10025</div>
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Window holder vertical right</div>	
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>		
	<div>Checked</div>				
	<div>Standard</div>				
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P19</div>	<div>1</div> <div>A4</div>
				<div>Scale: 1 : 1</div>	<div>Units: MM</div>

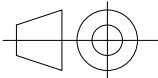


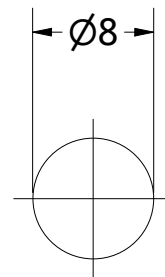
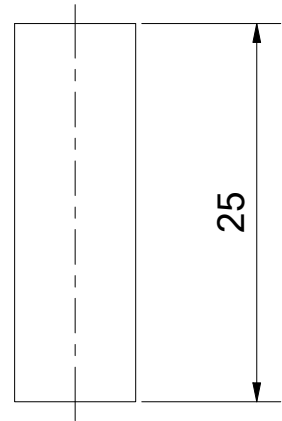
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,044 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
					<div>Stock Number:</div> <div>Sheet 3mm</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Closing plate tertiary air channel</div>		
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P20</div>		<div>1</div> <div>A4</div>
				<div>Scale: 2 : 1</div>	<div>Units: MM</div>	



<div>Grummels</div>	<div>First-angle Projection:</div> 		<div>DIN ISO 2768-mK DIN ISO 1101</div>	<div>Mass:</div> <div>0,102 kg</div>	<div>Material:</div> <div>Glass (ROBAX®)</div>
				<div>Stock Number:</div> <div>Heat resistant glass robax 4mm</div>	
<div>Mail: sander.grummels@outlook.com Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Viewing window burn tunnel</div>	
	<div>Drawn</div>	<div>4-1-2021</div>	<div>Sander Grummels</div>		
	<div>Checked</div>				
	<div>Standard</div>				
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P21</div>	<div>1</div> <div>A4</div>
				<div>Scale: 1 : 1</div>	<div>Units: MM</div>



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>	<div>Mass:</div> <div>0,092 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
				<div>Stock Number:</div> <div>Sheet 3mm</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Inlet slider secondary air</div>	
	<div>Drawn</div>	<div>5-1-2021</div>	<div>Sander Grummels</div>		
	<div>Checked</div>				
	<div>Standard</div>				
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P22</div>	<div>1</div> <div>A4</div>
				<div>Scale: 1 : 1</div>	<div>Units: MM</div>



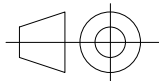
Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

Document-type:

Mono-Drawing

First-angle Projection:



DIN ISO 2768-mK
DIN ISO 1101

Mass:

0,010 kg

Material:

S235(JR) 1.0038

Stock Number:

Round bar Ø8

Date

5-1-2021

Name

Sander Grummels

Drawn

Checked

Standard

Title:

Slider pin

Remark-comment:

Revision:

0

Drawing Number:

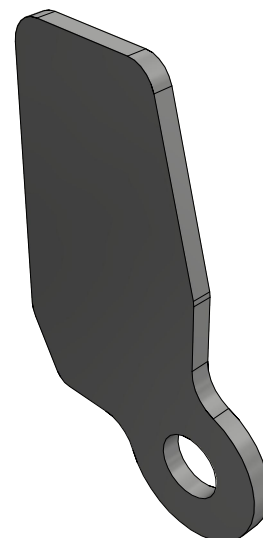
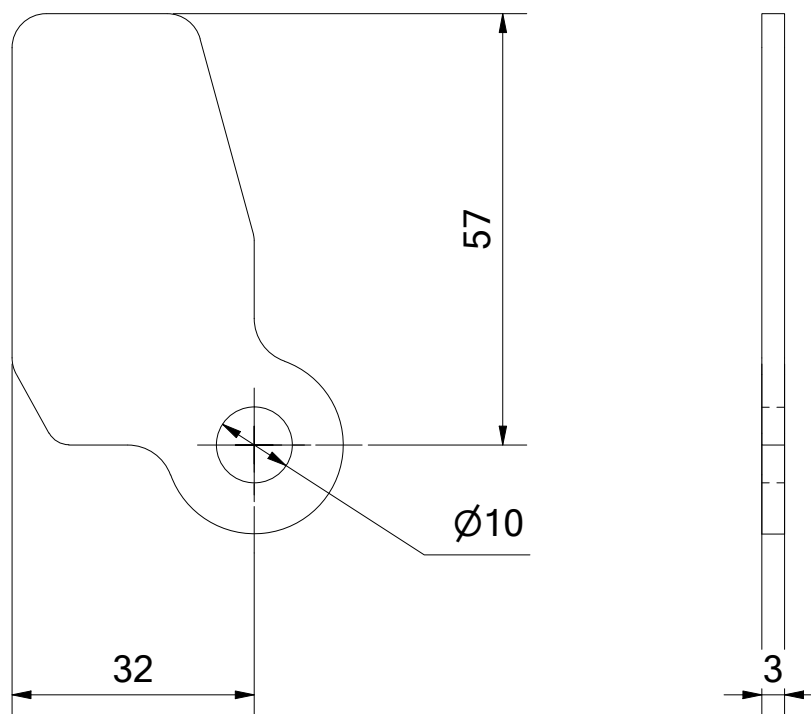
SGP2-P23

1

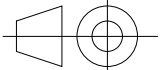
A4

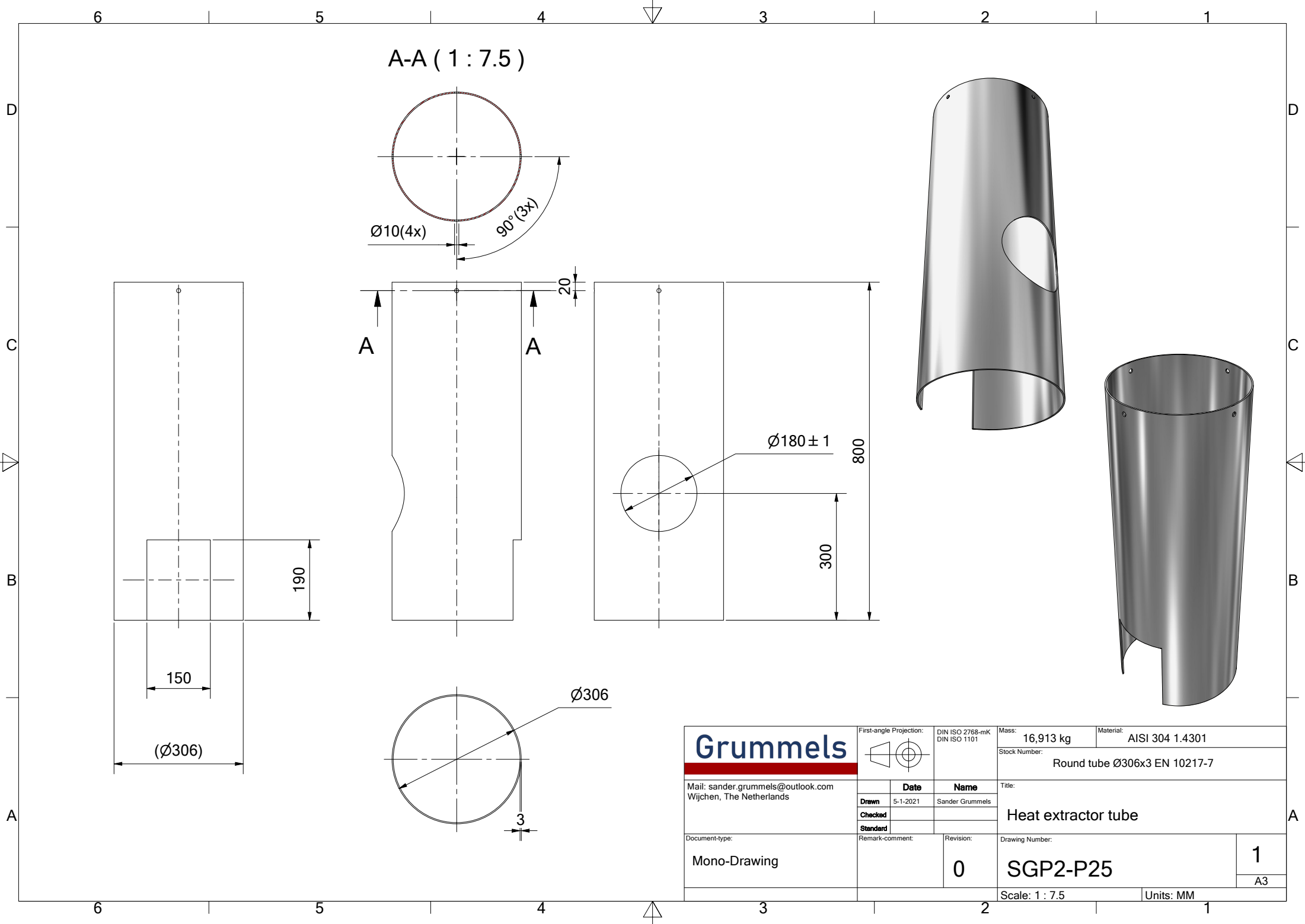
Scale: 2 : 1

Units: MM

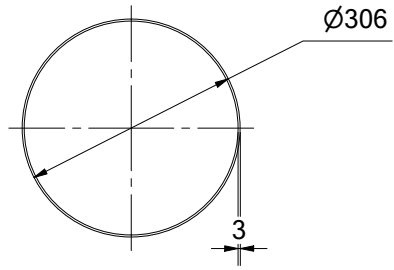
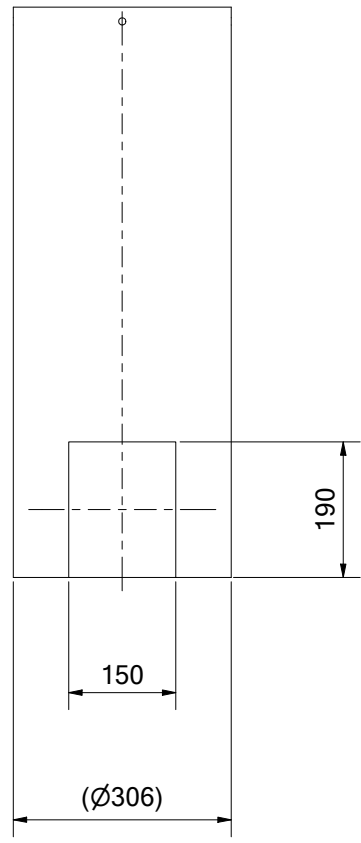
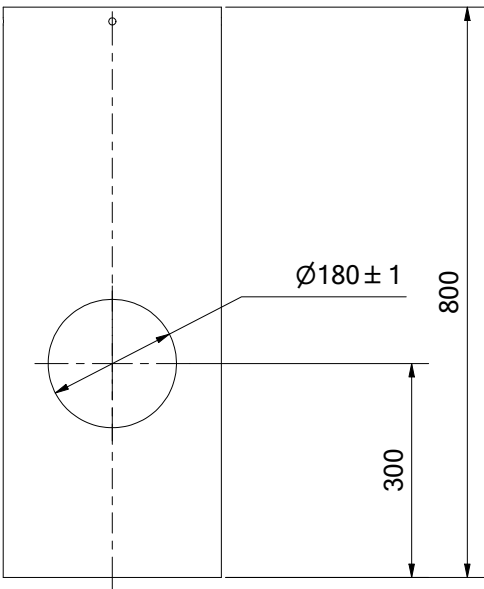
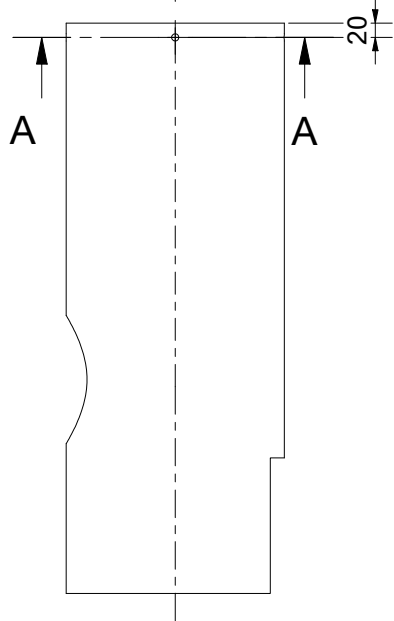
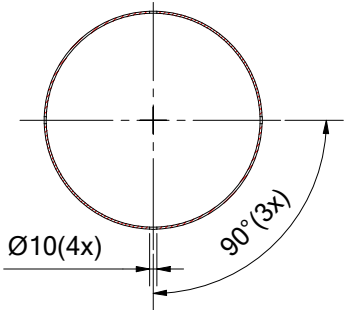


Treatment: Coat with Motip 04032 (Heat Resistant Lacquer Silver)

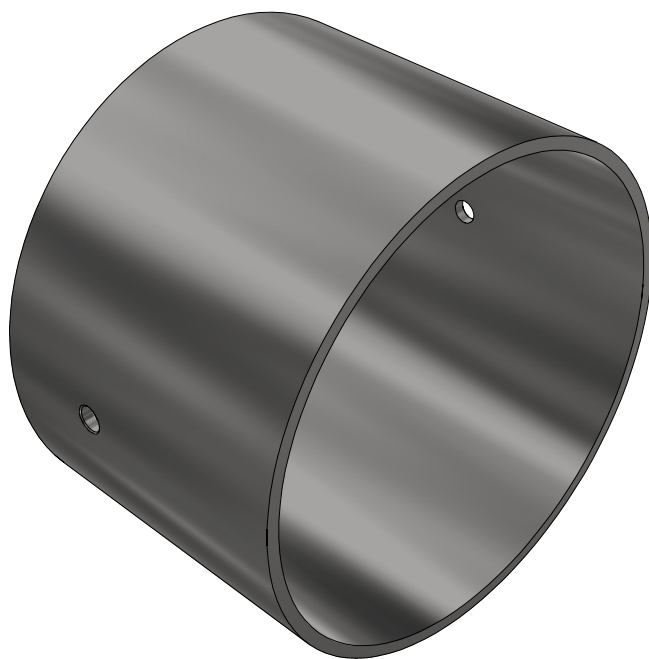
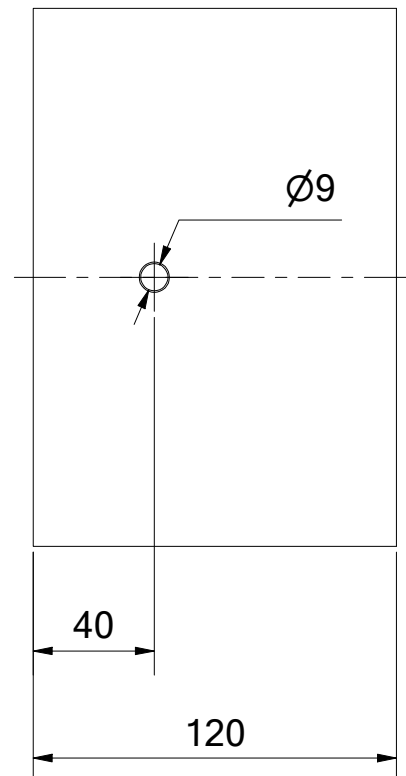
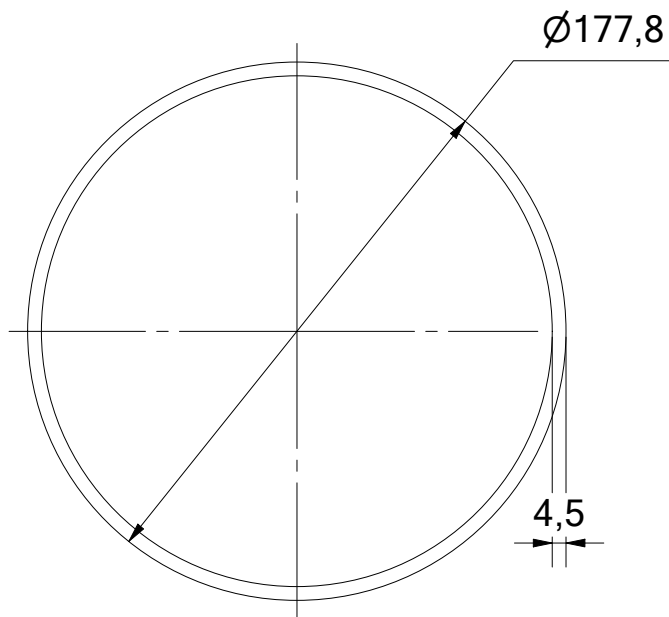
Grummels Mail: sander.grummels@outlook.com Wijchen, The Netherlands	First-angle Projection: 		DIN ISO 2768-mK DIN ISO 1101	Mass: 0,045 kg Stock Number:	Material: S235(JR) 1.0038 Sheet 3mm
	Drawn: 9-2-2021 Checked: Standard:	Date: 9-2-2021 Name: Sander Grummels	Title: Slider tertiary air	Drawing Number: SGP2-P24	1 A4
Document-type: Mono-Sheetmetal-Drawing	Remark-comment:	Revision: 0	Scale: 1 : 1	Units: MM	

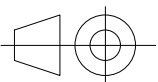


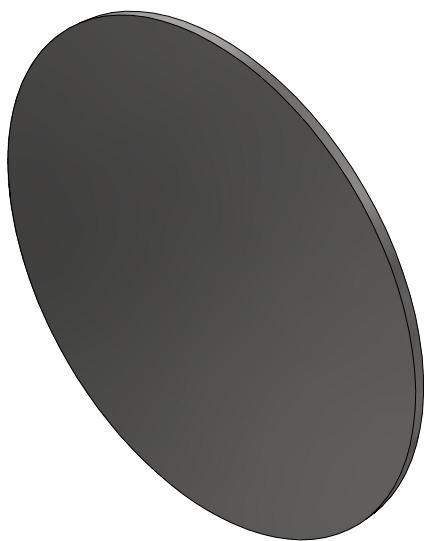
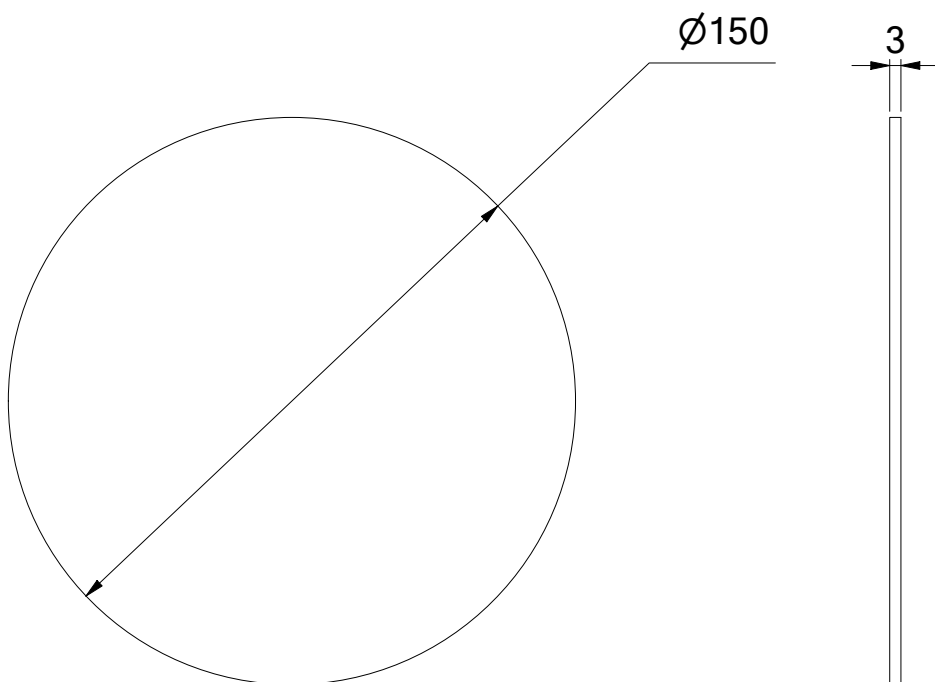
A-A (1 : 7.5)

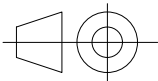


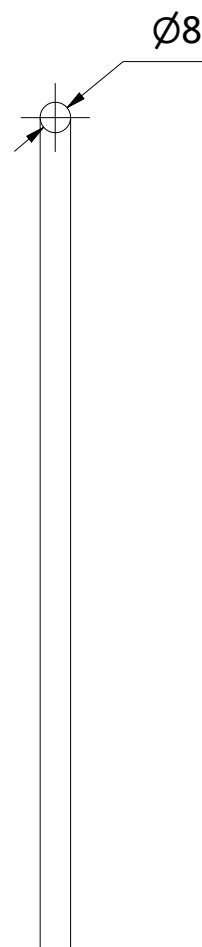
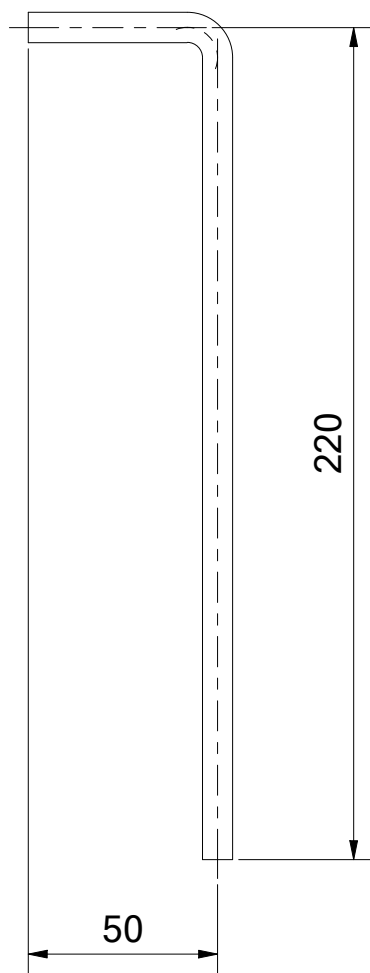
<div>Grummels</div> <div>Mail: sander.grummels@outlook.com Wijchen, The Netherlands</div>	First-angle Projection: 		DIN ISO 2768-mk DIN ISO 1101	Mass: 16,913 kg	Material: AISI 304 1.4301
	Stock Number:		Round tube Ø306x3 EN 10217-7		
	Drawn	Date	Name	Title: Heat extractor tube	
	Checked	5-1-2021	Sander Grummels		
Document-type: Mono-Drawing		Remark-comment:	Revision: 0	Drawing Number: SGP2-P25	
		Scale: 1 : 7.5		Units: MM	1 A3



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>2,303 kg</div>	<div>Material:</div> <div>S235(JRH) 1.0039</div>
					<div>Stock Number:</div> <div>Round tube Ø177,8x4 EN 10219</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Exhaust connection tube</div>	
	<div>Drawn</div>	<div>8-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P27</div>		<div>1</div> <div>A4</div>
				<div>Scale: 1 : 2.5</div>	<div>Units: MM</div>	



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>Mass:</div> <div>0,416 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>	
			<div>Stock Number:</div> <div>Sheet 3mm</div>			
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Exhaust valve</div>	
	<div>Drawn</div>	<div>8-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P28</div>		
				<div>1</div>		
				<div>A4</div>		
				<div>Scale: 1 : 2</div>		<div>Units: MM</div>



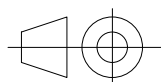
Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

Document-type:

Mono-Drawing

First-angle Projection:



DIN ISO 2768-mK
DIN ISO 1101

Mass: 0,105 kg

Material: S235(JR) 1.0038

Stock Number:

Round bar Ø8

	Date	Name
Drawn	8-1-2021	Sander Grummels
Checked		
Standard		

Title:

Handle exhaust valve

Remark-comment:

Revision:

Drawing Number:

0

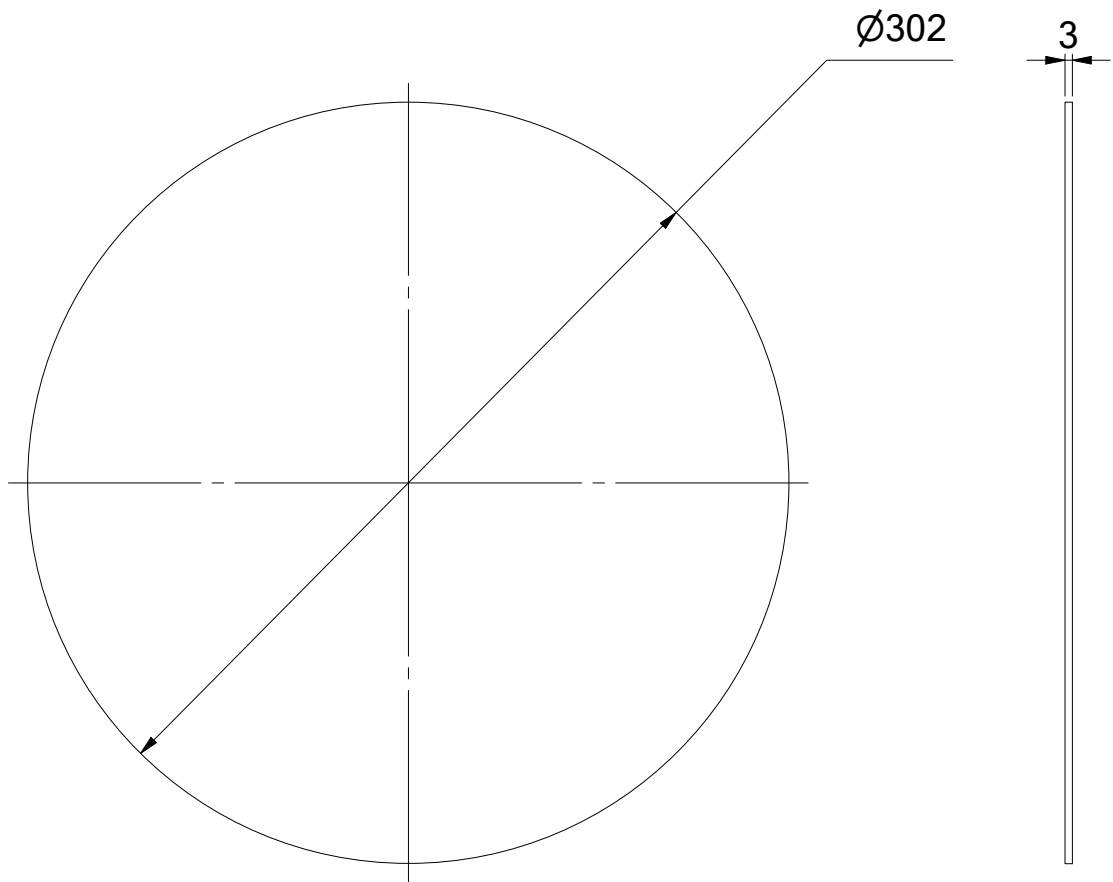
SGP2-P29

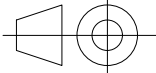
1

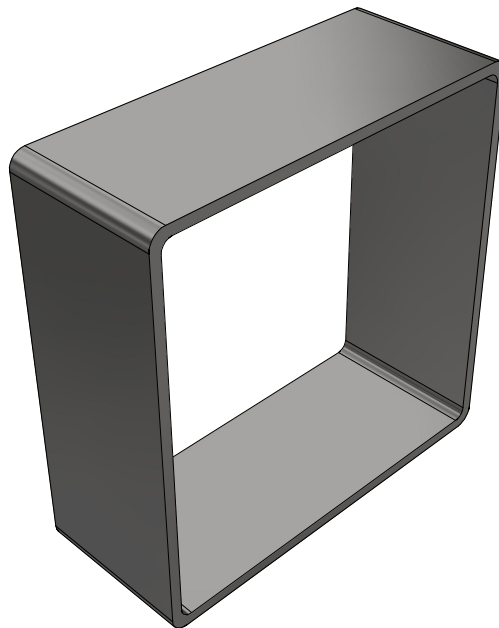
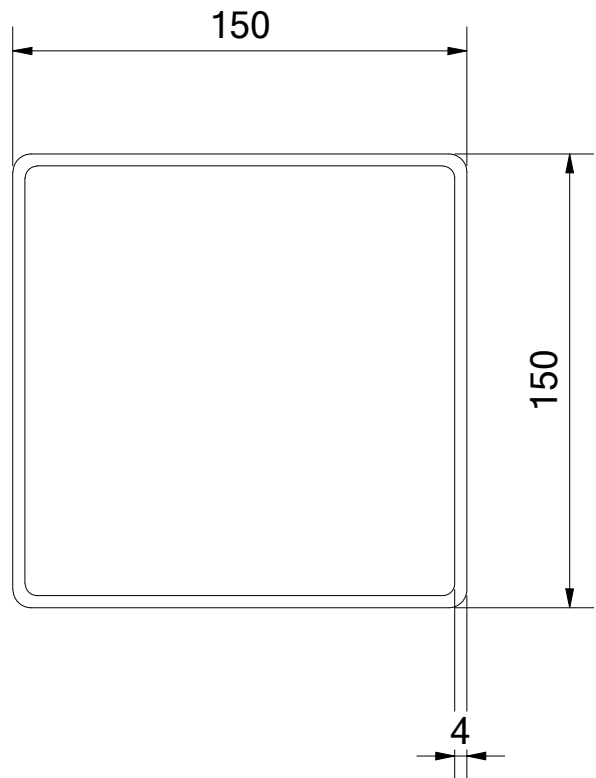
A4

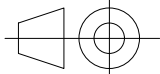
Scale: 1 : 2

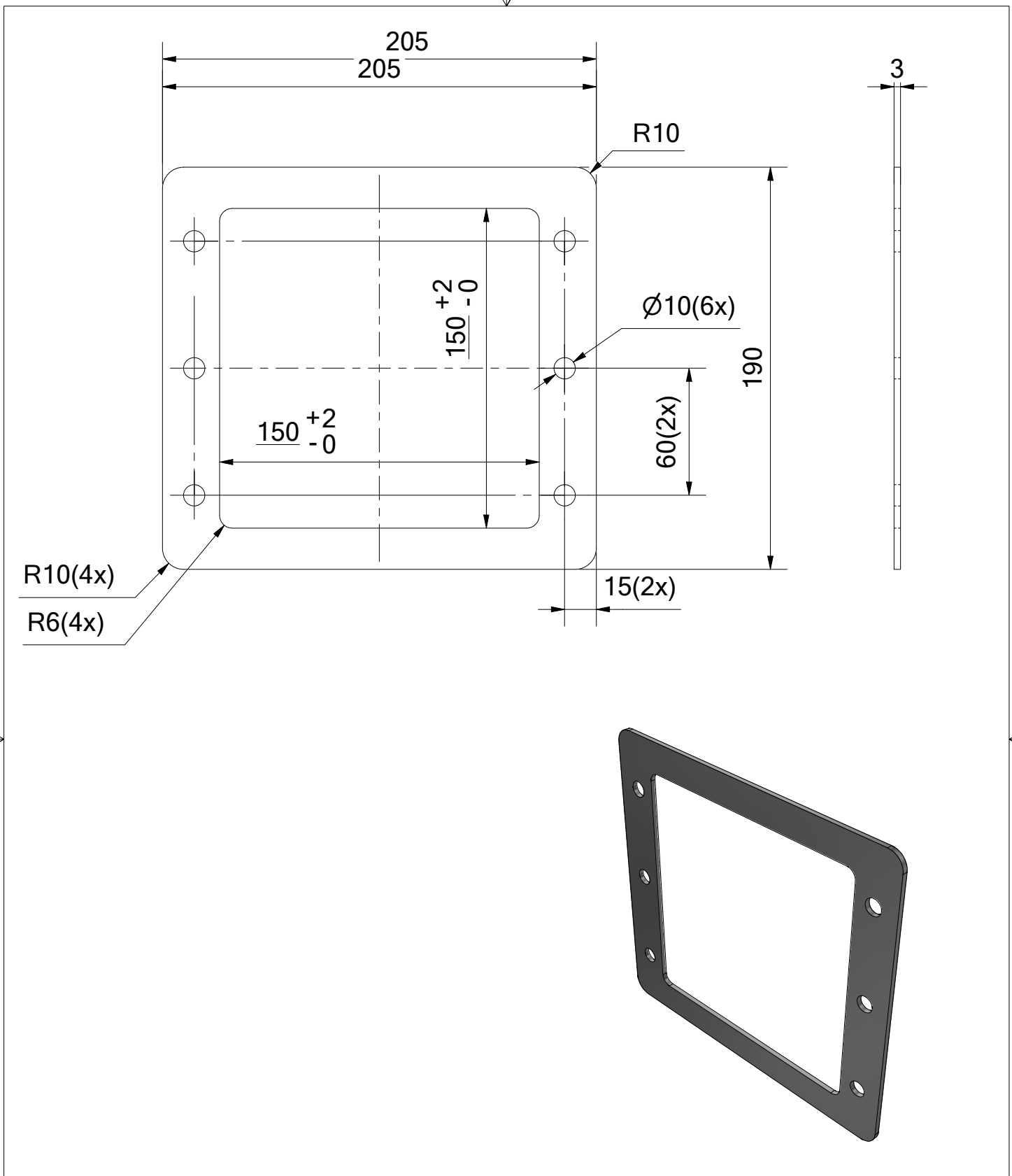
Units: MM

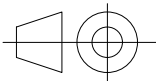


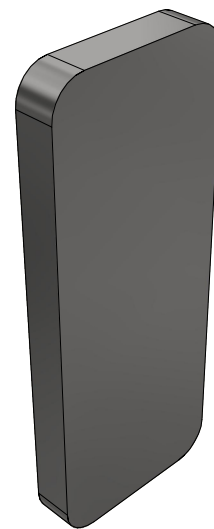
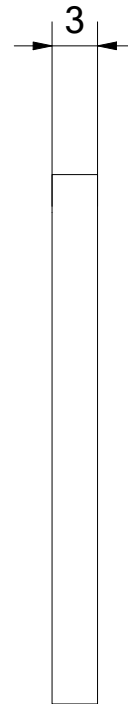
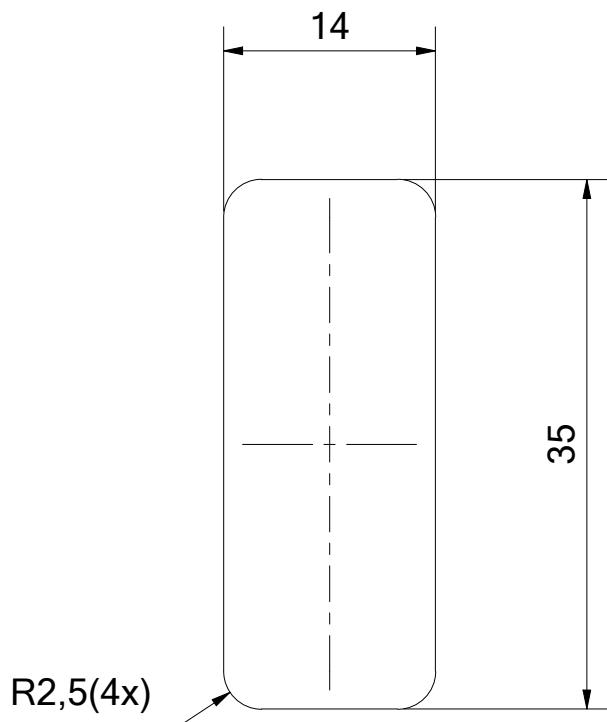
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div> <div>DIN ISO 2768-mK DIN ISO 1101</div>		<div>Mass:</div> <div>1,687 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
			<div>Stock Number:</div> <div>Sheet 3mm</div>	
<div>Mail: sander.grummels@outlook.com Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Cover plate upper heat extractor</div>
	<div>Drawn</div>	<div>8-1-2021</div>	<div>Sander Grummels</div>	
	<div>Checked</div>			
	<div>Standard</div>			
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>	<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P30</div>	<div>1</div> <div>A4</div>
			<div>Scale: 1 : 3</div>	<div>Units: MM</div>

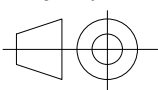


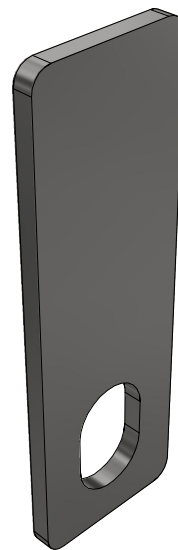
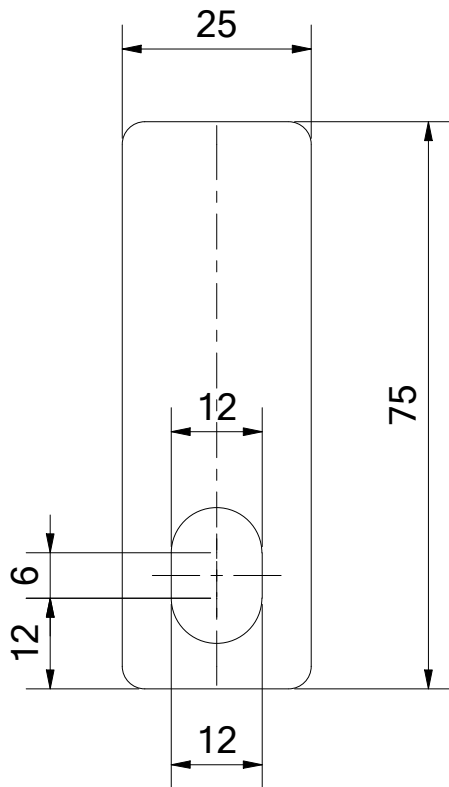
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>1,092 kg</div>	<div>Material:</div> <div>S235(JRH) 1.0039</div>
					<div>Stock Number:</div> <div>Square tube 150x150x4 EN 10219</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>View tube</div>		
	<div>Drawn</div>	<div>11-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P31</div>	<div>1</div> <div>A4</div>	
				<div>Scale: 1 : 2.5</div>	<div>Units: MM</div>	

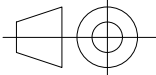


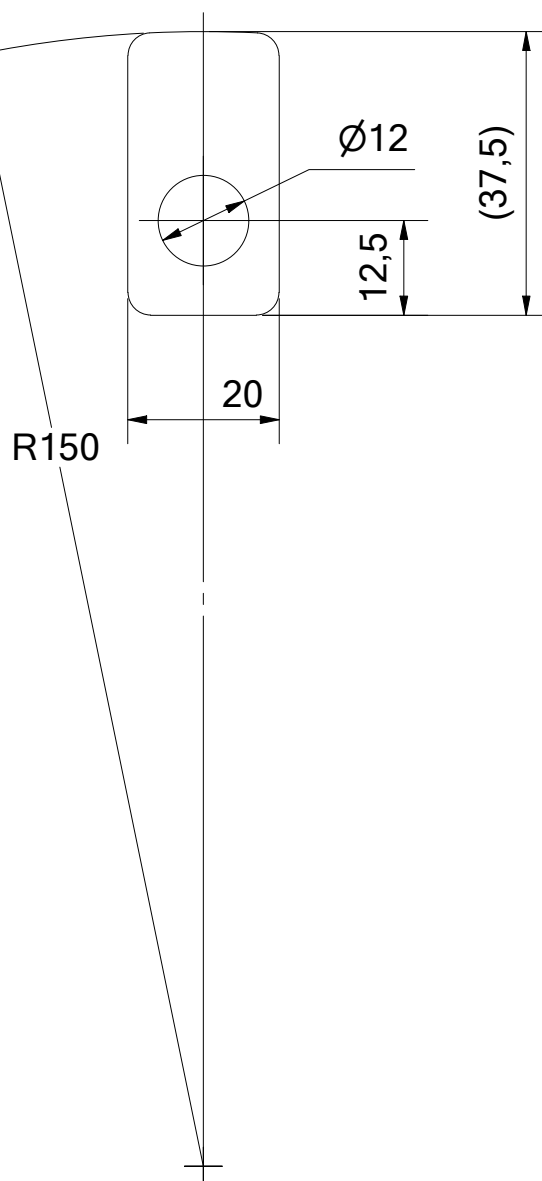
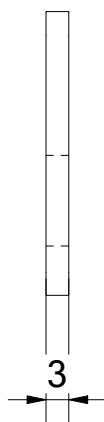
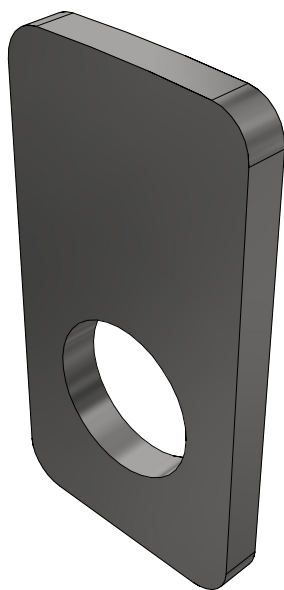
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,368 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
					<div>Stock Number:</div> <div>Sheet 3mm</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Seal plate viewing window 1</div>		
	<div>Drawn</div>	<div>12-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P32</div>	<div>1</div> <div>A4</div>	
				<div>Scale: 1 : 2.5</div>	<div>Units: MM</div>	



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div> <div>DIN ISO 2768-mK DIN ISO 1101</div>		Mass:	0,011 kg	Material:	S235(JR) 1.0038
			Stock Number:			
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Space plate 3mm		
	Drawn	12-1-2021	Sander Grummels			
	Checked					
	Standard					
Document-type:	Remark-comment:		Revision:	Drawing Number:		1
Mono-Sheetmetal-Drawing			0	SGP2-P33		A4
				Scale: 2 : 1		Units: MM



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>Mass:</div> <div>0,040 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>	
			<div>Stock Number:</div> <div>Sheet 3mm</div>			
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Connector plate upper heat extractor</div>	
	<div>Drawn</div>	<div>12-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P34</div>		<div>1</div>
						<div>A4</div>
				<div>Scale: 1 : 1</div>		<div>Units: MM</div>



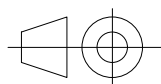
Grummels

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

Document-type:

Mono-Sheetmetal-Drawing

First-angle Projection:



DIN ISO 2768-mK
DIN ISO 1101

Mass:

0,015 kg

Material:

S235(JR) 1.0038

Stock Number:

Sheet 3mm

	Date	Name
Drawn	10-2-2021	Sander Grummels
Checked		
Standard		

Title:

Bolt attachment

Remark-comment:

Revision:

0

Drawing Number:

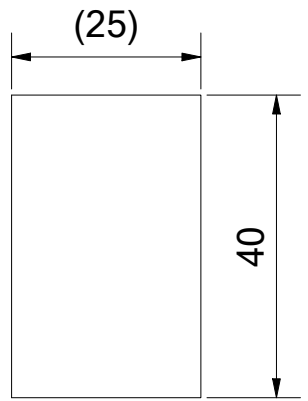
SGP2-P35

1

A4

Scale: 1 : 1

Units: MM

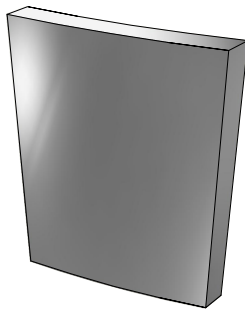


R150

50

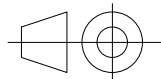
75

3



Grummels

First-angle Projection:



DIN ISO 2768-mK
DIN ISO 1101

Mass: 0,026 kg

Material: AISI 304 1.4301

Stock Number:

Round tube Ø306x3 EN 10217-7

Mail: sander.grummels@outlook.com
Wijchen, The Netherlands

	Date	Name
Drawn	17-1-2021	Sander Grummels
Checked		
Standard		

Title:

Closing plate

Document-type:

Mono-Drawing

Remark-comment:

Revision:

0

Drawing Number:

SGP2-P36

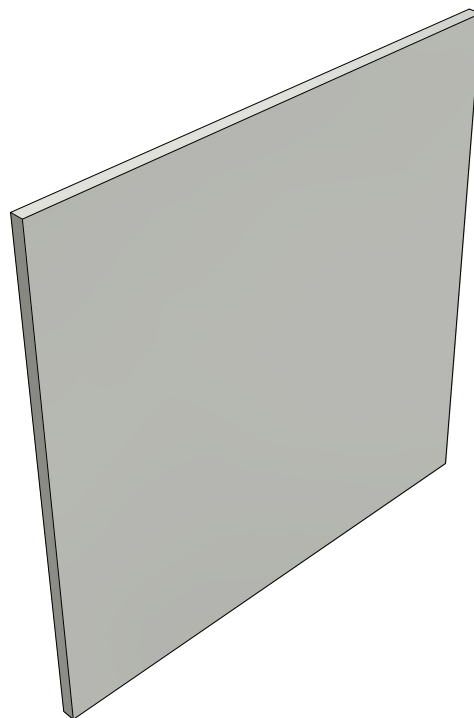
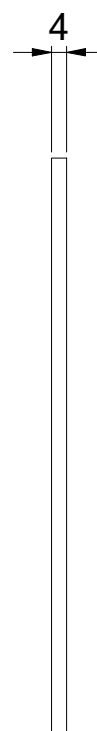
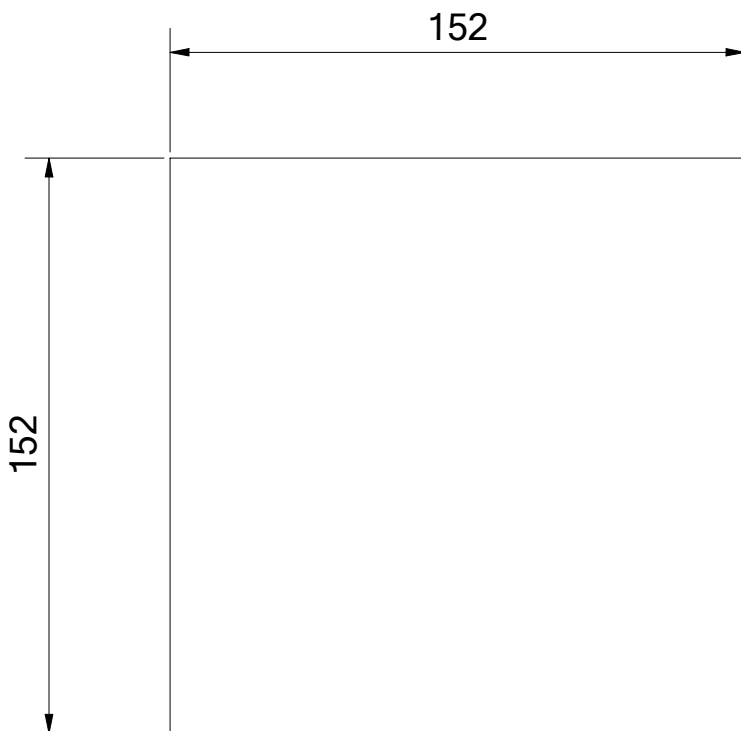
1

A4

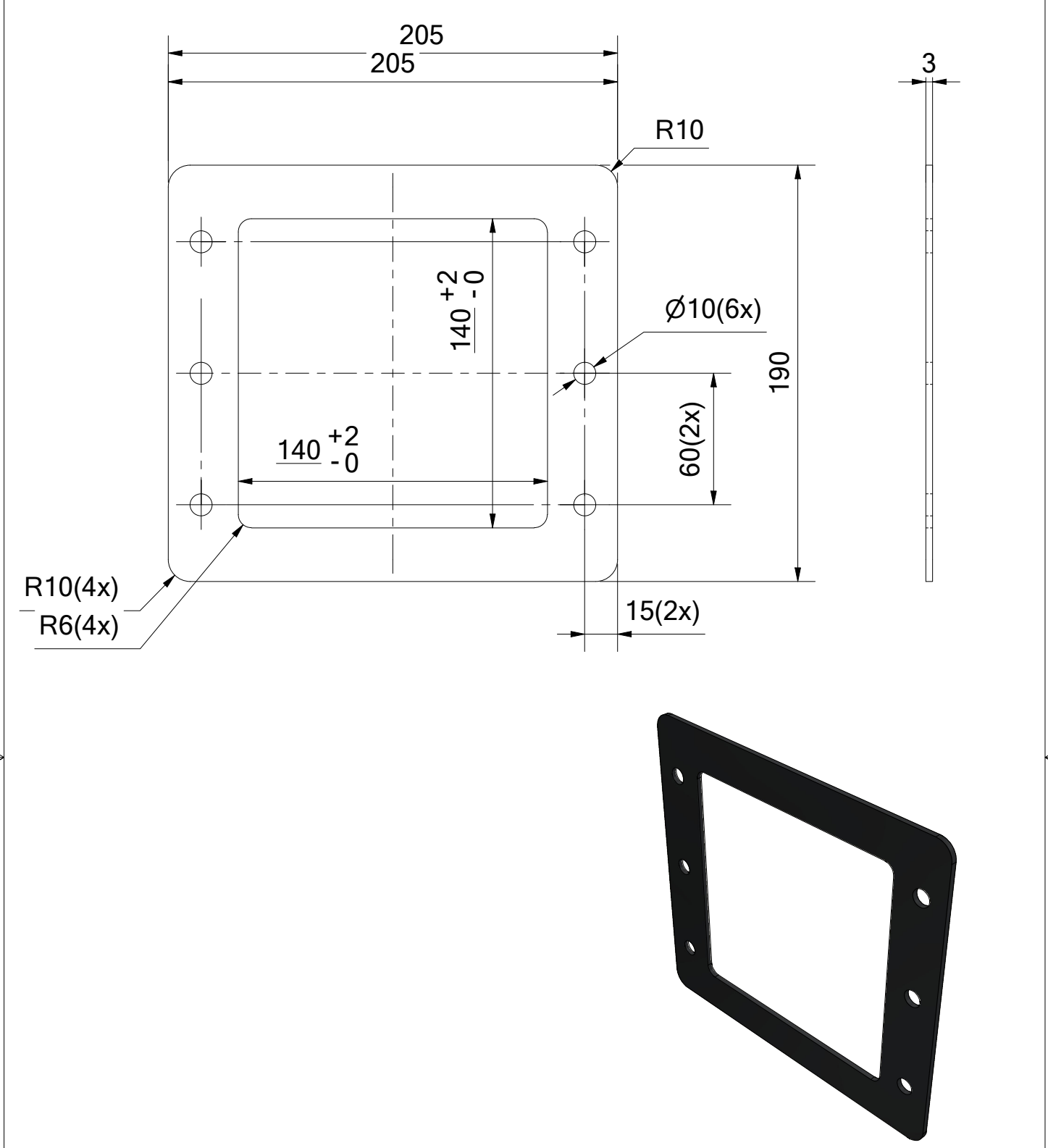
Scale: 1 : 1

Units: MM

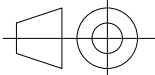




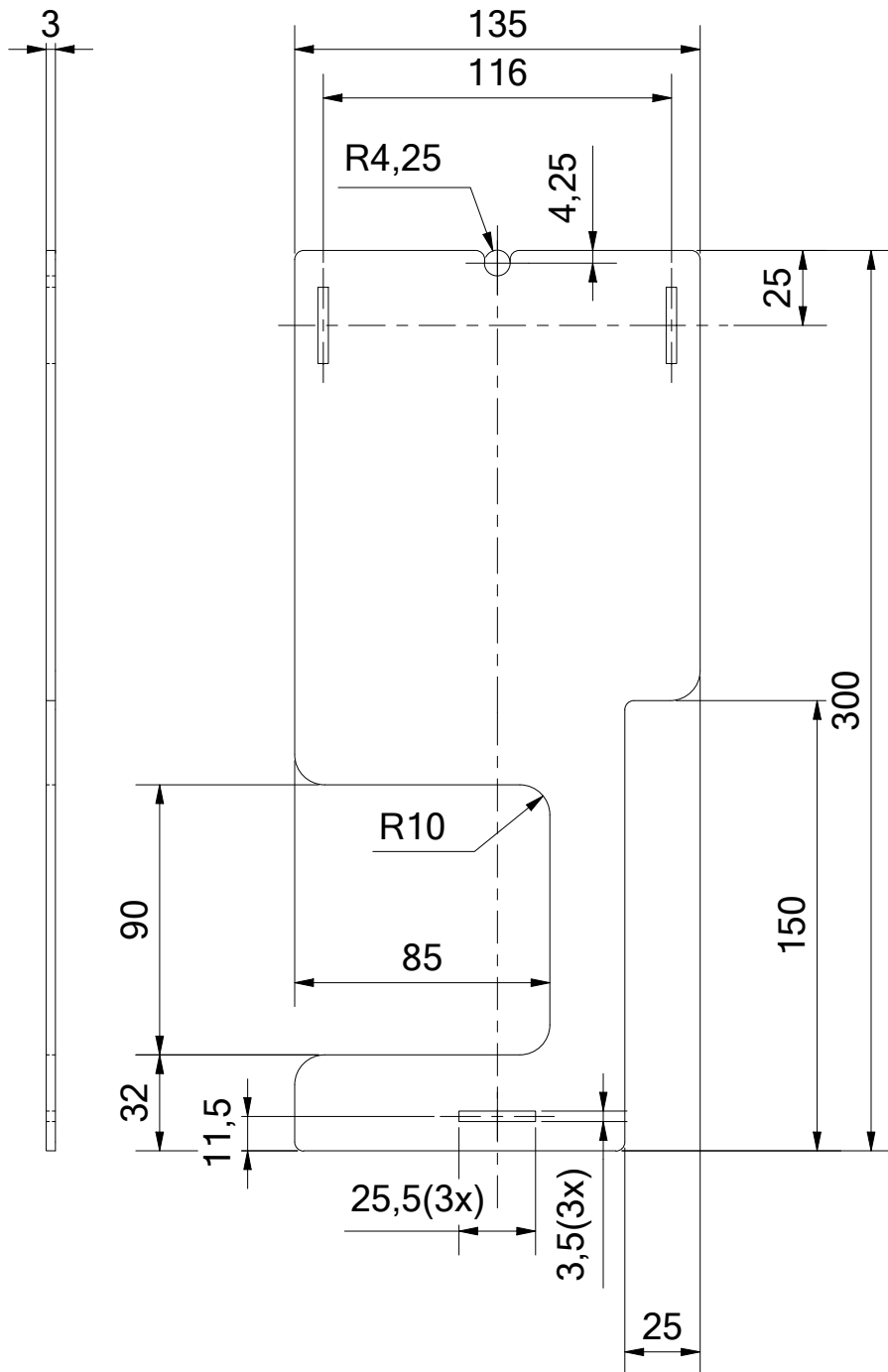
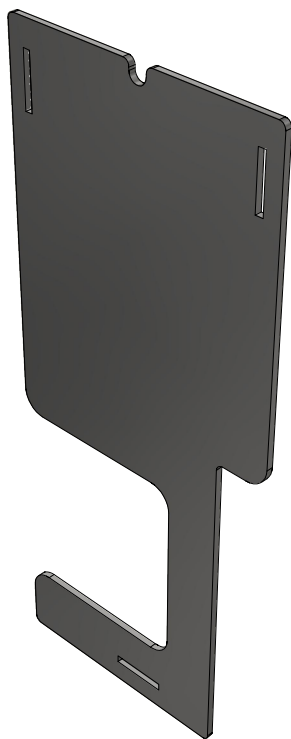
<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,201 kg</div>	<div>Material:</div> <div>Glass (ROBAX®)</div>
					<div>Stock Number:</div> <div>Heat resistant glass robax 4mm</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Viewing window top</div>		
	<div>Drawn</div>	<div>12-1-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P37</div>	<div>1</div> <div>A4</div>	
				<div>Scale: 1 : 2</div>	<div>Units: MM</div>	

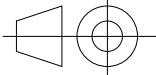


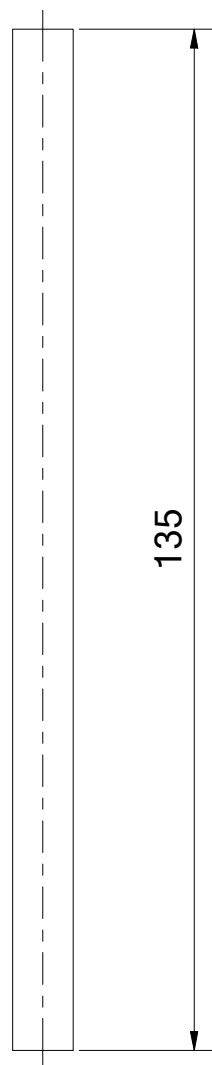
Treatment: Coat with Motip 04030 (Heat Resistant Lacquer Dark Anthracite)

<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		DIN ISO 2768-mK DIN ISO 1101		Mass: 0,437 kg	Material: S235(JR) 1.0038
			Stock Number: Sheet 3mm			
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Seal plate viewing window 2		
	Drawn	12-1-2021	Sander Grummels			
	Checked					
	Standard					
Document-type: Mono-Sheetmetal-Drawing	Remark-comment:		Revision: 0	Drawing Number: SGP2-P38		1
						A4
				Scale: 1 : 2.5		Units: MM





<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>Mass:</div> <div>0,677 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>	
			<div>Stock Number:</div> <div>Sheet 3mm</div>			
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Side plate basket</div>	
	<div>Drawn</div>	<div>11-2-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P39</div>		
				<div>1</div>		
				<div>A4</div>		
				<div>Scale: 1 : 2.5</div>		<div>Units: MM</div>



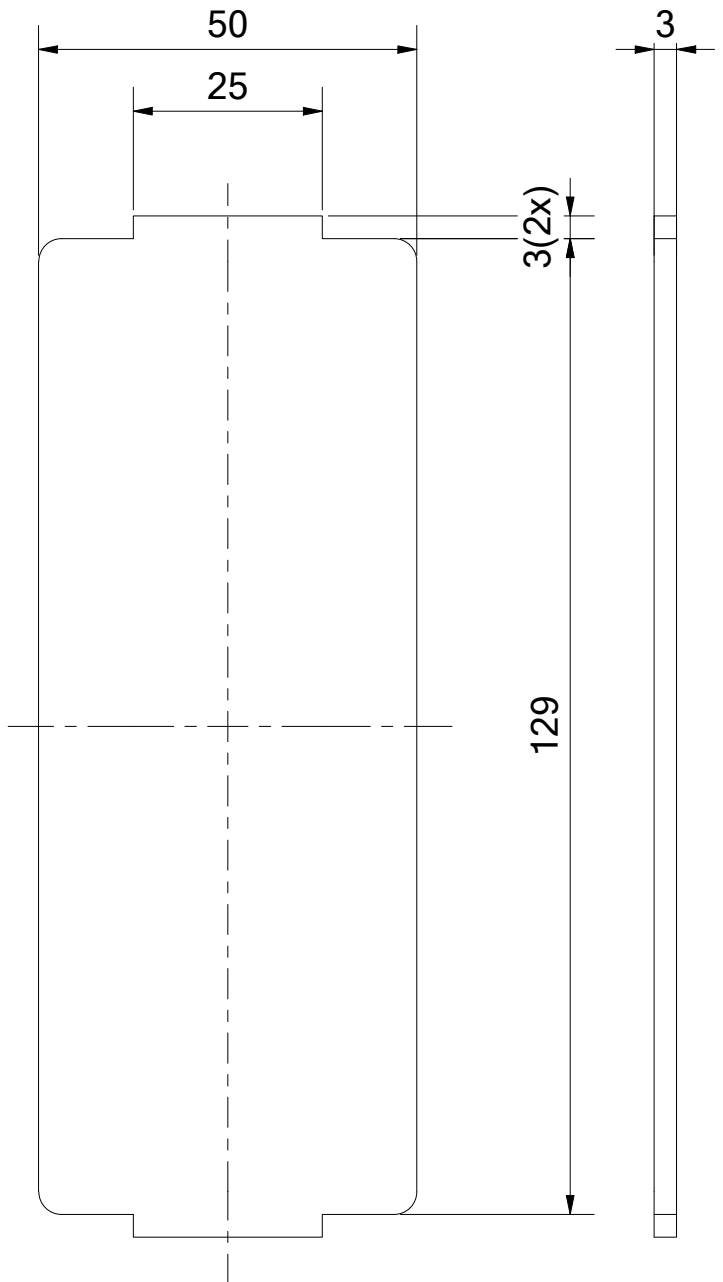
135

Ø8

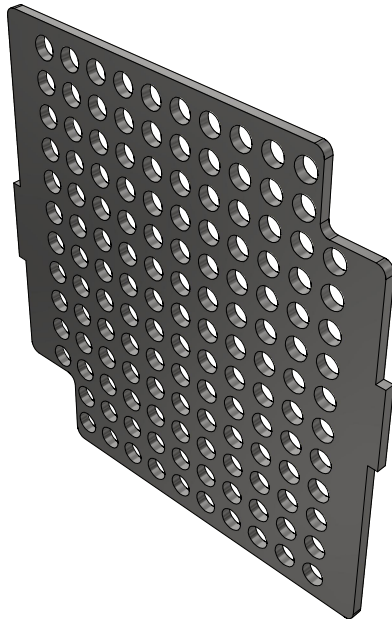
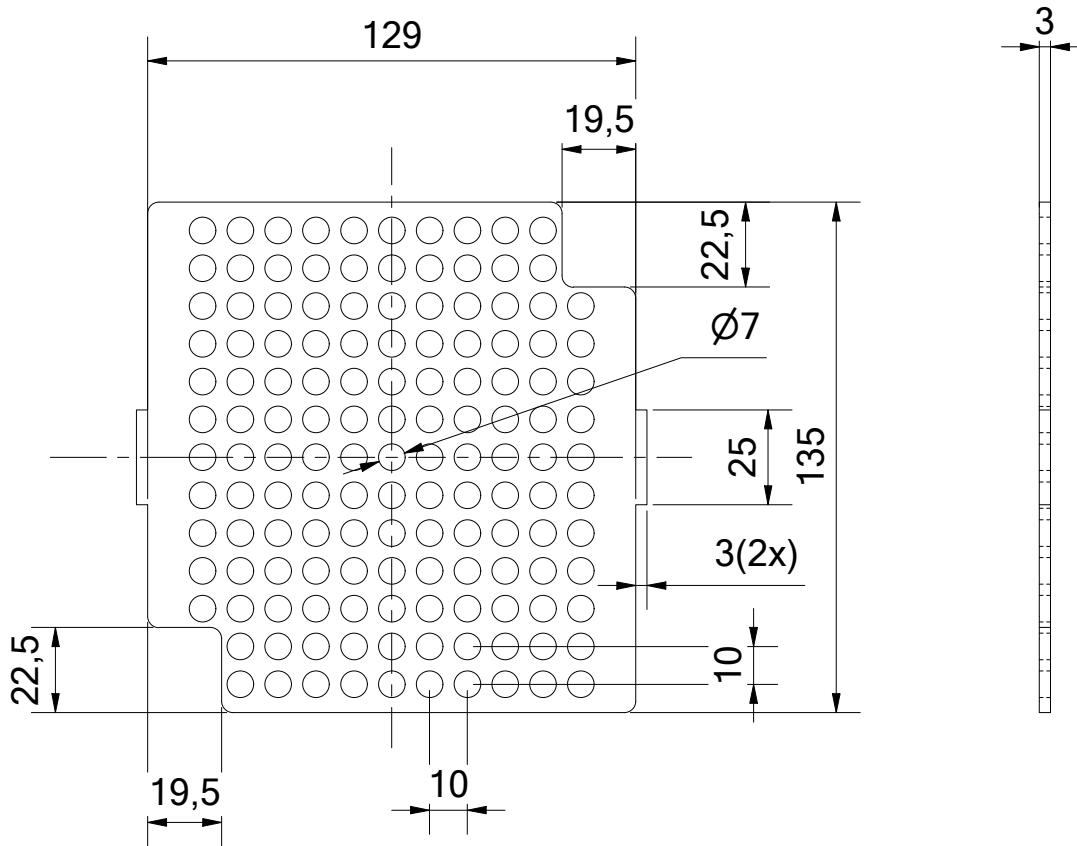


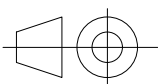
Grummels	First-angle Projection: 		DIN ISO 2768-mK DIN ISO 1101		Mass: 0,053 kg	Material: S235(JR) 1.0038
					Stock Number: Round bar Ø8	
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name		Title: Connecting bar basket	
	Drawn	11-2-2021	Sander Grummels			
	Checked					
	Standard					
Document-type: Mono-Drawing	Remark-comment:		Revision: 0		Drawing Number: SGP2-P40	
					1	
					A4	
	Scale: 1 : 1				Units: MM	

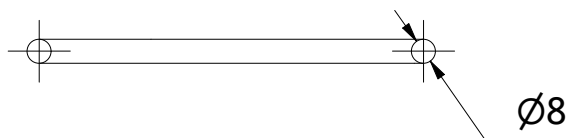
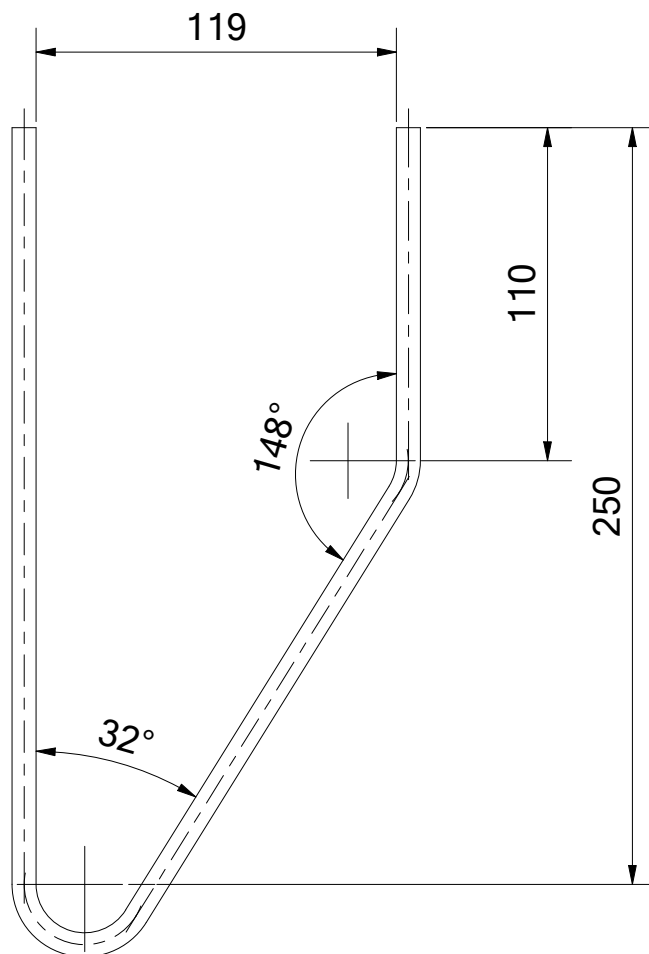


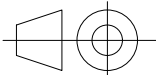


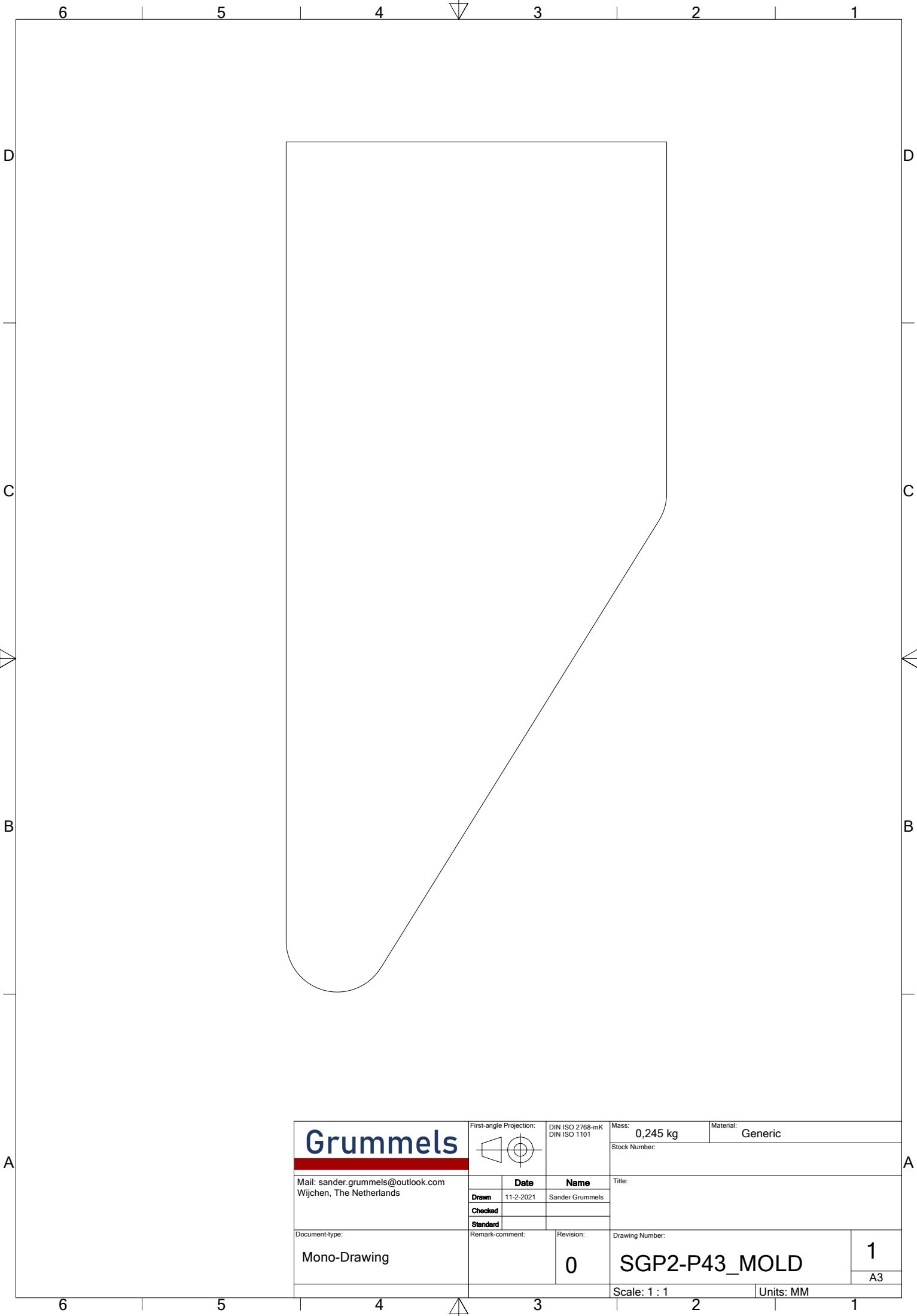
Grummels	First-angle Projection:		DIN ISO 2768-mK DIN ISO 1101	Mass: 0,155 kg	Material: S235(JR) 1.0038
				Stock Number: Sheet 3mm	
Mail: sander.grummels@outlook.com Wijchen, The Netherlands		Date	Name	Title: Connecting plate basket	
	Drawn	11-2-2021	Sander Grummels		
	Checked				
	Standard				
Document-type:	Remark-comment:		Revision:	Drawing Number:	
Mono-Sheetmetal-Drawing			0	SGP2-P41	1
					A4
			Scale: 1 : 1	Units: MM	

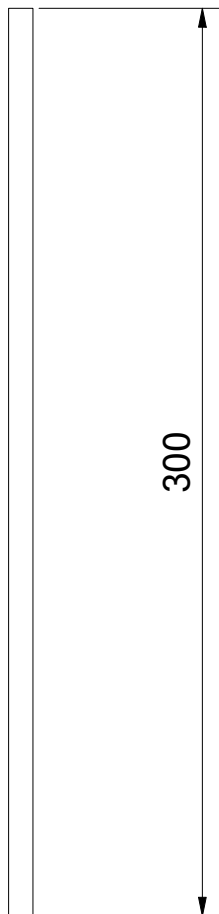


<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>Mass:</div> <div>0,267 kg</div>		<div>Material:</div> <div>S235(JR) 1.0038</div>	
			<div>Stock Number:</div> <div>Sheet 3mm</div>			
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>		<div>Title:</div> <div>Vent plate basket</div>	
	<div>Drawn</div>	<div>11-2-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P42</div>		
				<div>1</div>		
				<div>A4</div>		
				<div>Scale: 1 : 2</div>		<div>Units: MM</div>



<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>Mass:</div> <div>0,232 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>	
			<div>Stock Number:</div> <div>Round bar Ø8</div>		
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Feul holder bar</div>	
	<div>Drawn</div>	<div>11-2-2021</div>	<div>Sander Grummels</div>		
	<div>Checked</div>				
	<div>Standard</div>				
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P43</div>	<div>1</div>
					<div>A4</div>
	<div>Scale: 1 : 2.5</div>			<div>Units: MM</div>	

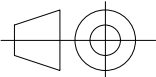


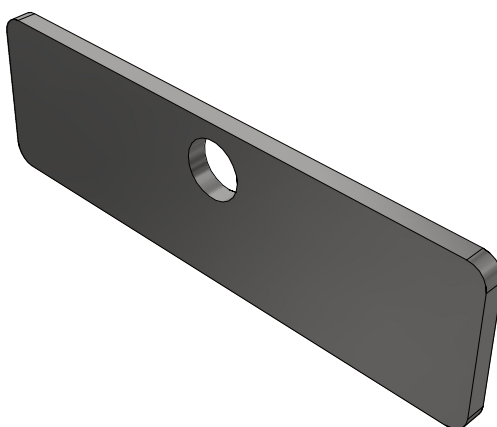
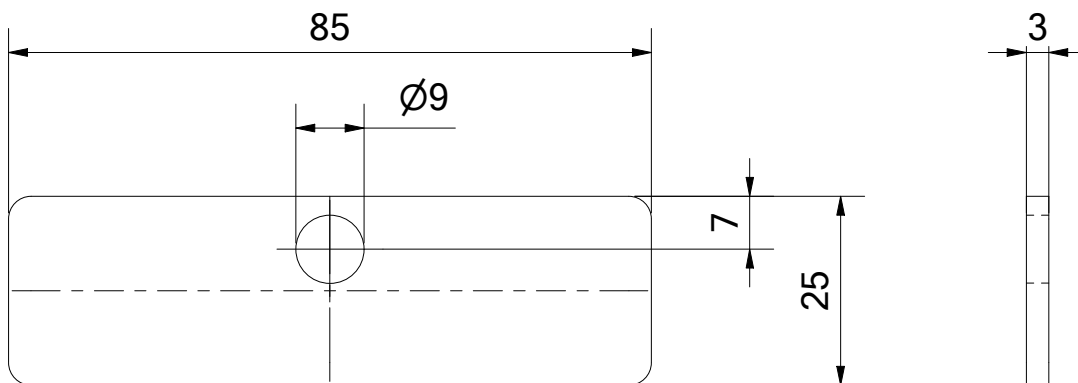


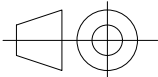
300

Ø8

























































<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,118 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
					<div>Stock Number:</div> <div>Round bar Ø8</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Handle</div>		
	<div>Drawn</div>	<div>11-2-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P44</div>	<div>1</div> <div>A4</div>	
				<div>Scale: 1 : 2.5</div>	<div>Units: MM</div>	





<div>Grummels</div>	<div>First-angle Projection:</div> <div></div>		<div>DIN ISO 2768-mK</div> <div>DIN ISO 1101</div>		<div>Mass:</div> <div>0,048 kg</div>	<div>Material:</div> <div>S235(JR) 1.0038</div>
					<div>Stock Number:</div> <div>Sheet 3mm</div>	
<div>Mail: sander.grummels@outlook.com</div> <div>Wijchen, The Netherlands</div>		<div>Date</div>	<div>Name</div>	<div>Title:</div> <div>Remover plate</div>		
	<div>Drawn</div>	<div>11-2-2021</div>	<div>Sander Grummels</div>			
	<div>Checked</div>					
	<div>Standard</div>					
<div>Document-type:</div> <div>Mono-Sheetmetal-Drawing</div>	<div>Remark-comment:</div>		<div>Revision:</div> <div>0</div>	<div>Drawing Number:</div> <div>SGP2-P45</div>	<div>1</div> <div>A4</div>	
				<div>Scale: 1 : 1</div>	<div>Units: MM</div>	

Appendix D.2: Part list

Item	Part Number	Thumbnail	BOM Structure	Unit	QTY	QTY	Stock Number	Description	REV	Vendor	Estimated Cost
1	SGP2-P1		Normal	1	1		Square tube 150x150x4 EN 10219	Burn tunnel	0		
2	SGP2-P2		Normal	1	1		Square tube 150x150x4 EN 10219	Fuel stock	0		
3	SGP2-P3		Normal	1	1		U-profile 100x40x3 EN 10162	Secondary air supply channel	0		
4	SGP2-P4		Normal	1	1		Sheet 3mm	Closing end cap	0		
5	SGP2-P5		Normal	1	1		Round tube Ø139,7x4 EN 10219	Riser tube	0		
6	SGP2-P6		Normal	1	1		Sheet 3mm	Flame/flow director plate	0		
7	SGP2-P7		Normal	1	1		Sheet 3mm	Bottom support plate	0		
8	SGP2-P8		Normal	1	5		Square tube 30x30x3 EN 10219	Support leg	0		
9	SGP2-P9		Normal	1	2		UNP 50x25 DIN1026-1	Tertiary air supply channel	0		
10	SGP2-P10		Normal	1	2		Sheet 3mm	Cap tertiary air	0		
11	SGP2-P11		Normal	1	1		Rectangular tube 100x40x3 EN 10219	Inlet tube primary	0		
12	SGP2-P12		Normal	1	1		Sheet 3mm	Lid primary air	0		
13	SGP2-P13		Normal	1	1		Sheet 3mm	Lid wood stock	0		
14	SGP2-P14		Normal	1	1		Angle 30x30x3 EN 10025	Valve slider	0		
15	SGP2-P15		Normal	1	2		Connection tertiary air slide	Sheet 3mm	0		
16	SGP2-P16		Normal	1	2		Sheet 3mm	Closing plate tertiary air channel	0		
17	SGP2-P17		Normal	1	1		Angle 30x30x3 EN 10025	Window holder horizontal	0		
18	SGP2-P18		Normal	1	1		Angle 30x30x3 EN 10025	Window holder vertical left	0		
19	SGP2-P19		Normal	1	1		Angle 30x30x3 EN 10025	Window holder vertical right	0		
20	SGP2-P20		Normal	1	2		Sheet 3mm	Closing plate tertiary air channel	0		
21	SGP2-P22		Normal	1	1		Sheet 3mm	Inlet slider secondary air	0		
22	SGP2-P23		Normal	1	1		Round bar Ø8	Slider pin	0		
23	SGP2-P24		Normal	1	2		Sheet 3mm	Slider tertiary air	0		
24	SGP2-P25		Normal	1	1		Round tube Ø306x3 EN 10217-7	Heat extractor tube	0		
25	SGP2-P26		Normal	1	1		Round tube Ø306x3 EN 10217-7	Heat extractor tube top	0		
26	SGP2-P27		Normal	1	1		Round tube Ø177,8x4 EN 10219	Exhaust connection tube	0		
27	SGP2-P28		Normal	1	1		Sheet 3mm	Exhaust valve	0		

28	SGP2-P29		Normal	1	1 Round bar Ø8	Handle exhaust valve	0	
29	SGP2-P30		Normal	1	1 Sheet 3mm	Cover plate upper heat extractor	0	
30	SGP2-P31		Normal	1	1 Square tube 150x150x4 EN 10219	View tube	0	
31	SGP2-P32		Normal	1	1 Sheet 3mm	Seal plate viewing window 1	0	
32	SGP2-P33		Normal	1	6 Sheet 3mm	Space plate 3mm	0	
33	SGP2-P34		Normal	1	3 Sheet 3mm	Connector plate upper heat extractor	0	
34	SGP2-P35		Normal	1	3 Sheet 3mm	Bolt attachment	0	
35	SGP2-P36		Normal	1	2 Round tube Ø306x3 EN 10217-7	Closing plate	0	
36	SGP2-P38		Normal	1	1 Sheet 3mm	Seal plate viewing window 2	0	
37	SGP2-P39		Normal	1	2 Sheet 3mm	Side plate basket	0	
38	SGP2-P40		Normal	1	1 Round bar Ø8	Connecting bar basket	0	
39	SGP2-P41		Normal	1	2 Sheet 3mm	Connecting plate basket	0	
40	SGP2-P42		Normal	1	1 Sheet 3mm	Vent plate basket	0	
41	SGP2-P43		Normal	1	7 Round bar Ø8	Feul holder bar	0	
42	SGP2-P44		Normal	1	1 Round bar Ø8	Handle	0	
43	SGP2-P45		Normal	1	1 Sheet 3mm	Remover plate	0	
44	SGP2-P37		Purchased	1	1 Heat resistant glass robax 4mm	Viewing window top	0	€ 11,55
45	SGP2-P21		Purchased	1	1 Heat resistant glass robax 4mm	Viewing window burn tunnel	0	€ 5,00
50	Clamping band Ø180mm		Purchased	1	3	Ø180x20x0,6 Stainless steel		€ 10,00
51	GN 128-60-MS		Purchased	1	2 GN 128-60-MS	Welding hinge fixed brass pin 60xØ10mm	Ganter Norm	€ 2,60
52	Stovepipe Ø180mm 1000mm		Purchased	1	2	Ø180x0,6 L=1000mm		€ 24,00
53	Stovepipe Ø180mm bend 45 degrees		Purchased	1	1	Ø180x0,6 45 deg L=250x250mm		€ 16,50
54	ISO 4032 - M8		Purchased	1	15	Hexagon nuts, style 1 - Product grades A and B		
55	ISO 4762 - M4 x 25		Purchased	1	1	Hexagon Socket Head Cap Screw		
56	ISO 4762 - M6 x 20		Purchased	1	4	Hexagon Socket Head Cap Screw		
57	ISO 4762 - M8 x 16		Purchased	1	6	Hexagon Socket Head Cap Screw		
58	ISO 4762 - M8 x 20		Purchased	1	2	Hexagon Socket Head Cap Screw		

59	ISO 4762 - M8 x 25		Purchased	1	6	Hexagon Socket Head Cap Screw		
60	ISO 7089 - 8		Purchased	1	22	Plain washers - Normal series - Product grade A		
61	Heat Resistant Lacquer Dark Anthracite	(NULL)	Purchased	1	1 04030	EAN: 8711347040308	Motip	€ 13,00
62	Heat Resistant Lacquer Silver	(NULL)	Purchased	1	1 04032	EAN: 8711347040322	Motip	€ 13,00
63	Heater cord flat fiberglass 10x2mm adhesive	*Varies*	Purchased	1	4 Heater cord flat fiberglass 10x2mm adhesive	Heater cord flat fiberglass 10x2mm adhesive		€ 10,90

Appendix D.3: Cut list

CUT-LIST VORTEX HEATER			
QTY	STOCK NUMBER	LENGTH (mm)	TOTAL LENGTH (mm)
1	Angle 30x30x3 EN 10025	150	155
1	Angle 30x30x3 EN 10025	142	147
1	Angle 30x30x3 EN 10025	102	107
1	Angle 30x30x3 EN 10025	102	107
TOTAL	Angle 30x30x3 EN 10025		516
1	Rectangular tube 100x40x3 EN 10219	50	55
TOTAL	Rectangular tube 100x40x3 EN 10219		55
1	Round bar Ø8	25	30
1	Round bar Ø8	267	272
1	Round bar Ø8	135	140
7	Round bar Ø8	575	4060
1	Round bar Ø8	800	805
TOTAL	Round bar Ø8		5307
1	Round tube Ø139,7x4 EN 10219	800	805
TOTAL	Round tube Ø139,7x4 EN 10219		805
1	Round tube Ø177,8x4 EN 10219	120	125
TOTAL	Round tube Ø177,8x4 EN 10219		125
1	Round tube Ø306x3 EN 10217-7	800	805
1	Round tube Ø306x3 EN 10217-7	250	255
TOTAL	Round tube Ø306x3 EN 10217-7		1060
1	Square tube 150x150x4 EN 10219	435	440
1	Square tube 150x150x4 EN 10219	430	435
1	Square tube 150x150x4 EN 10219	60	65
TOTAL	Square tube 150x150x4 EN 10219		940
5	Square tube 30x30x3 EN 10219	180	925
TOTAL	Square tube 30x30x3 EN 10219		925
2	UNP 50x25 DIN1026-1	890	1790
TOTAL	UNP 50x25 DIN1026-1		1790
1	U-profile 100x40x3 EN 10162	435	440
TOTAL	U-profile 100x40x3 EN 10162		440

Appendix D.4: STEP files

Appendix D.5: DXF files

Appendix E

Appendix E.1: ROCKET MASS HEATERS:

ROCKET MASS HEATERS: **Superefficient Woodstoves** **YOU Can Build**

The New Updated Version of:
Rocket Stoves to Heat Cob Buildings

Ianto Evans
Leslie Jackson

A COB COTTAGE COMPANY PUBLICATION
2006, 2007

Table of Contents

What this Book is About	9
Who this Book is For	9
The Fine Print	9
Cross-section of a Typical Rocket Mass Heater	11
Ianto Knows Why Rocket Stoves	12
Significant Features of Rocket Style Heating Stoves	13
Draft Works the Stove	14
Campfires	14
Chimneys	14
Woodstoves	14
Rocket Stoves are Different	15
Combustion and Heat	17
How Wood Burns	17
The Three T's	18
The Thermal Battery	18
How Heat Moves	19
Radiation	19
Convection	19
Conduction	20
Insulation	20
Comfort Through Stored Heat	21
Step-by-Step Construction	22
Designing Your Stove and Thermal Battery	23
The Combustion Unit	23
Directing the Heat	24
The Thermal Battery	25
Placing the Pipe	25
Sizing Built-in Furniture	27
Planning the Exit Flue	27
Materials and Tools You'll Need	29
Bricks	30
Clay	30
Sand	31
Barrels	31
Stovepipe	32
High Temperature Insulation	33
Insulation Containers	33
Steel Pipe	33
Urbanite	34
Straw	34
Dimention and Proportion	35
Constructing the Combustion Unit	37
Mortar	37
A Mock-up	37
Insulation Under the Stove	39

Building the Brickwork	39
Adding Insulation	40
Setting the Barrel	41
Tips on Laying Brick.	41
Building the Thermal Battery.	48
Materials for Building a Bench, Couch or Bed	48
Lay out Exhaust	48
Connecting Stove to Bench	48
Locate Clean-outs.	49
Sculpt the Thermal Battery	49
Feeding and Caring for your Dragon	50
Light my Fire.	51
Choice and Use of Paper	51
Adding Kindling	52
Stoking	52
The Fuel You Burn	53
Keep it Dry	53
Kindling Selection.	53
Choosing Firewood	53
Maintenance	55
Cooking on the Rocket Stove.	56
Fire! Fire!	58
Burning Questions.	59
Trouble Shooting.	64
Drawbacks of Rocket Stoves	67
Adaptations and Other Kinds of Rocket	69
The Rocket Hot Tub.	70
Detroitus and the Pocket Rocket.	71
The Guatemalan Cookstove: <i>Estufa Rocky</i>	72
The Bengali Pit Stove	73
Heating Water	74
Coffee Rocket	75
How to Make a Pocket Rocket.	76
Research Needed and Experiments	78
Case Studies	80
Tom & Calleagh	80
A Rocket-Fired Wood Kiln	85
Donkey's Rocket	86
The Reinharts	86
Bernhard Masterson	89
Kiko Denzer.	91
Flemming Abrahamsson.	92
Glossary	94
More Information	95
Resources on Pyromania	95
Books on Natural Building and Wood Burning	96
About Cob Cottage Company	97
Ianto Evans	97
Leslie Jackson.	97
Afterword.	98
Thanks	99

What this Book is About

This little book is about a revolutionary concept in wood burning stoves that ensures almost completely clean combustion with high efficiency use of the heat produced. Rocket Stoves are still experimental in that only a few hundred were in regular use by early 2006, but some have performed well, daily, for more than a decade. They save a lot of fuel and completely rearrange our concepts of house heating, of wood burning, and of dependency on coal, oil, hydro- or nuclear power for our comfort. Rocket Mass Stoves can be built at home by relatively unskilled people. While they are well-suited to earthen buildings with their thermally massive walls, floors and built-in furniture, they can be built into any kind of structure—from cargo containers to yurts.

The term Rocket Stove has been used loosely for about twenty years to mean a fairly wide range of combustion devices used for cooking and heating.

Aside from the model described in detail in this book, Rocket principles have been variously applied. Larry Jacobs and I came up with a version using only a metal drum and two stovepipes, later called the Pocket Rocket (see *Detroitus: The Pocket Rocket*). Later, in the late 1980's, I helped develop a lightweight concrete single pot cook stove for urban Guatemalans. More recently, small portable cook stoves have been developed using tin cans and simple insulation. Experimental rocket-fired ovens and water heaters have also been built.

Perhaps most significantly, the Rocket Mass Stoves used for house heating, which are now starting to appear all over North America and Northern Europe, have real promise in that they improve comfort and reduce the amount of fuel burned, thereby lessening the load of CO₂ on greenhouse gases. They turn almost all the wood into heat, and can store almost all of the heat generated for optimal comfort when you need it.

Who this Book is For

This manual is intended for pyromaniacs, tinkerers, people with curiosity about fire, owner-builders, people with an experimental mind, do-it-yourself builders who want to be less dependent on the system and have environmental concerns, and above all, those who want to be snug at home. The realm of Rocket Stoves is an experimental one whose time is overdue. Play and innovation are highly recommended. As our friend Tom Frame (see Case Studies, page 80) says, “Don’t be afraid to try something new or different. Don’t have the right part? Try something else. Can’t make a quick phone call for answers? Trust your own judgment. Just can’t figure it out? Wait, be patient. Move on to something else if you can. The answer will come. Most importantly, don’t rush this thing! You really want it to work when you’re done building it. Take the time needed.”

The model of heating Rocket we describe suits the Maritime Pacific climate quite well, but it is not limited to it. Once you understand the principles of the Rocket Mass Stove, you’ll be able to modify it to your own heating needs.

Rocket Stoves’ design is exploratory; their use is experimental; the attention they demand may keep you in fascination or you may find their quirks irritating. For the next edition, we will look forward to hearing (and learning from) your feedback, comments, stumbling blocks, epiphanies and wild fancies. So fire away, so to speak; send us images and drawings. If we use your material, we’ll send you two copies of the new edition.

THE FINE PRINT

Neither Ianto Evans, Leslie Jackson, nor Cob Cottage Company can be held in any way responsible for damage, fire or injury arising from the use of this material. These stoves are experimental and, besides, we don’t have any assets. So, enjoy to the full your fire damage and injuries. For some precautions, see Fire! (page 58).

The Combustion Unit...



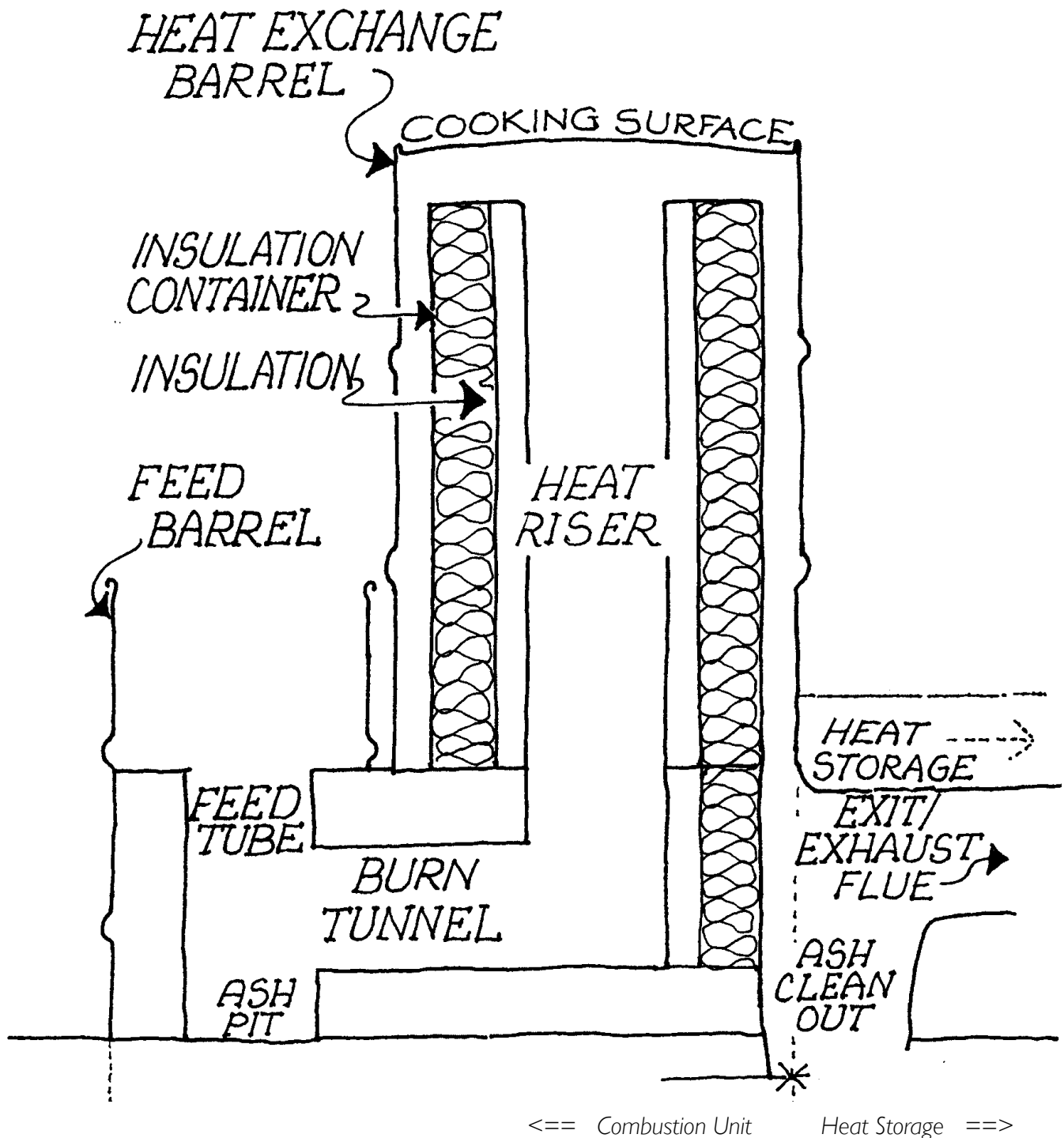
The Rocket Stove in Ianto Evans's cottage, seen from above. Dry firewood, cut thin, the small feed barrel with lid and the large heat riser barrel with tea kettle.

...is connected to the Thermal Battery



Ianto demonstrates the stove's use.

Cross-Section of a Typical Rocket Mass Heater



Ianto Knows Why Rocket Stoves

Rocket Stoves grew out of work I did between 1976 and the late 1980's, mostly on solutions to the international firewood crisis and the problem of smoke in the homes of traditional people. In Guatemala in the 70's, I helped worked on the Lorena stove system, which uses a sand-clay amalgam to contain the fire, hold up the pots and store surplus heat. It rapidly attracted worldwide attention and is now widely used in Latin America, Asia and Africa. Later, I worked as part of a team in over twenty countries, helping people create better cooking facilities. I spent much of a decade in villages, in people's homes, mostly with the women who actually do the cooking. One result of my experience as a professional pyromaniac was some work in the US on the challenge of improving wood-fired heating stoves for cold climates.

At that time, wood stoves had scarcely improved in more than a hundred years. The basic format had always been a simple metal box with an attached exhaust pipe. The stove heats the surrounding air, which rises to heat the ceiling, gradually circulating as it cools. To be optimally heated, you would need to be staked out on the ceiling directly over the stove. In general, the more heat lost out of the top of the chimney, the better the combustion.

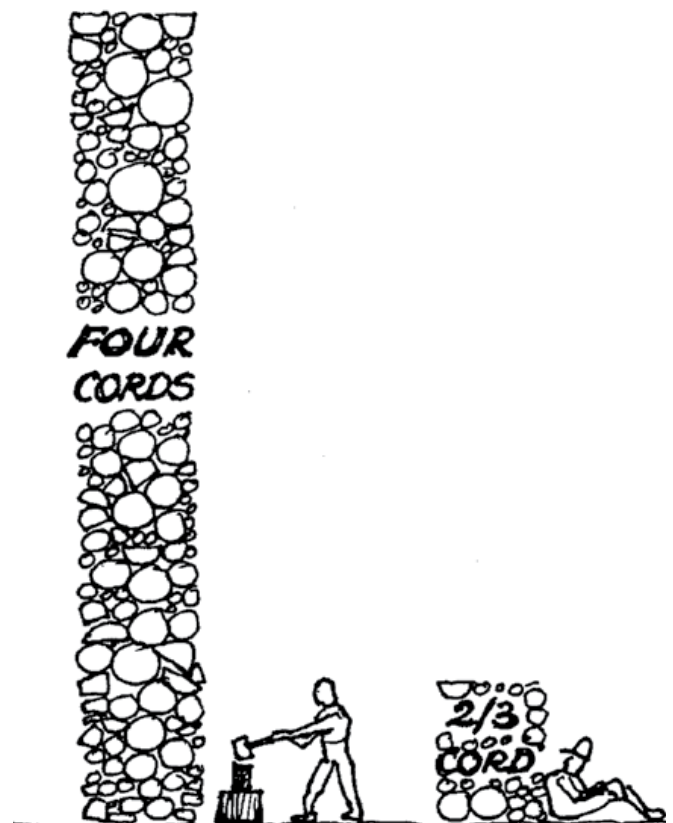
Clearly, this in itself is wildly inefficient. The sky has no interest in being heated. Worse, most wood stoves burn very imperfectly, that is, not all the energy available in the wood turns into heat. Much of the wood's potential heat leaves the stove as smoke, particles, and unburned gases. The results include poisoning your downwind neighbors, excessive firewood use, and personal frustration. Clean air standards imposed by the federal government in the 1980's attempted to limit the amount of smoke and particles put out by commercial wood stoves, but came nowhere close to ensuring clean burning.

Our goal in developing Rocket type stoves was to rethink completely the question of how to burn wood inside a house in order to improve human comfort, use less firewood, and cut pollution.

The results are impressive. In my own cottage I burn only about two-thirds of a cord of (fir and alder) firewood a year, while my neighbors average 3–5 cords. You can usually tell when any of the neighbors are around by the cloud of smoke coming out of their chimneys. By contrast, we burn so clean that visitors coming into my house want to know how come it's so snug without the stove burning. Imagine their surprise when they learn that in fact, it is burning merrily.

As I write, I sit by my own Rocket Stove, in my little cob house in the depth of Oregon winter. I built this stove myself in a day from recycled parts that cost less than \$50.

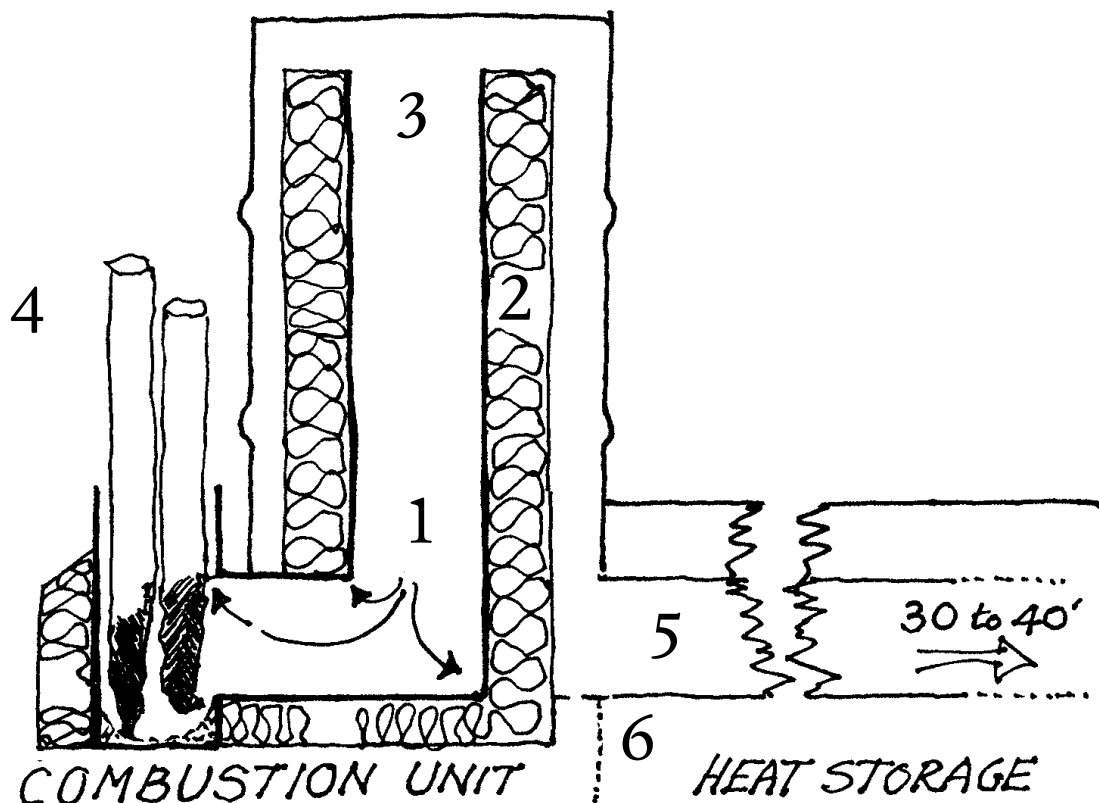
Since the late 1980's, Rocket Mass Stoves have been my only heat source apart from the sun. For seventeen years I have daily been able to evaluate these heaters that suit me better than anything else I can find.



A comparison of a year's supply of wood. The left stack is my neighbor's, the right is mine.

Significant Features of Rocket Heating Stoves

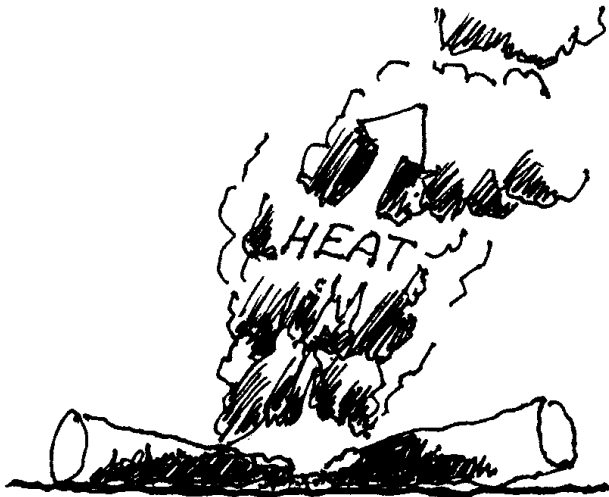
1. A roughly J-shaped combustion chamber with abrupt right angle turns. Hot gases rising up the long leg suck cool air down the short leg through the fuel.
2. A combustion chamber enclosed in high temperature insulation. (Insulation = high temperature = complete combustion = high efficiency).
3. An insulated chimney which is inside the stove itself (creates draft).
4. The firewood stands upright and burns at its bottom end only, feeding the stove by gravity as it falls into the fire.
5. The capacity to push heated gases through long horizontal passages in floors, beds, or benches.
6. The concept of separating the combustion unit from the use of the heat so produced, and particularly, storing that heat for hours or days in inexpensive built-in furniture.
7. Extraordinary efficiency, both in extracting heat from the fuel and in delivering heat for use when and where it is needed.
8. Easy to construct from inexpensive materials.



Draft Works the Stove

Campfires

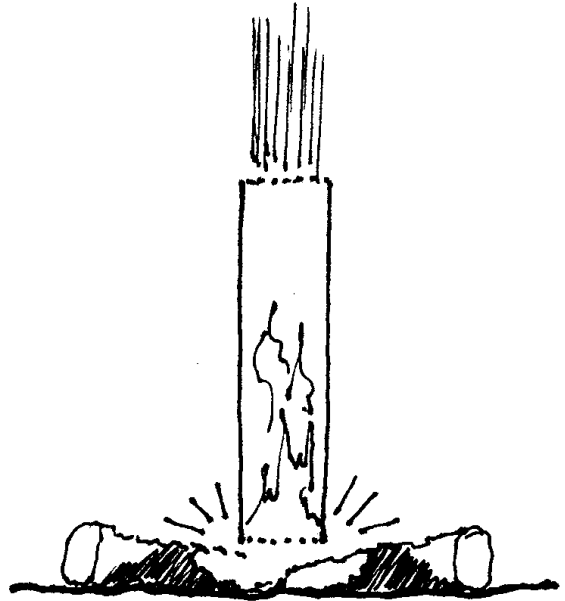
A campfire burns wood in the open air, outdoors. Its combustion success depends upon a steady flow of air. Oxygen, which constitutes a fifth of our air, combines with volatile oils and other gaseous products boiled out of the wood, generating heat. You can't heat yourself by contact; the coals are too hot; you would get burned, and if you were to sit in the hot gases trying to warm up, you would be slowly smoked and then asphyxiate. For heating people, only direct radiation is available from the coals and flame. But most of the heat is normally wasted. You can only warm up at a distance beside the fire.



Campfire: Heats mostly by radiation.

Chimneys

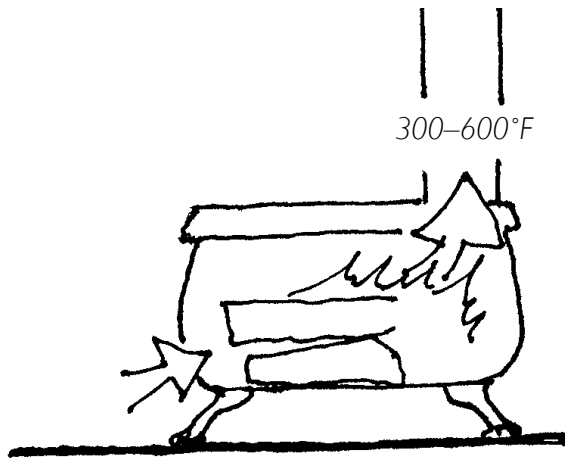
Chimneys suck. They draw air up themselves because the gas in them is hotter than the air that surrounds them. The draw is dependant on both the height and the average interior temperature: height multiplied by heat. So you can get the same effect from a very tall, rather cool chimney (as in most factories) or conversely, by a short, very hot chimney. A 100 foot high chimney that is twenty degrees warmer than the surrounding air generates roughly as much draw as a chimney just two feet high but a thousand degrees hotter.



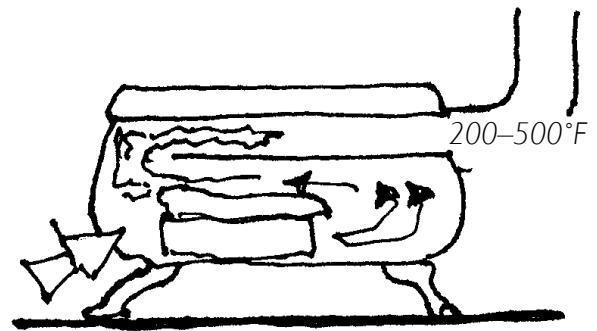
*Try a simple experiment:
Hold any kind of cardboard or metal tube over a
smoldering campfire, tight over the embers. The
fire will immediately come to life, the embers will
glow brighter and the smoke will lessen.
It will burn better.*

Wood Stoves

A wood stove is a fireproof container with a fire inside it. For oxygen to be drawn through the fuel, a chimney carries hot gases up, sucking cold air in past the fuel (and perhaps through your house). Hopefully, sufficient air is drawn in, or the fuel will merely pyrolyze—that is bake out the volatile oils without burning them—producing smoke which lacks sufficient oxygen to be burnt. If there is too much air coming in, the cold air will dilute the hot gases in the chimney and lower the combustion temperature, making the burn worse. For the whole thing to work, the chimney must be hot, and if it is outside the building, valuable heat is lost from the building to the sky.



A metal box stove is an advance over an open fire, but still wastes a lot of heat.



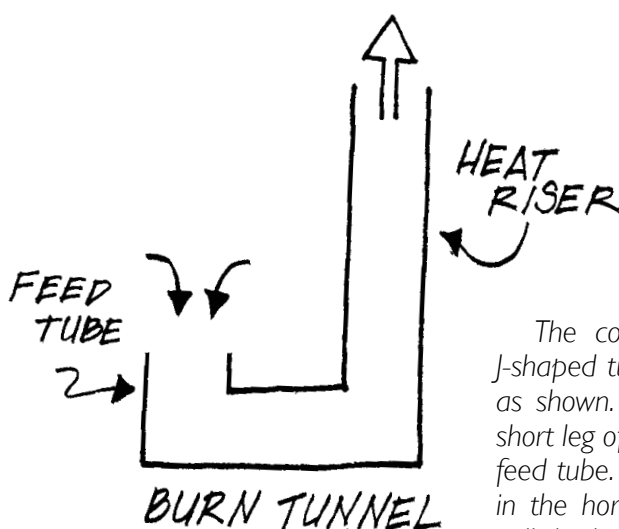
With a shelf damper, the situation is better: A cleaner burn and a lower exit temperature.

Rocket Stoves are Different

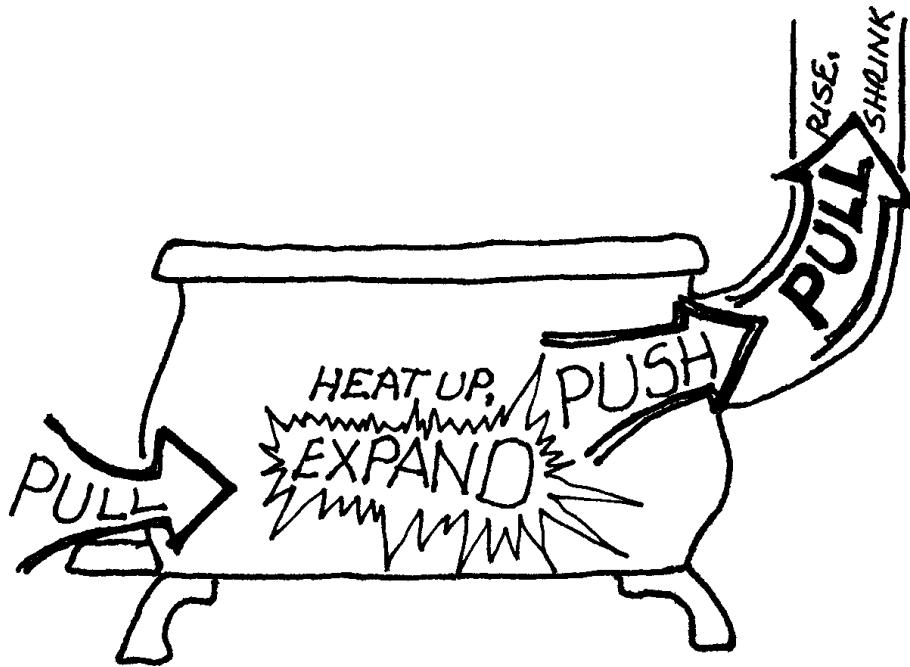
The revolutionary part of Rocket heating stoves is the concept of **putting the chimney** (the heat riser) **inside the stove**. This is done by enclosing the heat riser so that exhaust gases are captured with almost all the heat still in them. Then, by running these gases through a masonry mass, they are encouraged to cool before leaving the building.

The stove inside my own home has an internal chimney about 3 feet high, which

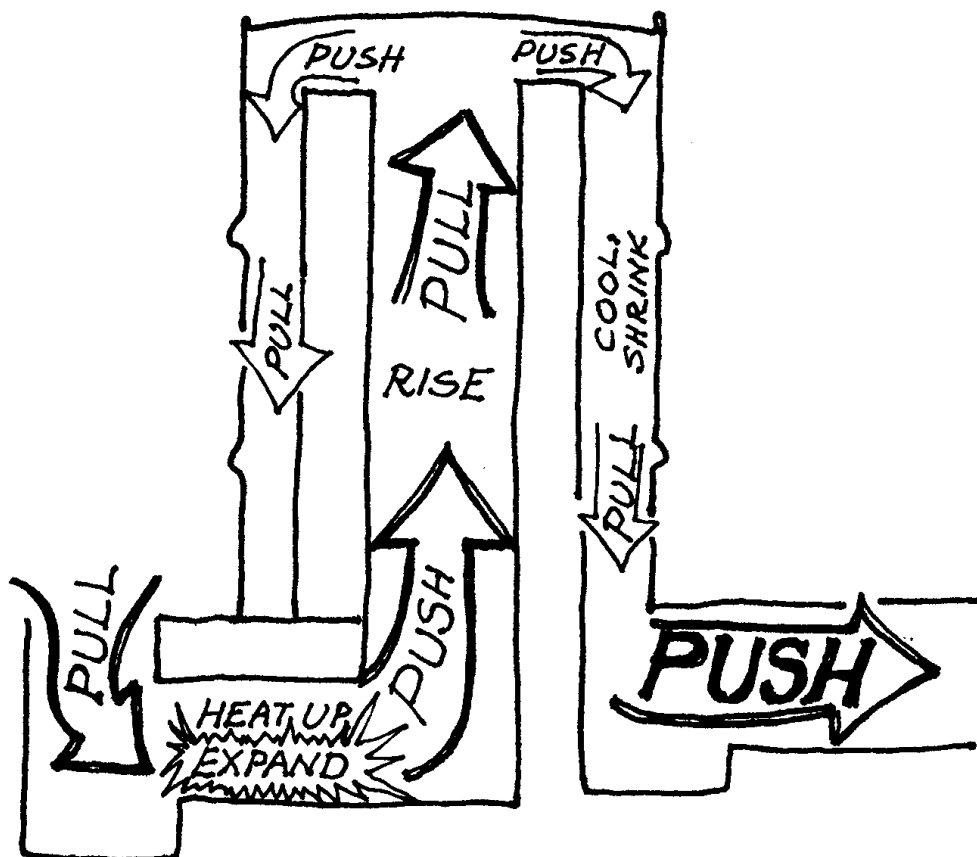
runs at between 1200 and 1800°F. The metal barrel that surrounds the chimney radiates enough heat that the combustion gases are down to perhaps 500–700°F by the time they leave the stove. But now instead of wasting that heat by discharging hot gas from my house, we feed it through a cob and rock day bed and seat so that it is down to between 90° and 200°F by the time it leaves the building.



The core of the Rocket is a J-shaped tube with square corners, as shown. The fuel falls down the short leg of the J, which is called the feed tube. Burning mostly happens in the horizontal part, which we'll call the burn tunnel, and the flame path extends up the long leg of the J, called the heat riser.



A metal box stove pushes hot gas up the stack, which in turn pulls air through the box.



A Rocket Stove pushes hot gases through a thermal battery to heat your body by contact.

Combustion and Heat

HOW WOOD BURNS

The air we breathe is about 20% oxygen. Oxygen is super-reactive and will combine at the right temperature with almost anything and burn it, releasing energy as heat. Different materials catch fire at different temperatures. For instance phosphorous will burn just by exposure to oxygen at room temperature, but steel needs to be heated to thousands of degrees in order to burn. When wood is first heated, the lignin and cellulose, which comprise most of its bulk, break down into a big range of simple to complex chemical gases. When they reach a certain temperature, they ignite and burn, combining with oxygen and producing flames, in a process known as combustion.

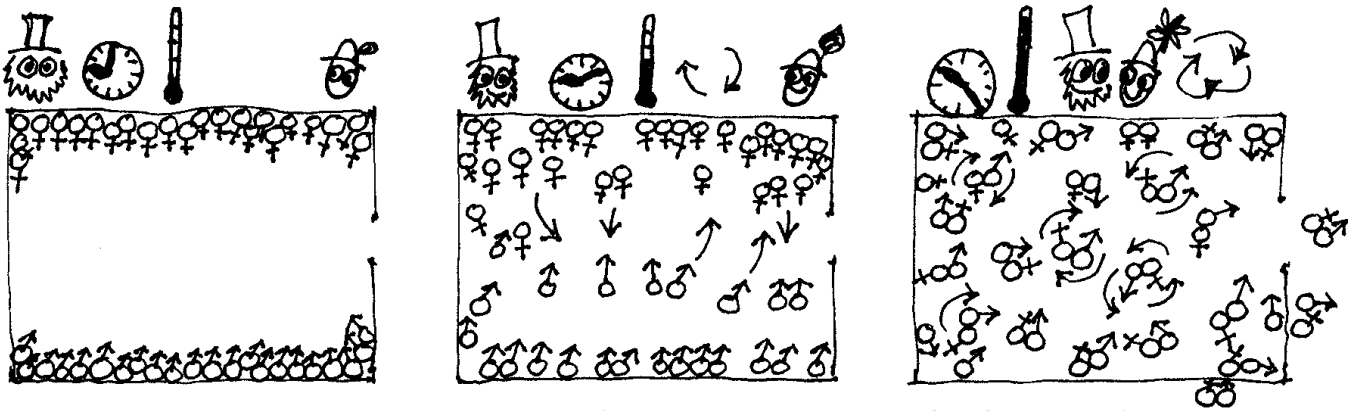
Watch a piece of firewood throughout its burn cycle, from when heat is first applied all the way to ash. First (a), you'll notice steam and pale visible gases squirting out as they reach boiling point inside the wood. Then (b), there will be smoke, blue or grey or sometimes black, difficult to breathe, smelling toxic (it is). Gradually (c), the outer parts will begin to glow as (d), the smoke catches fire. Then finally just (e), glowing coals, no smoke, no big flames, just little blue ones as those coals burn.

You just watched (a) the wood heating up and drying out, (b) the volatile oils boiling out as cellulose and lignin pyrolyze (break down under heat) into other chemicals, hundreds of them. When conditions are hot enough (c) the carbon which remains from pyrolysis, the charcoal, will then burn, glowing, creating carbon monoxide giving off heat and (d) the smoke catches fire with long yellow flames, turning itself into carbon dioxide and water vapor, and of course also giving off heat. Finally (e) the smoke is all gone, coals remain, glowing. Those short blue flames you see are the carbon monoxide burning, creating carbon dioxide and producing again more heat.

If there is insufficient oxygen, combustion will be incomplete, producing more smoke and carbon monoxide and, of course, less heat. The same happens if the burn zone is too cool or if oxygen is arriving too fast (blow out a candle). Campfires often smoke at first for lack of heat, but they also smoke if you restrict their air flow with wet leaves, shoveling dirt on, etc. The perfect stove has just enough oxygen, dispersed through the smoke gases, and a high enough temperature that everything burns down to only water vapor, carbon dioxide, *heat* and a little ash.

Given the problems of carbon dioxide and its notoriety as a greenhouse gas, people are sometimes shocked to hear that the stove puts it out, yet any wood stove even burning cleanly will put out carbon dioxide, as will a coal, oil or gas-burning power station, or a car using gasoline. The cleaner we burn wood, the less we use because we're burning more efficiently, thus creating less carbon dioxide. To be responsible, we need not to stop burning hydrocarbon fuels, but *to reduce* their use to a safe level. This is a good reason not just for clean burning wood stoves, but also for smaller houses, passive solar homes, snigger spaces, heating your body directly by contact, and not heating anything that you don't need to.

For a detailed readable further discussion see *The Woodburner's Encyclopedia* or *Heating Your Home with Wood* (see Recommended Books).



Time, Temperature, Turbulence. A barn dance is like a good fire. Good clean fun.

The Three T's

In seeking a clean burn, think 3-Ts: Time, Temperature, Turbulence. The molecules of oxygen and of the combustion gases all need to be able to find each other as well as commingle. It's like one of those huge country dances, where all the men line up on one wall, and all the women on the opposite one. When the music begins, everyone surges out onto the dance floor, looking for a partner of the opposite gender. For everyone to pair up, the tune needs to be prolonged (time), the music fast (temperature) and the dance rambunctious (there's your turbulence).

So your combustion unit needs an **insulated** combustion chamber (in order to maintain the dancers at a high temperature), a **tall** enough heat riser that all the oxygen is used up (as the hot, lightweight dancers strut and spin their way up it), and a non-streamlined profile to **tumble** the gases (shakin' their boogilators, as they say). Hence the **abrupt right-angle turns** in a Rocket Stove's interior.

The Thermal Battery

Even with the wood burning at a hundred percent efficiency, if we waste the heat by not using it, efficiency is moot. The cleanest burning conventional wood stove with a platinum afterburner may well burn all the wood cleanly, but in order to function at all, it needs to waste a proportion of the heat generated by discharging it up the exhaust pipe.

Unlike a conventional wood stove, Rocket Stoves don't need to waste heat to maintain a burn. The combustion unit at the core of a rocket stove turns wood into only carbon dioxide and water vapor with a little wood ash and heat. How we use that heat is a separate story.

Whereas with a wood stove, the chimney sucks cool air through the stove and pumps hot gases out of the building, the Rocket Stove creates pressure that we can guide and control in order to literally **direct the heat to wherever we need it**. We can cook with it or heat water or heat our houses or heat ourselves.

By attaching the Rocket Stove to a heat storage device, we are able to soak up the heat from the exhaust gases and store it for quite long periods. The 3-ton double bed attached to the rocket stove in our office stays noticeably warm for about three days after being heated up. It acts as a thermal battery, storing heat while the stove is burning, then releasing it slowly.

Note that in the heat storage—that is, the part downstream from the combustion unit—turbulence is not desirable. Any obstruction which would cause turbulence will affect the draw. On the other hand, exhaust gases move much slower than in a conventional wood stove so tight bends will be much less of a problem in a pipe of 6-inch or greater diameter. Long residency time and high temperature are both assets, at least near to the combustion unit.

HOW HEAT MOVES

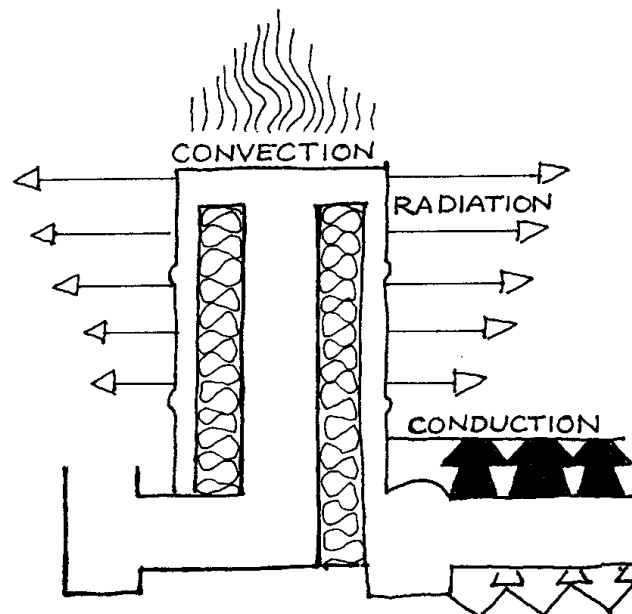
Heat is forever redistributing itself, the warmer parts of the universe constantly attempting democracy by generously heating their cooler surrounds. Anything warmer will always try to heat something cooler. If the temperature difference is great, the heat flow is faster, though impediments to heat transfer (insulants) will always slow it down. Remember that heat is flowing from warmer to cooler by three separate modes: radiation, convection and conduction.

Radiation is the direct transfer of energy through space. Sometimes it comes in the form of visible light, for instance sunshine; often the wavelength is longer and therefore invisible to us as is the heat from a metal wood stove. Sometimes it's a mixture, as at a campfire, or when you look down into the toaster, (which is a totally radiant heater with both visible and invisible rays singeing your bread).

Radiation moves in straight lines, in every direction, up, down and all around simultaneously through space until it meets a solid, where it is reflected and absorbed in varying proportions. Some surfaces such as polished aluminum reflect a high percentage. Skin, on the other hand, absorbs a much larger share, happily if you're cold and rather unfortunately if you're too hot.

All of this is useful if you are building a campfire, which heats you only by radiation, or a toaster, which is a radiant cooker. As a way of being comfortable, however, radiation has drawbacks. An obvious one is that it heats only exposed surfaces. Your front can be overheated while your back is freezing and clothing may prevent a radiator from heating you at all. To radiate best, stove surfaces need to be at dangerously high temperatures, and as the radiant surface changes temperature with the complexity of wood burning, you have to keep moving to stay comfy.

The **amount** of radiation received is proportional to how hot the source is and how far away it is. A hotter radiant surface loses disproportionately more heat as it warms up. If you get twice as close to a hot stove, you still get more than twice the heat.



*How heat moves
in a Rocket Stove.*

Convection is heat transfer by the bodily movement of a gas or a liquid. Smoke rises because it is warmer than the surrounding air. Peer into a glass of hot cocoa or miso soup and you will see a lot of movement as the warmer liquid rises and the cooler falls. It's all convection. A "convection oven" however, isn't—it has a fan. It is another misnomer that "radiators" under windows that heat public buildings are radiators because they really are convectors. They can't get hot enough to be effective as radiators as they would be too far away from most people. Most of the heat from those "radiators" is carried upward in moving air.

As a mode for heating people, convection isn't all that useful. To be warmed by convection, you need to be above the heat source. The best place to be comfortable for convective heating in a house is usually against the ceiling, where the warmest air ends up, and

convective heating from a fireplace would have you located in the chimney, unless your fire smokes into the room.

Conduction is heating by contact. When you shake hands with someone, if you think they have a cold hand it's because you're donating to them some of your body warmth. As with all heat transfer, conduction always flows from hotter to colder, however small the difference may be. If everything else is equal it flows equally in all directions, all around and up and down. "But doesn't heat always rise?" No, only by convection. Heat rising is not a characteristic of either radiation or conduction.

Conduction is most apparent through solids, depending upon how well the solid allows heat to pass through it. Conductivity varies a lot, from that of still air, which is extremely low, to that of metal (sit on an aluminum chair on a cold day).

Somewhere in between are masonry materials. The denser they are, the faster they transmit heat. Limestone and brick are medium-fast conductors; granite and basalt are faster; iron ore would be even faster because it's heavier. Denser materials and those that contain metal can be dangerously conductive, such as hot stones straight out of a campfire or a cast-iron frying pan's hot handle. They conduct faster because they're heavier.

In houses, conduction is rarely used for personal comfort. Fireplaces give us none at all, the warm parts are all far too hot to touch, and the same is true for most metal box stoves. We use hot water bottles, electric blankets and hot tea, all with quite brief effects. Cuddling with someone else is useful but not always practical. Most houses have only one conductive way to warm up fast; take a hot shower.

Insulation is any material that slows the passage of heat transfer. To delay heat moving by conduction, a good rule of thumb is to choose the most lightweight material available. Lightweight usually means there is air trapped in it. A down parka, sheep's wool socks, or a fiber-filled bed quilt all contribute to our comfort by trapping air, one of the most effective insulants known.

At high temperatures, most biological insulants either burn or fall apart and foam-boards melt and offgas dangerous toxins. For stove construction we need mineral insulants such as pumice, vermiculite or perlite. Clay is less insulating though not nearly as bad as sand, which is a lot heavier.

COMFORT THROUGH STORED HEAT

The Rocket Stove is a thermal pump that shoves out hot gas which can be used to heat built-in furniture. It can easily push hot gas through 30 or 40 feet of horizontal pipes, storing heat in the interior walls, floor or seating in a house. By sitting or lying on a heated seat, your body is warmed directly wherever it makes contact. You also bask in the warm air rising from that seat. In my own house I can comfortably do paperwork, sitting on the bench that my Rocket Stove heats when the temperature in the room is in the 50's. To be as comfy by heating all of the air in the building, the temperature would have to be in the 70's. Rocket Stoves take what would otherwise be wasted chimney heat to warm built-in furniture such as beds, couches and chairs, as well as floors and interior walls.

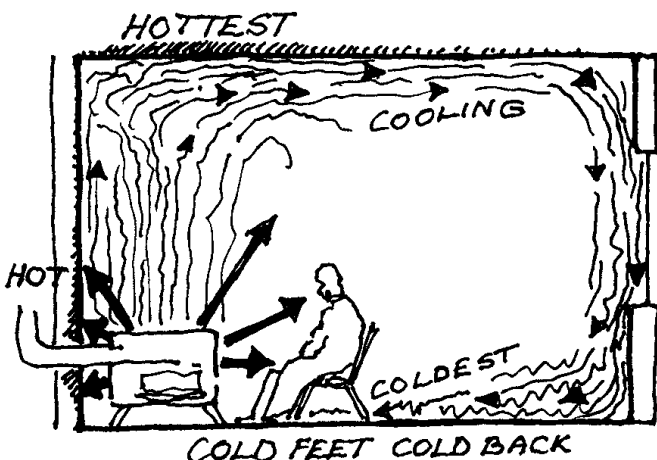
We live in surprising times. Every so often one can wake up to a societal myth that one has accepted all one's life. The myth that *houses need to be heated* permeates North America and society has encapsulated this obvious fable in law. Building regulations have demanded that whether you're home or not, every single corner of the interior of your house should be heatable to an equal

70°F. Let's be clear. Provided you don't let the water freeze, your house could not care less whether it's heated. The inhabitants are the only beings who count. We want to heat people, not houses. Once we understand this, the situation gets much easier.

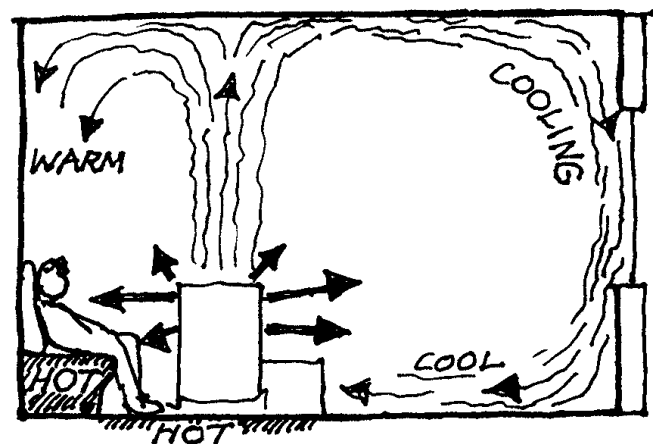
Humans, like all mammals, are self-heating. We have our own internal stoves, burning food to make heat. But as we become less physically active and spend more time indoors, we have become used to wearing clothes to slow the loss of our autonomously generated heat. In an unheated building we can adjust our comfort by adding clothes or through activity or by surrounding ourselves with warmth or through all three.

Houses heated by forced air or furnaces depend upon our bodies being in contact only with the warmed air inside the house. A house can contain an awful lot of warm air, of which only a very small proportion ever comes in contact with us. All of the other heat is effectively wasted. Air, being one of the best insulants, certainly isn't a fast or efficient way to warm up, and it escapes easily.

Standard Box Stove



Rocket Stove



How Rocket Stove heat is different.

Step-by-Step Construction

For first-time builders, we will describe a single well-tested model that we know will work well and is easy to build. The stove in my own house is similar; the Cob Cottage Company's office has one almost identical, as has the North American School of Natural Building. Here is a suggested order for designing the stove and its attached heat storage, materials and tools needed, dimensions and proportions, actual construction of the combustion unit, and finally the heat storage unit.

1. In an existing building, examine the site where the stove will be built.
2. Measure the space available.
3. Design your stove and heat storage unit.
4. Do a scale drawing of brick layout.
5. Assemble tools and materials (see list, page 29).
6. Clean all bricks, burn paint off barrels, make sure all pipes fit together, straighten them if necessary.
7. Build a mock-up of the combustion chamber outdoors. Use the materials you will build the permanent stove with.
8. Build a test fire in the mock-up.
9. Experiment with the test model in order to trouble-shoot and optimize your system.
10. Mix mortar, then insulation, then cob.
11. Level and compact stove site, if needed.
12. Roughly draw out position of the base of the entire device, including ducts, etc. Adjust as necessary, *in situ*.
13. Re-check the design. Does it still make sense?
14. Install any insulation needed below the stove.
15. Build the combustion chamber including the heat riser, one full course of bricks at a time. Check level and plumb at each course.
16. Install the small barrel at the feed hole.
17. Set up containment for insulation around the heat riser.
18. Pack insulation in.
19. Install big barrel around the heat riser.
20. Now test combustion again. Adjust barrel position to give heat where you want it.
21. Connect all the parts of the internal duct work.
22. Open all the windows and test drive.
23. Build heat storage.
24. Test drive again.
25. Clean up.
26. Fire up stove, put on tea.

Designing Your Stove and Thermal Battery

THE COMBUSTION UNIT

The combustion unit for a system that uses 8-inch diameter pipes, combustion chamber and flue will measure about 4 feet long by 3 feet high by 2 feet front-to-back, though it can take up less vertical space if you sink the whole thing into your floor. A six-inch diameter pipe system could be a little smaller.

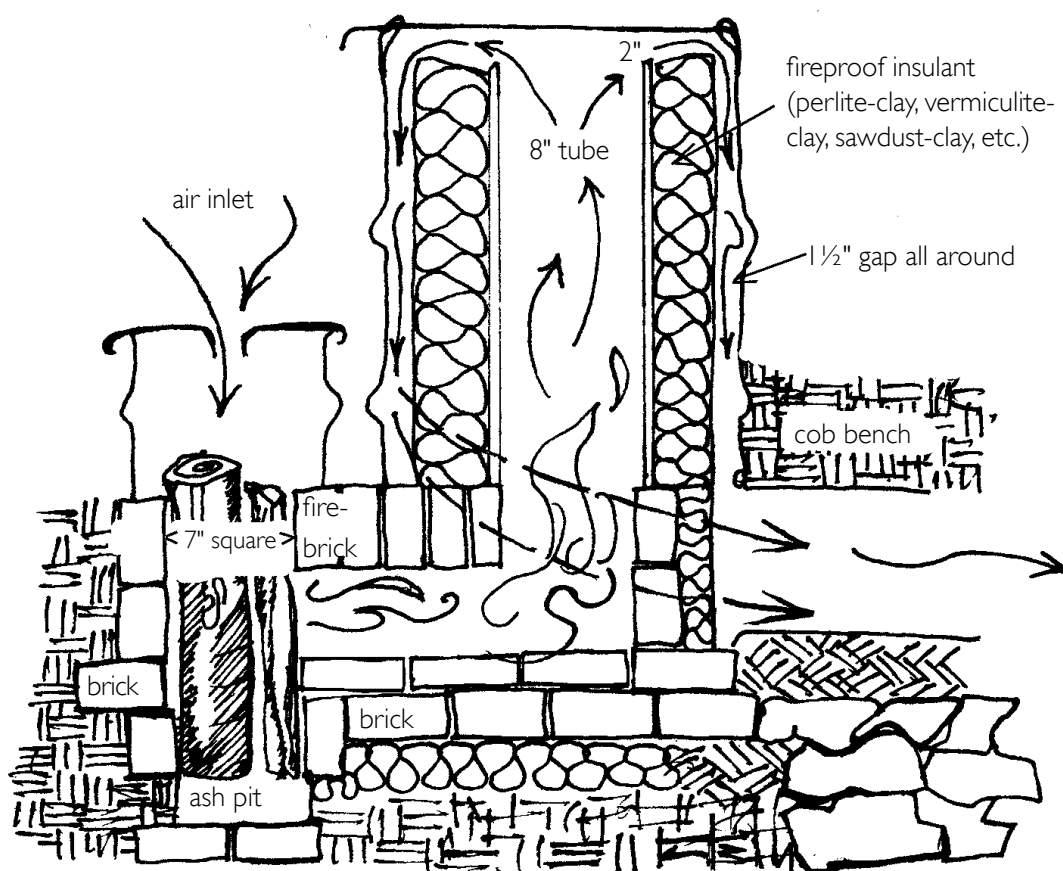
For your first-time build, play it safe with an **established and tested model of the combustion unit**. The heat storage, on the other hand, can be custom designed to reflect your family's needs. Don't try a complete floor heater the first time around, but you have many options for heat storage in your snug corner, your heated bench or a warm bed.

In very cold areas and a house over 1200 square feet, you may need a bigger system

altogether, including a larger barrel. There's probably a limit to how big you could build a Rocket without very specialized, high temperature materials. You don't want the whole thing to melt.

Placement of the stove in your house can determine where and how heat is available, how much is stored (or lost through walls or windows), and ease of stoking and fuel storage. For instance, a stove used a lot for cooking might be close to the food preparation, one mainly for lounging—guess where—in the lounge of course! Carrying in firewood can be messy, so you can reduce floor sweeping by locating the feed tube close to the door.

Components and dimensions of an 8-inch rocket mass heater.



Arrows with broken lines show gases passing around the barrel.

DIRECTING THE HEAT

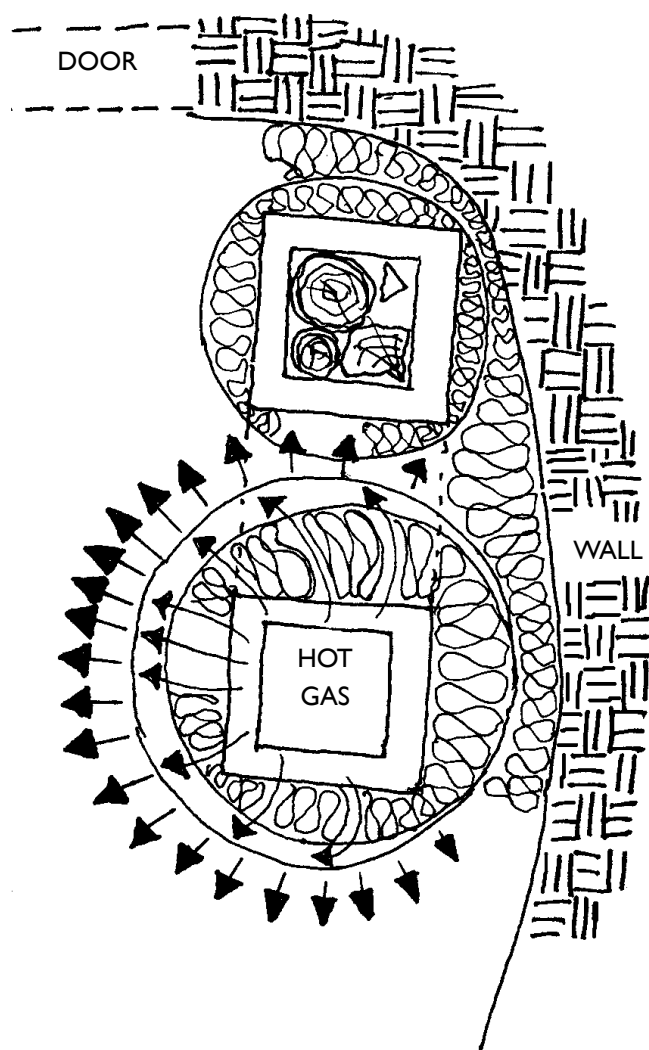
There are variables which change where the heat is delivered. You can divide the heat that your stove generates according to your needs. There will be a trade-off between fast radiant heat and a long-lasting thermal battery. What heats up quickly—for example, a radiant barrel with little insulation around it—also cools down quickly. Conversely, what heats up slowly cools down slowly, so that the system with its pipe sunk several inches into a massive bed or couch provides warm comfort all night, hours after the fire has gone out. Decide well in advance what proportion you would like to have available for cooking,

fast convective heat in your house, direct radiant heat that you can sit in front of, or contact heat that you sit, sprawl or lie on.

For instance, to maximize cooking efficiency, keep the top of the heat riser close to the barrel, about two inches. You will create a circular hot spot in the middle of the barrel top. For most usable radiant heat, leave a wider sleeve inside the barrel on the side where you would be sitting and pinch the sleeve in other directions. For a quick warm-up in the room you could build a taller heat riser with a bigger radiant barrel, possibly welding two barrels together end-to-end or using another conveniently sized metal container.

If radiant heat is prevented from escaping from the barrel, more heat will flow into storage. Part or all of the barrel can be encased in cob, and/or the barrel could be replaced by cob or brickwork. Thus, a bigger proportion of your heat will be available for storage and contact heat. You may want to size storage and the length of buried flue with that in mind.

If the wall behind the stove and bench is not well insulated, incorporate insulation between bench and wall and extra insulation behind the stove. Temperatures probably won't be high, but avoid foams as they may outgas. A couple of inches of clay-vermiculite, clay-perlite, or even clay-sawdust would be sufficient.



Eccentric gap around heat riser/insulation to favor radiant heat into the room. Serious insulation against exterior wall.

The Thermal Battery

Working with cob* offers structural flexibility like nothing else. Here is a medium which is eminently sculptable because you apply it handful by handful. The shapes are as limitless as anything you can build with clay, though you should avoid sharp corners, which can break off easily.

The shape you end up making your heat storage can be elegant and eloquent, whimsical yet grounded and comfortable, in conformation with your body's geometry.

The heat storage—the thermal battery—works best by slowly heating while there's a fire burning. Then that heat disperses throughout the mass, and finally heat leaves slowly, mostly by contact and convection, mostly at the points where and when you want it to leave. Total storage is limited by weight, not volume, so use heavy materials packed tight around the heat transfer ducts, then lighter, better insulated materials to enclose the whole thing.

The best way to achieve the thermal mass required is to use rock or broken concrete mortared together with a sand-clay mix without straw. If the bench is made entirely of cob it will have substantially less heat storage capacity than one that is largely stone.

On the other hand, the *proportion of available heat* you can extract from the hot gases depends upon the length, surface area and number of ducts exposed to the gas. Both the length and the diameter of the heat transfer ducts within the storage are critical.

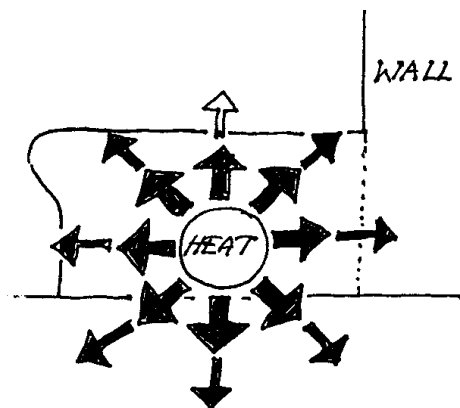
Placing the Pipe

The longer the run of duct inside your bench, the more heat you can extract from the combustion gases. For more even distribution of heat across a wide bed, you can loop the ducts back and forth or run more than one from a common feed, reuniting them later. Bench systems with 30 feet of pipe work well and can reduce

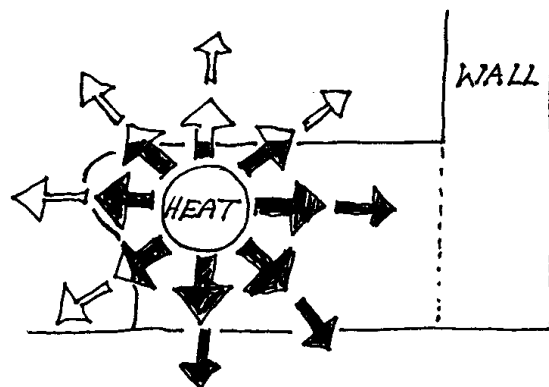
the exit temperature of the gas to as low as 100°F, thus storing a very high proportion of the heat generated. For example, the 7-inch pipe in one of the benches at the North American School of Natural Building in Coquille Oregon is 31 feet long. When it's burning really hot, I can actually lick the exhaust pipe, to the amazement of visitors.

To rescue most of the heat, a 6-inch system should have at least 20 feet of internal duct, and a thermal mass of about three tons. An 8-inch system needs 30 feet of duct and should weigh about 5 tons. If you have a suspended floor, the extra weight will probably need additional structural support so your floor doesn't sag.

If you have a masonry slab floor, positioning the heat transfer duct low down can utilize the mass of the floor for extra heat storage.



Exhaust tube sunk low in center of bench allows more heat storage in the bench (above). With the exhaust tube located higher (below), the surface of the bench is hotter, but less heat is stored and the bench cools faster.

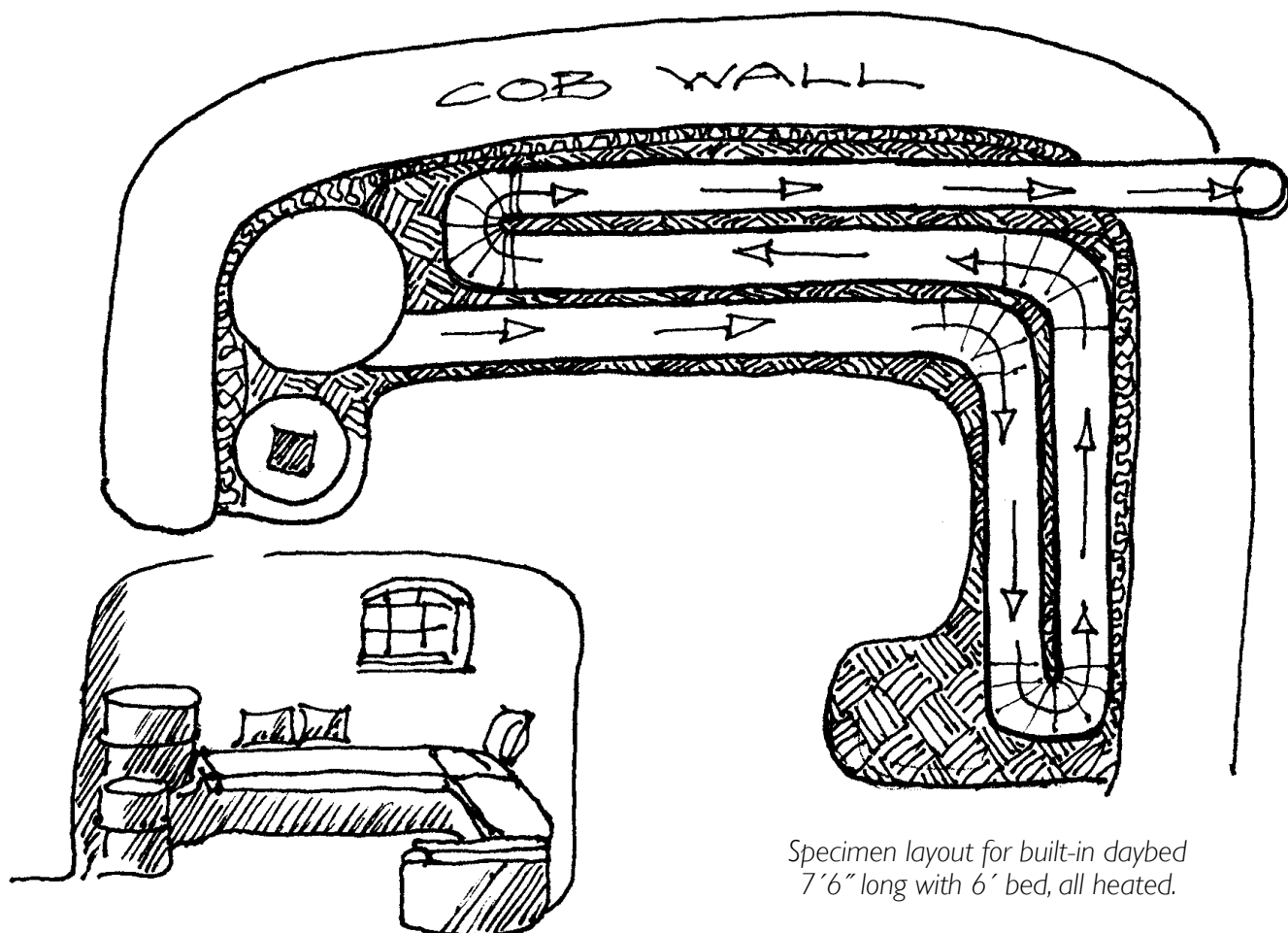
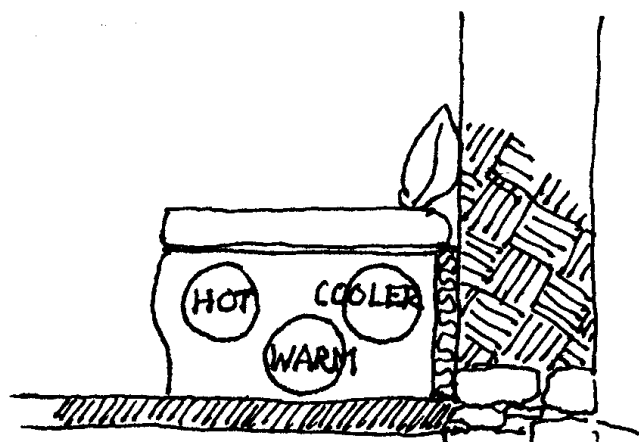


* See Glossary

Heat travels through cob at about an inch per hour and through rock about twice that fast. The duct that carries the hot gases through the bench can be positioned high to deliver fairly fast heat in a limited area or to store more heat for longer periods by being buried deeper into the bench. The effect is more noticeable with a wider bench. For instance, a duct with two inches of cob above it would provide a hot strip about two hours after the stove is lit. A bench 16 inches deep with a 6-inch duct 2 inches below the surface is left with 7 inches beneath it to be heated, so less is stored for a shorter period because heat is being lost faster and earlier from the surface. A duct that is too close to the surface can also make the bench uncomfortably hot along a line above the duct, yet quite chilly to either side. Our first Rocket Stove had a six-inch duct only two to three inches below the surface. In order to store sufficient heat

to warm the building adequately in very cold weather, we once got the bench so hot that it set fire to the cotton padding in the futon on top of it. If you plan to have a thick mattress or cushions on top of the heated bench, keep hot ducts deep in the body of the bench -- six inches, if possible.

Generally, it is advisable to set the duct work fairly low in the bench. This will give more even heating, and retain heat a lot



*Specimen layout for built-in daybed
7'6" long with 6' bed, all heated.*

longer especially as ash that accumulates in it will be at the bottom. Ash is an excellent insulator, so less heat travels downward than up or to the sides, unless the duct is always scrupulously clean. There's no necessity for the duct to continuously rise towards the exit. In fact if you wish, you can bring it up close to the surface, then to create a hot spot in the bench for rapid warm up, drop it again.

Sizing Built-in Furniture

Wall benches are comfy at 18 inches deep (front-to-back), though tolerable at 15 inches and should be 14 to 18 inches high. A lower bench has less capacity to store heat. You could accomplish both heated bench and bed by designing a bed that tapers at the foot and is widest at the shoulders. For seating, the bench is most comfortable if it is widest at the top of the seat, being undercut 3 to 5 inches, so there is space for your heels when you are sitting down. Make allowance for the overhang when you begin building.

If against a wall, a heated bed should be at least 7 feet long, 2½ feet wide (single) or 4½ feet (double). If free-standing both should be wider. At 7 x 4½ x 1½ feet it would weigh about 2½ tons. A 1½ foot wide bench 15 inches high would need to be 10 to 12 feet long to weigh one ton. In either case, a deep-set exhaust duct on top of a mass floor could substantially increase the effective amount of heat stored. You will first need to decide what power output and heating capacity you will build, based on exhaust duct diameter. Experience so far suggests that using the model described, a six-inch exhaust duct will heat only a tiny space in a rather mild climate, say, where temperatures don't normally drop below 20°F. In colder temperatures or in a larger house, you need an 8-inch system. We give step-by-step instructions for building an 8-inch system. If the system is bigger than you need, you can always simply run it for less time, but a too-small system is more difficult to remedy.

PLANNING THE EXIT FLUE

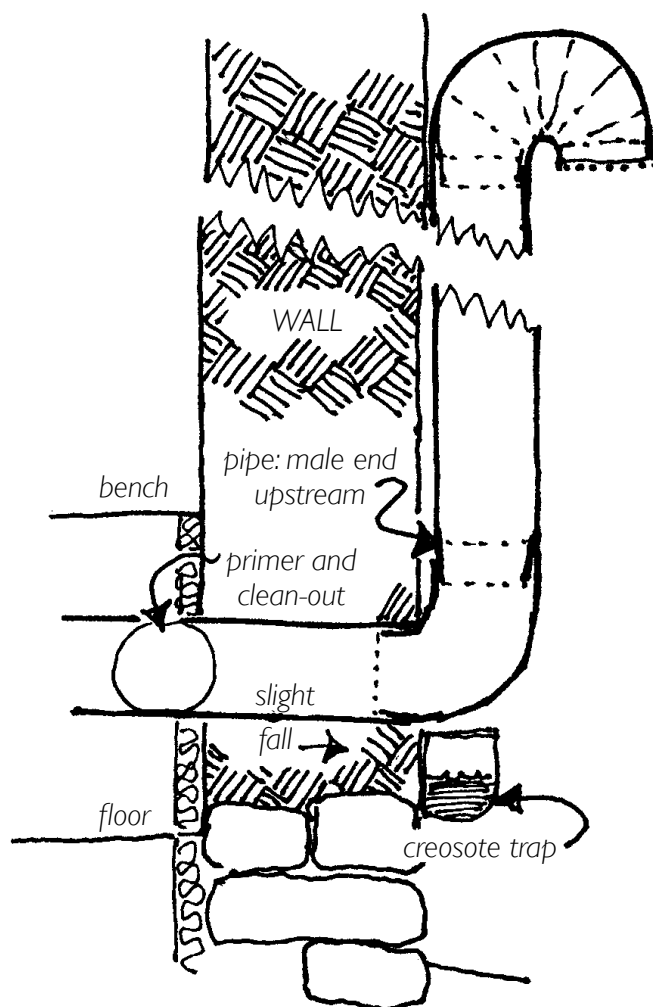
Rocket Stove chimneys behave differently from those of most wood stoves. When they are operating properly, gas temperatures are so low at their exit that fire danger is almost zero, but because of these low temperatures, water vapor in the stack is more likely to condense with creosote in solution at times. Higher efficiency of both combustion and heat use means a generally lower output of gases so the slower passage of cool moist gases contributes even more to condensation. Unprotected steel corrodes very quickly if it is uninsulated, or exposed to rain, or if its inside surface is not galvanized.

Consider carefully where the exhaust pipe will exit the building and where its outdoor end will be. Because a Rocket Stove pushes gas along the exhaust flue, there will be pressure inside the flue trying to squeeze gas out through any cracks. At some point of the burn, there may be CO and NO_x present, both very toxic. So, if you leave any exposed metal pipe inside the building, seal the joints very thoroughly with high-temperature silicone or high-temperature tape, to make really sure no gas can escape. With clip-together stovepipe, seal all along the clip joint as well as the connections between pipes. Then test for leakage by building a very smoky fire and blocking the exit at the top of the flue.

With *extremely* low temperatures (below 100°F in some cases) it is possible to end the stack in a position where rain will seldom reach it, under a lean-to roof or under the eaves.

If the stack is more than a few feet from the stove the exit gas will have cooled enough that there's no fire danger, so normal precautions for insulating an exit stack or isolating it from flammable materials may not apply. For other precautions, see the chapter called Fire! Fire! on page 58.

Make particularly sure the clean-outs and primer hole are well sealed. Any small crack downstream of the heat exchange barrel could leak dangerous gases, especially if the



Make sure the flue tilts down to the outdoors, that male ends of pipes are upstream (not necessarily up the pipe vertically) and that there's a primer just inside the building.

flue is long and/or you have an uninsulated exterior exhaust pipe. If you have any doubts at all it's probably worth investing in a carbon monoxide detector. They are inexpensive and easy to find.

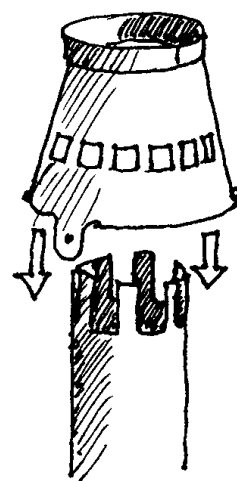
As for locating the flue outside the building your main enemy is wind, particularly in sudden gusts. It's hard to predict where this may be a problem so have an alternate plan if there's even a suggestion of smoke backing up into the house. Consider relocating the pipe completely on the downwind side of the house, or making it much taller or using a commercial wind cowl on the top. If there is a known prevailing wind at times when you'll be using your stove, try not to exit your stovepipe on that side of your house.

Following a long run through a bench, the exit gas temperature should be very low

and there should be very little smoke. So it's possible to end the pipe in a sheltered position such as under the eave of the building. Mount an elbow on the top of the pipe and point it slightly downward to stop rain accumulating in the stack. A piece of $\frac{1}{4}$ " hardware cloth over the end of the flue will prevent animals climbing in.

Chris and Jenn Reinhart use the commercially bought T-connectors, arranged as a letter H. See more about the Reinharts' stove in Case Studies.

Ernie Wisner has used a galvanized steel bucket set over the end of the flue, with slots cut into the pipe for gas escape.



Preventing blowback

Some things to consider about chimneys:

Q. Should I exit the building down low or keep the stack inside as long as possible to strip a little more heat from it?

A. Well, if your flue temperature is already low at the end of the heat storage, say under 120°F, there really is little advantage to keeping the flue indoors. Take it out. Complications from creosote, toxic gas leaks, chimney fires, etc are much better dealt with outside a building.

Q. Should I go all out and build a masonry chimney or just settle for metal pipe?

A. Masonry chimneys take a lot of materials and labor. They are a potential entry point for rainwater. In earthquakes, they are often the only things to fall down. Our preference is for a good quality metal pipe, though it may not be as durable.

Q. Should I put a chimney damper at the end of the stack?

A. NO. Don't install a chimney damper! It can cause carbon monoxide to back up into the room.

Materials and Tools You'll Need

for an 8-inch flue system with a cob bench for heat storage

MATERIALS

Bricks, about 60–70 for the entire combustion chamber. If you don't use brick for the heat riser, 30–40 should do it.
Clay or clay soil
Sand } for cob and cob mortar
Straw (½ bale) or dead grass
15–17 gallon barrel for the feed tube
30 or 55 gallon barrel for the heat exchanger
8" diameter stovepipe/metal duct
Insulation: vermiculite, perlite or pumice (a 4 cu. ft. bag is plenty)
Insulation container: Water heater tank or ⅛" wire mesh (metal screen) or metal roofing, or sheet metal
Scraps of ⅛" or ¼" hardware cloth (optional)
Urbanite, rock or brick for heat storage

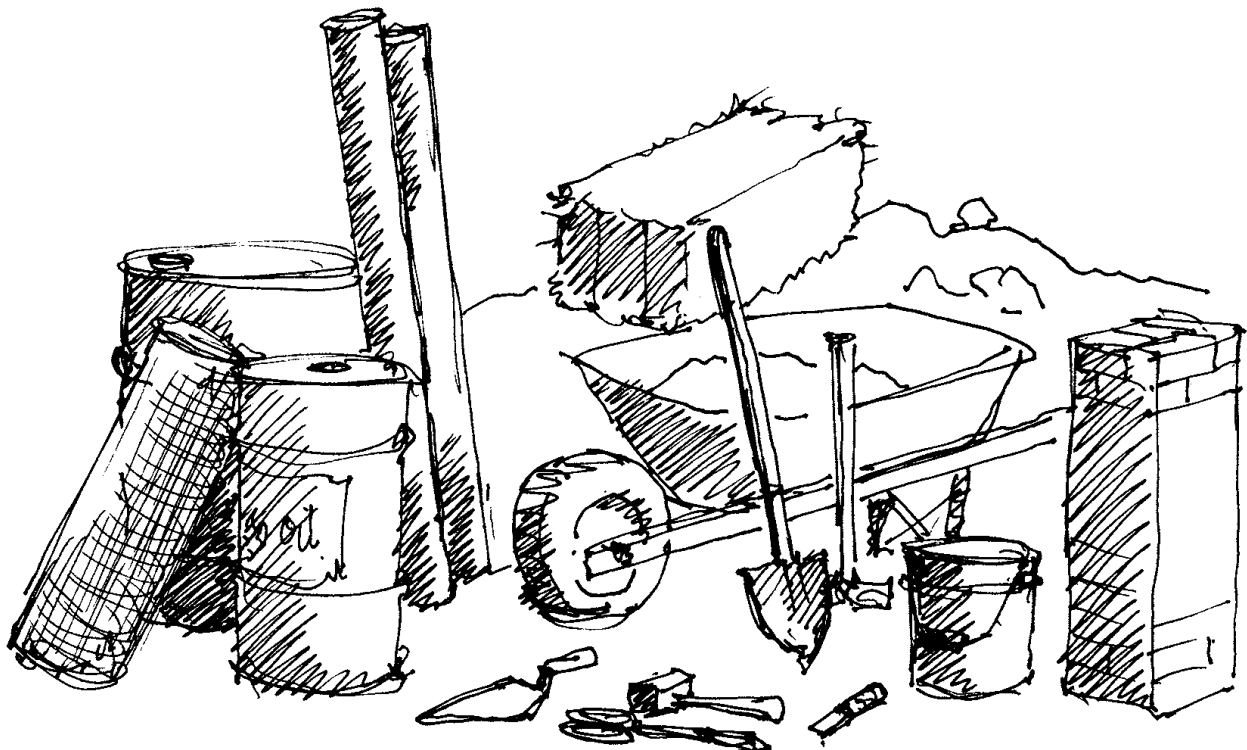
Alternative heat riser/burn tunnel: ¼" thick steel pipe, 2" shorter than interior of barrel, same diameter as ducting (exhaust system).

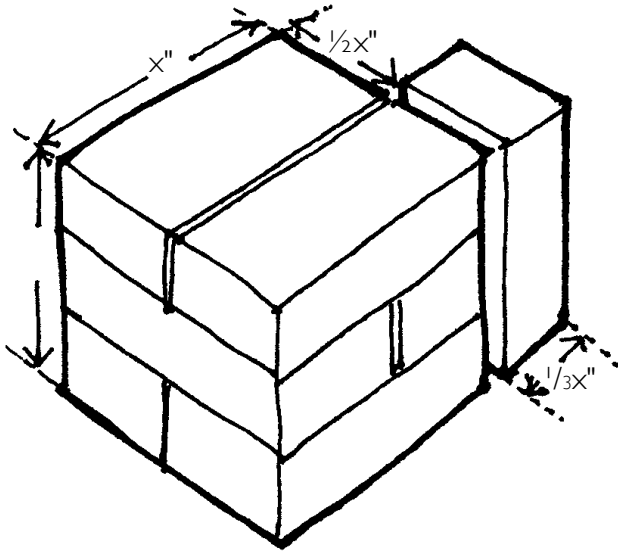
TOOLS that are essential

Shovel
Mattock or pick
Buckets
Wheelbarrow
Sharp pocket knife
Builder's level, 2 feet to 4 feet long
Measuring tape

OTHER TOOLS that you might need

Plastic tarp, about 8 x 10 feet
Hammer, cold chisel
Brick hammer, brick chisel
Mason's trowel
Chimney thermometer (magnetic, stick-on type)
Tinsnips, pliers
Old window screen (for sifting sand)
Rags





*Most bricks have proportional dimensions.
Firebrick notably so.*

Bricks

From the bottom of the feed tube to the top of the heat riser, temperatures are intense. Temperature change happens very suddenly so the materials need to withstand sudden thermal shock, and of course need not to melt or burn at up to 2000°F. We have tried a lot of different materials and in general find the most durable to be soft common brick or a thick-walled steel pipe. Sooner or later most bricks seem to crack and break up in the extremely stressful conditions inside the area of combustion. Firebricks are perhaps more durable but quite costly, especially lower density kiln grade which is the better insulator. Soft common brick seems to work well, is easy to cut, and is often more resistant to cracking, particularly really old, low fired orange colored soft brick. But old bricks can be of irregular size and shape so make sure you have matching sizes.

Make sure you have sufficient bricks in good enough condition to do the job. Most of them will need to be intact, though you may be able to use partial bricks in places.

They should be clean of mortar and without bulges or parts missing and they should be quite similar in size. Clean off lime mortar by rubbing two together, grinding every face flat. Or use a machete, flat blade or brick hammer first. Note that many bricks are made to modular proportions to fit together in all dimensions. Thickness is about a third of length; width about a half, allowing for mortar joints. Old bricks were not necessarily made to standard dimensions and different manufacturers each had their own size. Any irregularities should be readily apparent. The more irregular your bricks are, the more mortar it will take to keep them apart as you build. You'd like to limit mortar thickness because brick is stronger than mortar and you want to minimize the weakness inherent to mortar joints.

Clay

Clay can be found in the ground within about a mile of most places in North America. It will probably be mixed with sand, silt, organic matter and possibly stones. For making mortar, you will need wet clay, pressed through a $\frac{1}{16}$ " screen or metal fly screen to remove rocks and impurities. For the combustion unit, that is, the stove itself, you'll need no more than five gallons. In the unlikely event that you can't find native clay, you could buy potter's clay from a ceramic supply store or ask your local potter for unwanted scraps. Or buy a bag of powdered "fire clay" from the building supply store. It performs better at high temperature and is easy to mix for mortar.

For building the cob parts of the heat storage, such as a built-in seat or bed, the clay may not need to be screened. If your clay soil is rich and sticky, you could need up to a ton or so (about 25 five gallon buckets) to build a heat storage bench or bed. If the soil has less clay, you will need more of it, but would need less sand to stabilize it and prevent cracking.

Sand

For mortar, you need a bucket full of $\frac{1}{16}$ " screened washed **mason's sand**, which you could either buy from a building supply store or screen yourself from cheaper coarser mixed sand. Don't use fine sand from beaches or sand dunes. It doesn't lock together well. Additionally, if you are building the heat storage with clay-rich soil, you'll need **builder's sand**—sometimes called **concrete sand** or **fill sand**—and you'll need quite a lot, depending on the size of the storage unit. It is normally sold by the cubic yard and you can expect a cubic yard to weigh over a ton, so don't put more than half a yard in a half-ton pick-up truck. Start with half a yard and see if that's sufficient. You can always get more later.

Barrels

To contain the hot gases issuing from the top of the heat riser, we often use a simple steel barrel, though people have used water heater tanks, garbage cans, or custom built cob or brick cylinders. You can regulate the amount of heat that the barrel gives up by the size of container you choose, and by whether parts of it are enclosed by a thermal buffer of cob, brick, etc.

To contain the fuel that sticks up from the feed tube, those 15 to 18-gallon grease drums that you sometimes see in gas stations or truck repair shops are ideal. Some have a press-down lid with rounded tabs all the way around the edge. Take out the rubber gasket. Usually, there's a two-inch bunghole in the center with a threaded cap that you can screw in or take out. Most Rocket Stoves with eight-inch flue size get just the right amount of oxygen to sustain a clean burn with the lid on and the bung open.

Used barrels are available many places. You shouldn't have to pay more than about fifteen bucks for a really good quality 55-gallon barrel. It might be worth trying one with a detachable clamp-on lid for ease of inspection, cleaning, etc. Try your local



Just barrels, in this case two 55 gallons, a 25, and a 17, often unwanted and in good shape.

dump, bulk food stores or caterers, building materials reuse stores, second-hand stores, scrap metal places and old industrial sites. Other sources include yard sales (ask, because they won't have them up front with the clothes and books), suppliers of honey or cooking oils, service stations and mechanics. 55-gallon barrels are easy to find, but in some areas, smaller ones are scarce, as plastics take over the barrel industry. The feed barrel isn't essential to a good stove; you could fashion it from sheet metal fairly easily, or use part of a hot water tank.

Barrels are highly likely to be painted and may have residues of what they contained. It's necessary that you burn off the paint before you get them inside the building, ideally in a good hot bonfire. Stay upwind and wear a respirator, as both the exterior paint of a barrel (not to mention the mysterious substance on the inside) can be toxic. Think about who is downwind. Clean out as much residue as you can before you burn them and make sure the bungs are detached before they get near the fire. After burning, use very coarse sandpaper from an industrial sanding belt to take off any remaining paint. You can use it with or without the belt sander.

Can a barrel melt in these temperatures? We haven't seen it happen yet. The melting point of the steel used in the typical oil drum is a much higher temperature than the stove will achieve.

Stovepipe

You'll need pipe to form the tunnels in your heat storage, or you could build a brick tunnel. The tunnel, however, does need to have a smooth interior surface so that the gases can flow along it gracefully, without being slowed by the drag of the walls. So the best option is to build your bench, bed, etc around metal duct work or stovepipe. Of preference, choose pipes bigger than you think you need, rather than smaller; they will get effectively smaller over time as ash, soot and dust accumulate.

Pipe diameters should be the same throughout and it's helpful to have adjustable elbow sections for changes of direction. Measure the diameter in advance, occasionally you will find a piece of $5\frac{3}{4}$ " in the 6" pile, for instance, and they won't quite fit together. You need a tight fit to prevent the chance of carbon monoxide escaping through cracks in your masonry.

Preferably the pipe should be circular in section, not square. For strength, use steel or aluminum. You're going to leave it inside the furniture, so it's best if it's not painted, as some paints will burn off at bench temperatures and could escape through cracks in the cob.



Hot gases spiral up a flue. A round flue will carry more gas, more smoothly.

Buying new stovepipe can be expensive, so go to your local building reuse place, or a rural dump, or try yard sales, second-hand stores or dumpsters where demolition is happening. The pipe doesn't have to be in perfect condition, even small holes, dents, etc will be okay. Reuse stores in some places

are not allowed to sell certain used stovepipe back to the public, so I have been asking stove contractors and dealers to save their used pipe for me, which would otherwise be thrown away. It should be possible to buy old 6 or 8-inch pipe for less than a dollar a foot. New stove pipe is quite expensive, particularly the triple wall variety, while air-conditioning or heater duct is cheaper.

High Temperature Insulation

Thermal insulation uses trapped air to prevent the passage of heat. The more air in a substance, the better it insulates, witness your down-filled parka or thermal sleeping bag. Thus the insulation you use should be as light as possible. There are three materials that we have found work well to insulate the heat riser in a rocket stove: lightweight pumice and vermiculite and/or perlite mixed with clay slip. All three are fairly easy to find, inexpensive and simple to use, although both vermiculite and perlite may give off dust, so use a respirator when mixing them. The clay slip helps to bond the lightweight dusty particles together and to hold a shape. Buy the coarsest grade of perlite you can find. Sources would include masonry building materials suppliers. Avoid horticultural suppliers, as horticultural grade perlite is very porous and takes up a lot of water.

Perlite comes in big plastic bags. We get four cubic feet for around ten dollars. You might need two bags for a 55-gallon stove, a single bag for a smaller one. Make up a clay slip by mixing clay and water very thoroughly. You can do this with your bare hands, with a paint paddle on an electric drill, or with a wooden paddle. I like the bare hands method; I enjoy the feel of the clay between my fingers. The mixture should be thick enough that after you dip your fingers in it you cannot see your fingerprints. Mix slip with perlite at 1 measure of slip to 6–9 parts of perlite. Dump a few gallons of perlite onto a tarp or into a wheelbarrow and sprinkle the clay slip over the pile as broadly as you can. Tumble the pile with your bare hands or a shovel or by

rolling the tarp. Try different methods. The idea is to get the white grains dirty all over, totally clothed in clay. It may take quite a lot of time to get it completely mixed. When you're through, you should be able to pat together a little snowball of the mixture and have it stay intact on the surface of your palm. Don't use any more clay than you have to because clay is denser than perlite and will reduce the insulating qualities of the mix. And don't compact the mix in tumbling it or in setting it into the stove. Compaction will reduce the insulative value of the mix.

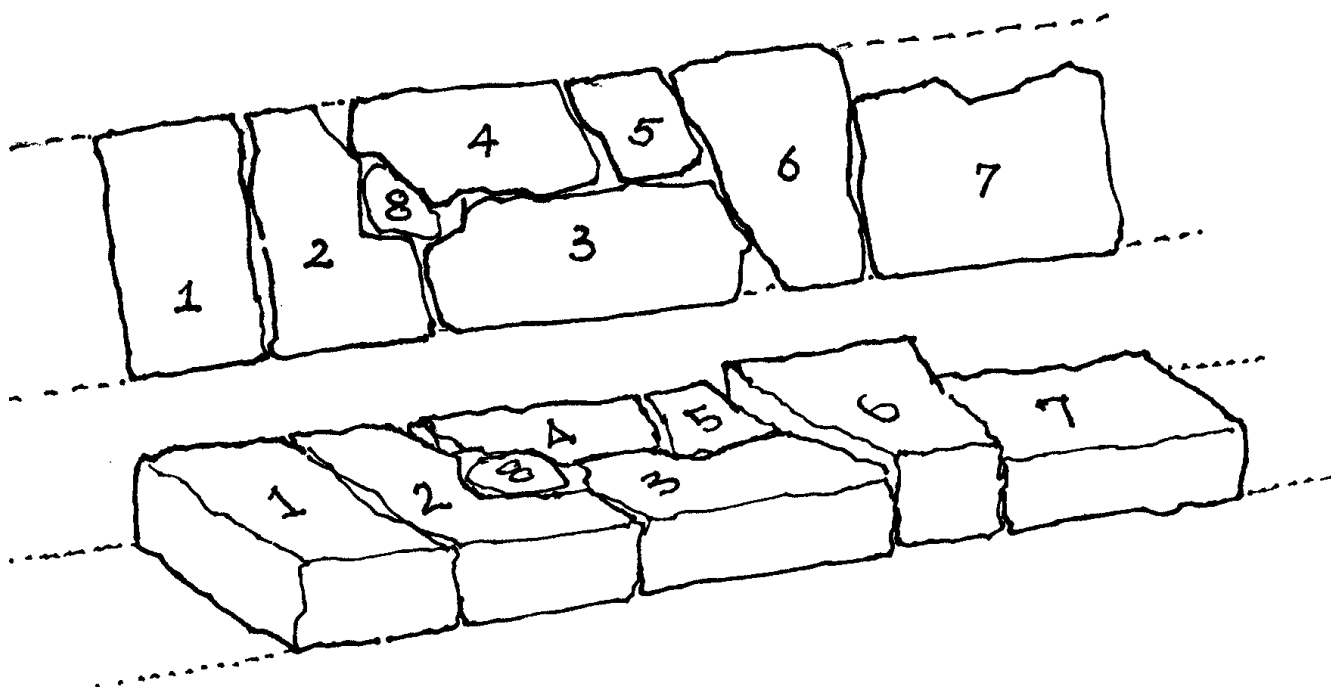
Insulation Containers

Most fireproof insulation is either in the form of loose-fill or sheets of fiber. Both need to be contained, even if you mix clay with perlite or vermiculite. You will create a cylinder of wire mesh or of sheet metal, or perhaps use a ready-made container such as an old water heater tank with the ends cut off. Used materials should be quite adequate, obtainable from scrap metal merchants or at your local dump or used building materials centers.

Steel Pipe

If you choose to use a pipe for the heat riser, the best source is usually a scrap metal place. Sometimes they will cut it to length. It should be at least $\frac{1}{8}$ " and preferably $\frac{1}{4}$ " thick. Pipe can be round or square, but note that a square tube of the same cross-sectional area won't carry gas quite as fast, so for an 8" round flue you might use an 8" square heat riser. If you choose steel for the burn tunnel or feed tube, be aware that where oxygen is plentiful it will gradually burn away.

Several people have experimentally used triple-wall stainless steel pipe. Its durability in Rocket Stove use is not known, but its thermal mass is low and its insulation value is high. So it could be a valuable material to use. It makes narrower heat exchange barrels possible. In some areas triple wall is available second-hand.



Selecting Urbanite. Choices in order of preference are: (1) Parallel sides, right angle corners, good face on each side of wall, rectangular. (2) Two good faces, three right angles, large. (3) One long good face. Half-width of wall, large. (4) Medium long face, half-width of wall. (5) Small, half-width of wall. (6) Less desirable: two good faces, but stone is thicker or thinner than most (problems laying next course). (7) Big and a good face, 3 right angles, but being about $\frac{3}{4}$ wall thickness, difficult to add to alongside. (8) No good faces, but can be used as infill.

Urbanite

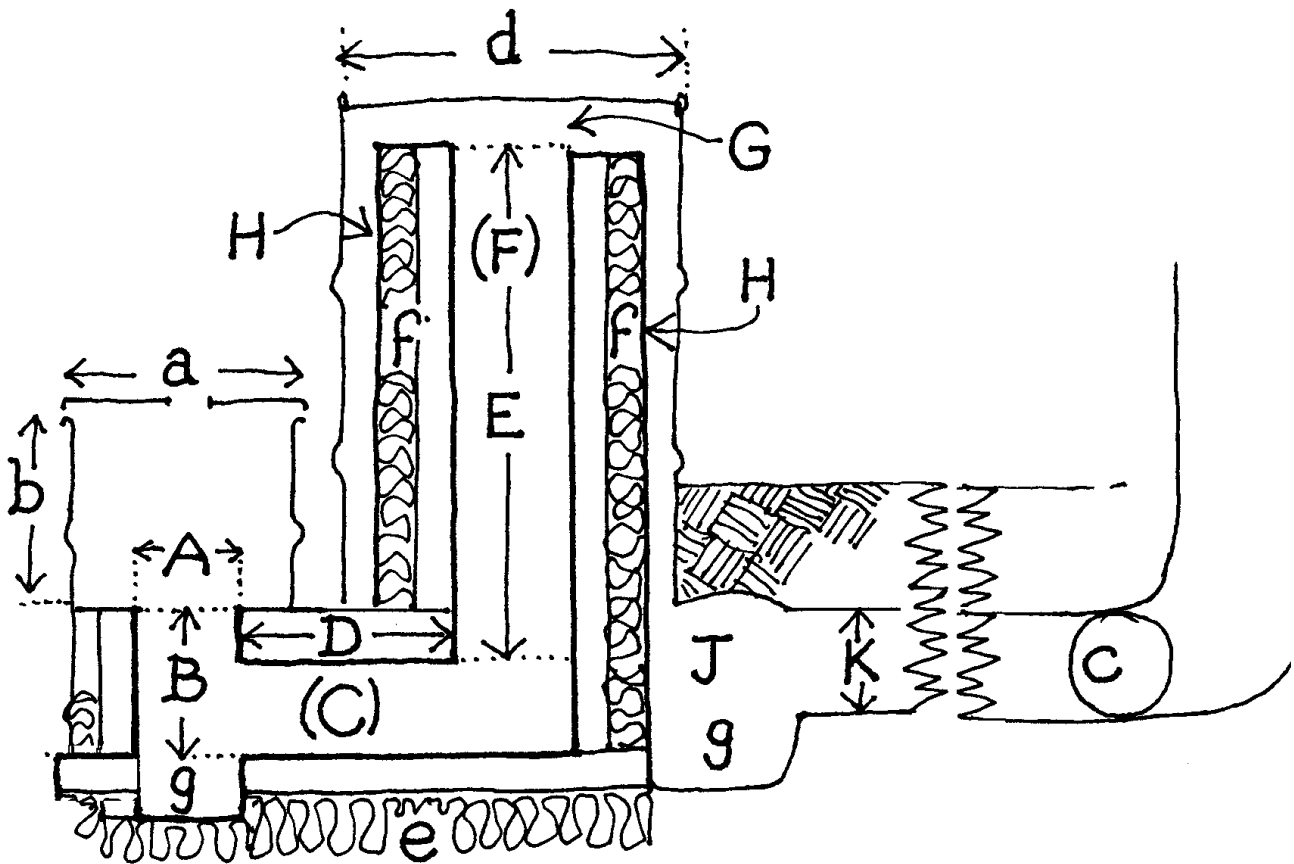
Urbanite is a common mineral found mostly in cities. When sidewalks, driveways, patios and garden paths are broken up, chunks of concrete are often hauled off to a landfill dump or recycled to make gravel. Urbanite is very common in the waste stream and sometimes can be delivered free to your site or is at least free for the taking, saving the owner a dump fee. Look for 3", 4" or 5" thick chunks. Really thick urbanite is too heavy to handle and when there is rebar or wire mesh reinforcement in it, it's too hard to break. Go with a sledgehammer and goggles, you may need to break it up at the source. For ease of layout, try to choose pieces that are the width of your wall, or about half that width, nothing in between. Take pieces as big as you can handle. A wide 2-inch thick board about 8 feet long makes it easy to slide heavy pieces into your vehicle. Urbanite is very heavy, so

the economics of hauling long distance soon get to be an issue. Look for it close to your building site.

Straw

Straw is the fiber portion of cob that gives the material its tensile strength. There are many sources of straw: Animal feed supplies (be sure to get straw, not hay). The cheapest way is to find cast-offs from carnivals, country fairs, and large strawbale house building contractors who have purchased extra. Used horse bedding, although it may contain urine or dung, will make excellent cob. Just make sure straw bales haven't gotten wet, as straw can rot and cause problems. A bale can cost from \$4 to \$12.

Dimentia and Proportia



A few dimensions and relative proportions are critical to your rocket stove working at all. Some others are not crucial, but are strongly recommended. The dimensions of critical importance are keyed in the diagrams on this page and on page 38 with large, bold capital letters. Some dimensions are not critical; we note that too. Throughout this section, we'll describe the dimensions and proportions of a basic downdraft self-feeding cooking and heating rocket stove with a 55-gallon drum heat riser and an 8-inch stovepipe flue. Refer to the diagrams on page 38 and double-check all of the numbers and letters before you begin building.

A is the cross sectional area of the feed tube. It should be kept **very tight**. Note that an 8-inch pipe at K gives you about 50 square inches, so the cross sectional area of A would allow a hole about 7 inches square or 6 inches by 8 inches. (A 6-inch exhaust pipe can take about 6 inches by 5 inches, (30 square inches) at A. (The calculation for area within a circle is πr^2 .)

B is the effective height of the feed tube, down which fuel self-loads by gravity. **Keep it short.** The fire should not burn all the way up the feed tube. In a well working stove there will be enough draw through the stove to keep combustion to the very bottom of that tube. The tube is best rectangular or square (not rounded), in cross section.

C is the area of the horizontal burn tunnel, normally made of brick, in which most of the burning happens. If convenient, make it slightly wider than high. A single brick on edge is about 4 inches high, so arrange bricks flat or on edge to make up the required height.

C should be the **tightest part** of the intestinal system. The size of the cross sectional areas of all parts of the stove's internal ducts or intestines **should never decrease below that of C**. In other words, the cross sectional areas of E, G, H, J and K should all be greater than that of C. Make sure you keep the cross sectional areas of the exhaust stack, the horizontal flues, and

the gap at the top of the heat riser bigger than the area of combustion at **C** to avoid bottlenecks which could slow combustion or back up smoke into the room.

D is the distance from the feed tube to the heat riser and should normally be as short as possible to minimize heat loss and increase the barrel temperature. Optimum proportion is about half the height of the heat riser. Longer tunnels will need more insulation.

E is the most important single dimension. **E** is the height from the bottom of the feed tube to the top of the heat riser. **E** affects how much air the stove is able to suck through the fuel and therefore the rate of burning, the potential power output, the temperature of the cooking surface, and also radiant heat production from the sides of the barrel. Draw is proportional to height, so if **E** were twice as high, you would have twice the draw. The height in the specimen 8-inch system shown is 33 inches, but could be anywhere from 25 to 50 inches.

F is the cross sectional area of the heat riser and should be not less than **C**. The heat riser can be 7 inches by 7 inches square or 8 inches diameter round.

G is a little hard to describe. It's an imaginary cylinder rising from the top of the heat riser to the roof of the barrel. The total area of the walls of that cylinder should also be greater than the area of **C** to avoid slowing the gas flow at this point. With an 8" system, its height should be 2" to 3". (With a 6" system, it should be 1½" to 2").

H needs to be about 1½" wide. For even heating from all sides of the barrel, we need to encourage the hot gases to swirl down equally all around the barrel, not just short-cut to the exit tube. It's good to place the barrel eccentrically over the heat riser with the gap slightly wider on a side where you want extra radiant heat and make the gap narrowest where you want the least heat.

J is an easy place to unwittingly create a bottleneck. Make sure to bell out the cross-sectional area at this point, with a good deep

ash pit so that ash build-up doesn't constrict the flow. **K** is the exhaust, the horizontal flue that carries hot gas through your floor, heated bench, bed etc. This should be at least the size of the heat riser (8" to 10" diameter) or it could be made of more than one duct, totaling a much bigger cross sectional area, as for instance, if you're using it to heat a floor. Any abrupt turns in the stove's intestines will somewhat slow the flow of gases, so try to make elbows less than 90 degrees or a larger diameter than straight runs.

The following dimensions are less important but please read the notes.

a is the diameter of the 15 to 18-gallon barrel, which encloses the feed tube. **a** will be in the region of 14".

b is the additional height the feed barrel rises above the feed tube. Keep it less than a foot, or there's a danger that hot gases can accumulate in that space and reduce the efficiency of the draw. It is, however, valuable to install this barrel, which makes it easy to control occasional stray smoke, and to regulate the air input to the stove.

c is a primer/clean-out hole. Put it as close as possible to the bottom of the vertical stack.

d is the diameter of the heat riser barrel. A standard 25-gallon steel barrel is 18½" across; a standard 55-gallon is 22½". 25 or 30-gallon barrels work well with a 6-inch duct system and a 55-gallon barrel does fine with an 8-inch system. The bigger the barrel, the lower its surface temperature will be.

e is the insulation beneath the burn tunnel. To keep the temperature in the heat riser as high as possible, you'll need 2" to 3" of insulation here. If you wish to store some of the heat generated in the floor beneath the stove, leave out the insulation.

f is the insulation thickness around the heat riser. Put in as much insulation as you have space for.

g is a clean-out. Make the opening big enough that you can get a cleaning brush in. Flare the clean-out into the duct so you can reach your arm in there.

Constructing the Combustion Unit

Once you've decided how high in the room you want the barrel to be, you can decide on the floor level of the burn tunnel (which can be below, at, or above the floor level of the room). You may want to plan for a few inches of insulation below the burn tunnel. The insulation (e in the cross-sectional drawing on page 35) and the brick ash pit (at c) could be inset into the floor or laid on top. To recess stove parts into the floor is a lot easier if you build stove before floor. The floor of the burn tunnel should be level, flat, solid, and at least two feet in any direction including downwards from any burnable parts of the building. **Don't build directly on a wooden floor or up against a wooden wall.** Also be sure not to place the barrel or feed tube beneath anything in the room that may present a fire hazard, such as overhead shelves.

Mortar

You will be using a mortar that you can compound yourself or you can buy commercial fireplace mortar. To make your own, you'll need mason's sand (that means fine grained, sharp sand) and fairly pure clay. Unless you buy commercial clay, put both of them through a $\frac{1}{8}$ " or $\frac{1}{16}$ " screen or a fly screen, to eliminate lumps on which the bricks could teeter. Mix in advance about a bucket full of mortar, that is, four to six gallons, at about one part clay to four or five parts sand. Clay mortar will keep as long as it is damp. Don't use cement-based mortar unless it's fire cement mixed with clay. Most cement is non-refractory and would be likely to break up rapidly under the thermal shock it would experience. The same may be true of lime or gypsum-based mortars, whereas clay merely becomes fired and in fact itself turns into a brick-like material.

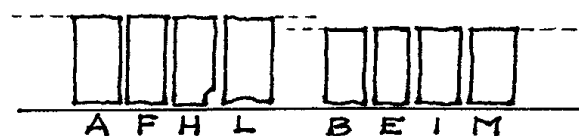
A Mock-Up

Begin by laying out your bricks on any unburnable flat level surface, preferably outdoors just to practice how they might go together. I would recommend that you build a mock-up—without mortar—of the entire brick structure, not necessarily in the final position, and fire it up really hot to make sure it works.

For the feed tube and the heat riser tower, use bricks on edge to keep the tower as thin as possible so it doesn't take forever soaking up heat, and to leave plenty of space for insulation. Bricks can be laid flat and/or on edge in various combinations in the base and along the burn tunnel to get the interior height of the burn tunnel right.

It helps to use bricks exactly the same height for each course (not a concern if you have perfect new identical bricks). Easier than measuring them and more precise is to lay them out on a really flat surface such as a straight board or a concrete floor, a dozen or so at a time.

Sometimes instead of using bricks we build the heat riser with *thick* steel pipe ($\frac{1}{8}$ " or $\frac{1}{4}$ "), and recently, people have used triple-wall insulated stainless steel. Solid pipe is very durable, but triple-wall we can't vouch for.



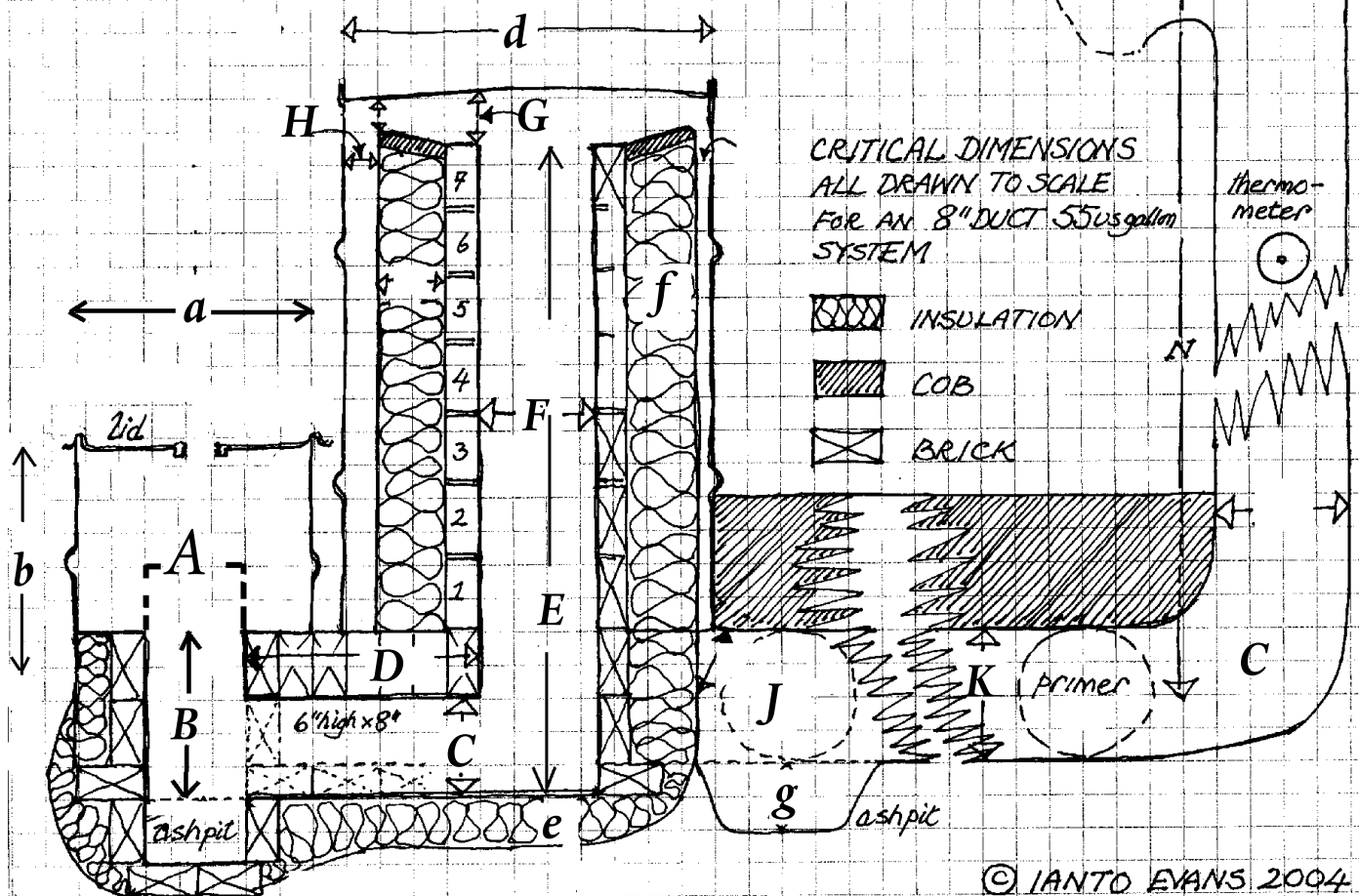
Sorting Bricks: A, F, H and L are all the same height. B, E, I and M are a different height but are equal. Each group of four will make a course of the heat riser.

ROCKET MASS HEATER

CROSS SECTION

ONE SQUARE = 2"

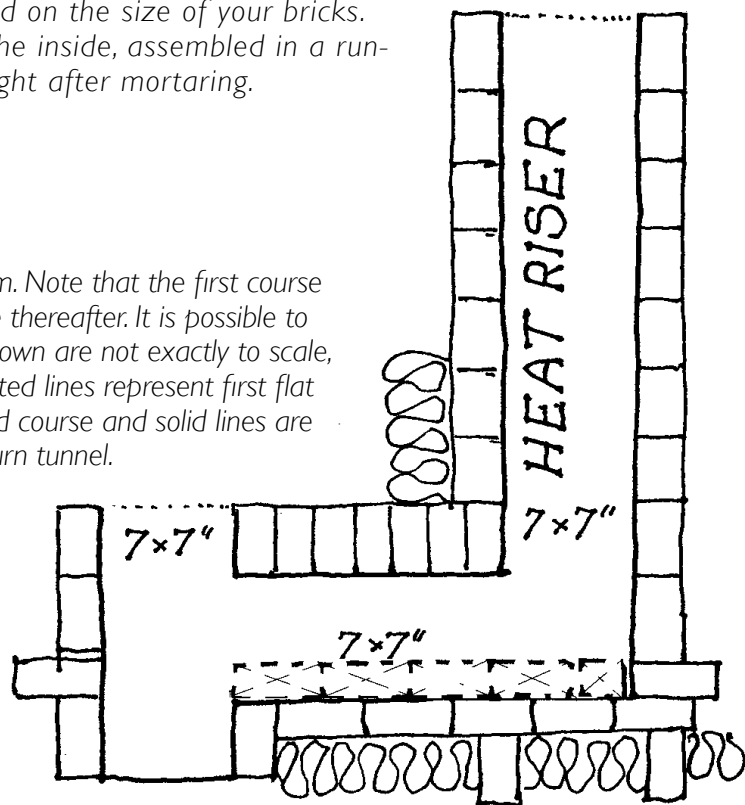
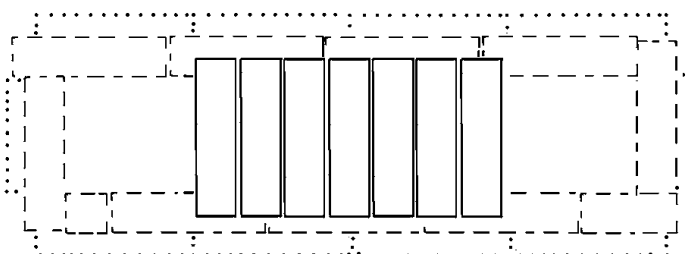
0 2 4 6 8 10 12 14 16"



© IANTO EVANS 2004

Above: A cross section of a stove, showing some of the relationships in Dimentia and Proportia, lettered as on page 35. The number of bricks it takes to complete a course will depend on the size of your bricks. Bricks should have smooth surfaces to the inside, assembled in a running bond and should be airtight after mortaring.

Right: section view. Brick arrangement for 8" exhaust system. Note that the first course above the stove floor is shown with brick laid flat, on edge thereafter. It is possible to shorten the burn tunnel (see illustration, page 23). Bricks shown are not exactly to scale, as size varies with manufacturer. Below, left: Plan view. Dotted lines represent first flat course, dashed lines are bricks on edge forming the second course and solid lines are bricks on edge forming the roof of the burn tunnel.

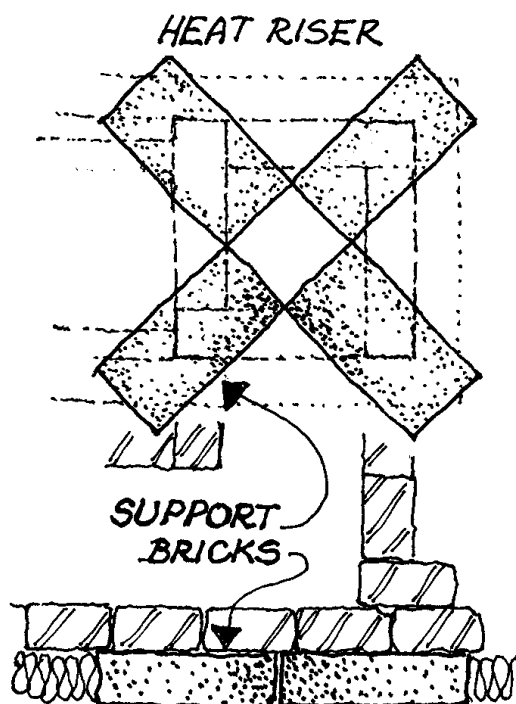


Insulation Under the Stove

Build the permanent model on a hard, flat, level base, preferably brick. Whether to use insulation beneath and around the burn tunnel depends upon whether you want to use the ground beneath the stove as thermal storage or if you are more interested in having your stove heat up quickly. If, for instance, one function of your stove is to heat tea water, then you would want to rush the hot gases through the system losing as little heat along the way as possible.

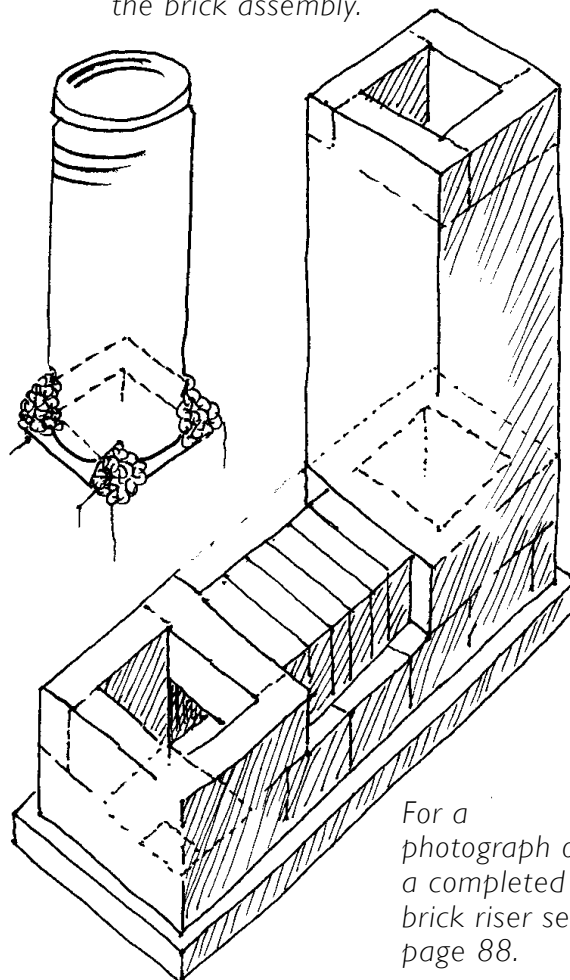
On the other hand, if the stove is to be used only for space heating or charging up a heat storage bench or even for slow cooking, then it might be in your interests to allow the ground beneath your floor to heat and slowly release that heat over time.

Bernhard Masterson suggests a diagonal cross support of bricks laid flat in the insulation beneath the heat riser to support the weight without crushing the insulation.



Infloor Insulation: Shows diagonal brick support for weight of the heat riser, (above in plan view) surrounded by mineral insulant (below, in section view).

A steel tube is an option for heat riser material. Mud the corners onto the brick assembly.



For a photograph of a completed brick riser see page 88.

Building the Brickwork

Set the first course of bricks very carefully. Their position and stability will affect how easy it is to build the whole structure. Mortar courses should be as thin as possible, $\frac{1}{4}$ " or less. Arrange bricks so the corners interlock, without straight line vertical joints more than two bricks high. Check each course for level carefully as you build it. Check regularly for vertical with a builder's level. It's important. (More images on pages 42-47).

As you build, clean off surplus mortar that squeezes out between the bricks on the inside of the tower very carefully with a dry cloth without disturbing the stability. Finally, clean out the burn tunnel very thoroughly to remove every vestige of mortar that could affect the gas flow. Fuel needs to fall freely into the feed tube, so make sure there are no edges of bricks protruding into the tube.

You'll want the heat riser to extend up to close to the top of the barrel. So measure the height of the barrel in advance and make sure that the courses of brickwork fit that dimension closely. If the gap above the top of the heat riser is less than about 1½ inches, it may be too tight, so the combustion gases will have trouble with their exit. Conversely, if the gap is too deep, the cooking surface (the top of the barrel) may not get hot enough fast enough to cook on. To get just the right height, you have some flexibility in using thicker or thinner mortar courses and in how you support the barrel, using broken brick or tile plus the mortar seal.

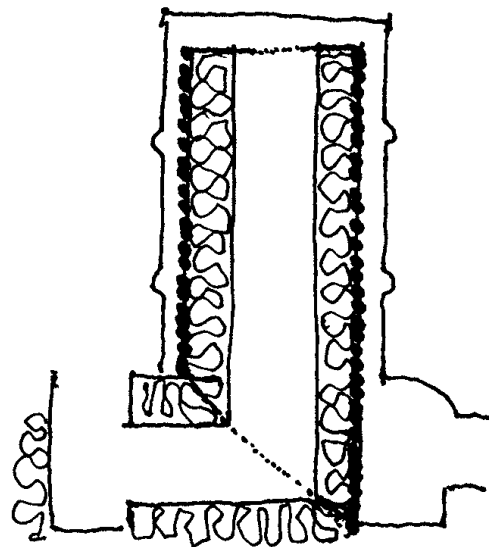
It is possible to build the feed tube and burn tunnel out of brick and to use steel tube for the heat riser. Steel in that position will be much more durable than if it's used where there is more oxygen available further "upstream."

Adding Insulation

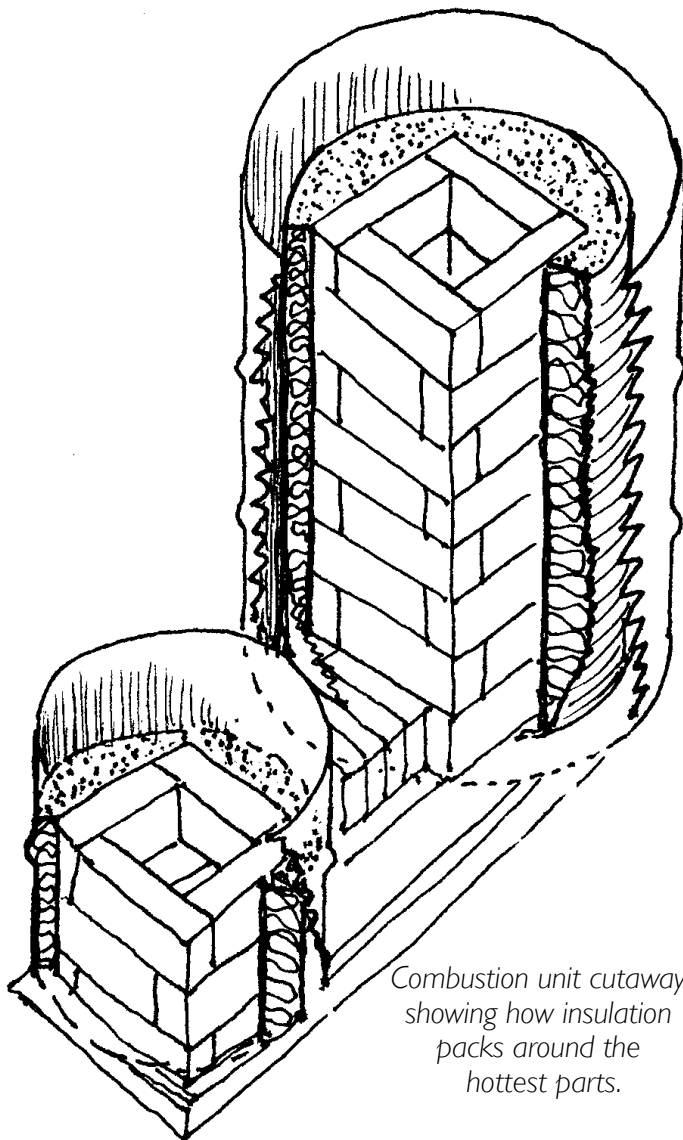
After the combustion chamber (including the heat riser) is constructed and any protruding mortar is smoothed off inside, you can apply the insulation. First build up a circular base on which both insulation and the heat exchange barrel will stand. Use whatever is to hand: broken brick, chunks of old concrete, rocks, etc. The base needs to be airtight, so cob everything together. Test for height with a level and tape measure.

The insulant mixture needs to be in a cylindrical container surrounding the heat riser and fitting within the heat exchange barrel, but extending down to the level of the bottom of the exit flue. A standard electric water heater tank is just about the right size if you cut off both ends. If you don't have a water heater tank, sheet metal can be rolled and wired together.

Recently, we've been using ⅛" or ¼" hardware cloth (steel mesh) formed into a rough cylinder and wired together. It's fairly easy to lightly pack the insulation inside it to maintain its cylindrical shape. At the top of the insulation, make a little cap of sand-clay



Insulation container. Note that the insulation in the container extends all the way down to the ash pit.



Combustion unit cutaway showing how insulation packs around the hottest parts.

up to the height of the top of the heat riser. It's important to **maintain the sides of the insulation container vertical** so as not to impede the flow of exit gases.

Remember that the bottom of the heat exchange barrel should be located higher than the exit duct or you will have to cut a hole in the side of the barrel to get the gas to flow out.

In order for gases to flow smoothly through the tight gap between barrel and flue as they enter the thermal mass, there needs to be extra space all around the bottom of the barrel, a ring-shaped channel that collects the falling hot gas and directs it to the flue. As this is a prime trap for lightweight ash, make it big enough that you could get your hand or a vacuum cleaner tube into most of it. This channel needs to extend all around the base of the barrel, dropping and widening from above the bridge to the clean-out/ash pit where the flue begins. Shape it in a sand-clay mixture without straw, leaving the sides and base really smooth, so that a clean-out tool can rake out ash without snagging.

Setting the Barrel

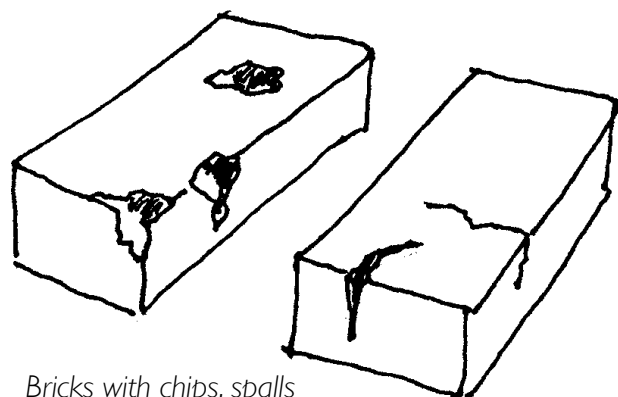
It takes two people to carefully lower the barrel over the heat riser. Be very cautious not to bump the heat riser and knock it out of alignment. Seal around the bottom of the barrel with sand-clay. Now test the stove by lighting a very hot fire and feeling for radiant heat off the side of it. Run your hand from top to bottom and around every side, slowly, a few inches from the barrel, feeling with the back of your hand for radiant heat. If there are any cool spots, or if one side is a lot cooler than another, you may need to pick up the barrel and reposition it to correct the situation.

Tips on Laying Brick

Brick will resist heat better than mortar, so keep mortar courses as thin as possible. The finer you sift the sand and clay, the thinner the mortar courses can be—a ¼" pebble means the course can't be less than ¼" thick.

Make sure bricks have no projections wherever they meet other bricks. Clean off old mortar carefully. Lime mortar will usually fall off easily; cement mortar is more difficult, it sticks tightly to the bricks and sometimes you'll break the brick trying to clean it off.

Spalls, cracks and chunks missing may not be a problem depending on location. Mix mortar wet about the consistency of guacamole or custard, so that it is easily worked. Clay-sand, unlike lime or cement, is kind to the skin, so you can apply it without tools, though if you have a mason's trowel, a bricklayer's trowel, try building your skill with it. Soak bricks in a container of water before use or they will suck water out of the mortar too fast. You have very little time to adjust, so try to set bricks level and plumb and in place the first time. Remember the mortar is there mostly to hold the bricks apart (to stop them rocking) not to glue them together. Before ending work each day or every couple of hours, stuff mortar into remaining cracks and holes, then smooth it all down with a coarse damp rag (burlap is ideal) or a big coarse plastic sponge.



*Bricks with chips, spalls
and cracks*



The first course of bricks in a mock-up directly on the ground. Bricks are laid flat, clean sides into the center for good gas flow. This shows the base of the burn tunnel. In the actual stove, this course is set on a flat smooth layer of brick. That layer of bricks may or may not be on a bed of insulation, depending on the design.



The first course determines the length of the burn tunnel, the horizontal leg of the "J." Note builder's level ready for use.



Level each course as you build. Maintain the same width all along the channel.

The second course is on edge; check for vertical and square. Lay bricks in a running bond, each brick spanning a joint below it.



Provided a good face of each brick looks into the combustion zone, imperfections in other parts of bricks are less important.

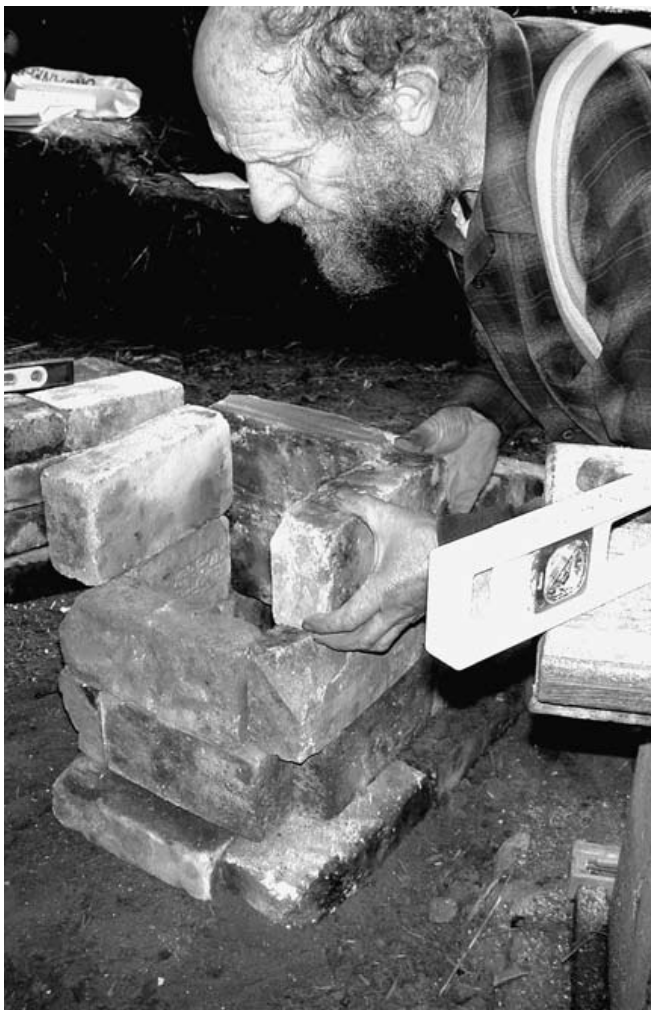
The second course, one brick short. The partial brick at upper left will allow the last brick to span the joint below it.





The bridge of brick over the burn tunnel is a good place to put your better firebrick, stacked on edge in this case.

Below, left: Fourth course going up. Check for square, level and vertical.



The brickwork is ready to support a heavy steel heat riser.





Looking down the barrels of the feed tube and heat riser.



Left: Two Rocket Stoves side-by-side in an experimental session with heat risers of steel instead of brick. The brick fortresses around the burn tunnels form the supports for the heat exchange barrels as well as containment for the gases flowing down the barrels and into the exit flues, at right. The bricks and barrels' bottoms will be sealed from outside with cob.

The entire assembly ready for the horizontal flue. Brick and cob form the neck for the exhaust pipe. Make sure these are airtight junctions.



Photos this page: Kirk Mobert

The insulation around a steel heat riser in a greenhouse Rocket is contained by sheet metal, bent into a cylinder and held with wire. A sand-clay cap at the top few inches holds perlite in.



The completed system, ready for testing. Note steam escaping from exit flue.



A good example of a brick tower under construction in Chris and Jenn Reinhart's house. A fortress of brick is mortared in to support the barrel. Photos, this page: Chris Reinhart.



The same stove, completed.

Building the Thermal Battery

Materials for Building a Bench, Couch or Bed

You will use rocks or urbanite (recycled concrete chunks), filling the gaps with cob. Cob is a mineral-fiber composite made by mixing together damp clay soil, sand and usually straw. The easiest way to make small quantities of it is to lay a tarp on the ground, dump the ingredients on it then roll and tread it together with your bare feet. The final consistency for heat storage should be very sandy and homogeneous, sticky and damp enough to hold together for hand sculpting. For a thorough explanation of cob see *The Cobber's Companion* or *The Hand-Sculpted House* (in Recommended Books).

Lay Out Exhaust

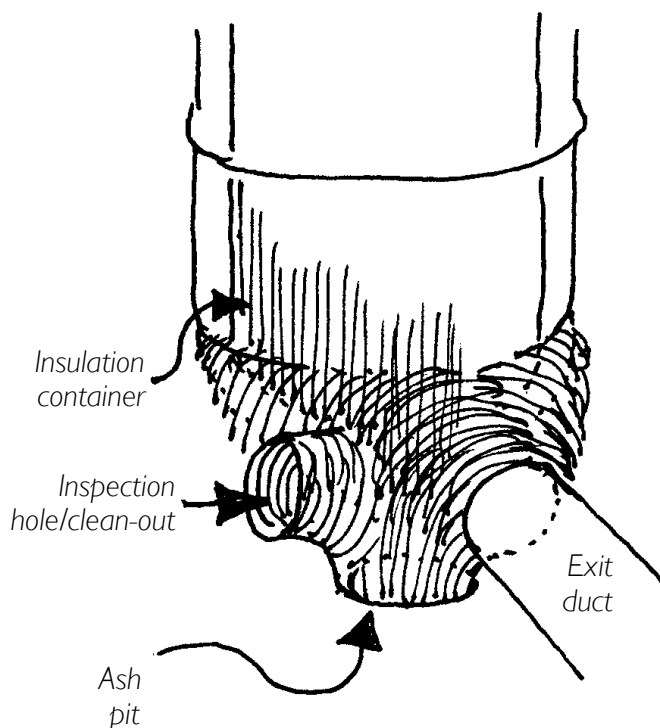
Draw out on your floor the shape of the heat storage you want to build. Set a layer of rocks in damp cob to begin with, and then place your exhaust pipe on top of the rocks.

The exhaust pipe may be made of metal duct or stove pipe, aluminum or steel. Lay out the pipes beginning at the stove end, facing the male ends of the connectors upstream, that is, towards the fire. This way, if there's a condensation drip in the outdoor part of the pipe, it can't run out at the joints, but can be caught in a creosote trap at the bottom of the vertical stack, where there should be a clean-out. If the flue passes outside through a wall, build it to drain outwards as protection against condensation running in from the outdoor stack. If you are simultaneously building a thermal battery and a cob wall, build in a pipe of equal or greater diameter than your system. You may need to reinforce a thin metal pipe to protect it from distortion caused by differential settlement in the wet cob. Make all pipe connections airtight to avoid carbon monoxide leaks.

CONNECTING STOVE TO BENCH

The three-dimensional shape of the transition from stove to bench is hard to describe, yet fairly easy to sculpt. Effectively, you're connecting a thin, partial cylinder to a fat cylindrical tube at right angles. English has no word for this geometry. The ideal material for the connection is a sand-clay mixture fairly rich in sand and stiff enough that it can't fall into the hole.

To simplify construction, use scraps of ¼" or ⅛" hardware cloth or expanded metal lath or scrap sheet metal. Curve the lath into place to fit the shape using several small pieces, and then plaster your sand-clay very carefully



This shows the shape of the chamber.

over its surface. Add extra volume of space at this location, as it is a prime candidate for ash build-up and blockage. If possible leave an ash pit here up to one-gallon capacity.

An alternative—if less aerodynamic—approach is to rough out the box in brick, then plaster it inside and out with cob, really smooth. We have also used slate roofing tiles and flattish rocks. The result may look funky but will work fine if you emphasize **leaving plenty of space inside**.

Locate Clean-Outs

You will need to put an inspection hole close to where the pipe exits from the barrel and another one at the bottom of the vertical exhaust pipe. You may need others if your pipe has many bends and turns. The hole at the base of the vertical pipe doubles as a primer into which you may need to put burning newspaper to get the stove started in unusual weather conditions (see *Light My Fire*). Each inspection hole may also be used to clean out the flues. The simplest way to build them is to use a T-junction in standard duct work or stovepipe. Metal caps are made commercially to fit these pipes, or you could make a plug of your own design. Make this plug airtight to prevent carbon monoxide leaks into the room.

Sculpt the Thermal Battery

The cob immediately surrounding the pipe should be packed in really tight for good thermal contact and should contain no straw within six inches of the pipe. Pack cob very thoroughly between the rocks and tight against the stovepipe, working up the sides of the stovepipe evenly and carefully, adding rocks as you build. If the work is done with love and the bench is protected until it's dry, there's no danger of the pipes collapsing. Straw is only necessary in the cob that is close to the surface of the bench. Without the straw the cob may crack or be subject to shattering if it's hit with a heavy object, so put in a good amount for the surface layer, chopped to two inches in length. Protect the

bench with a half-inch or so of a hard earthen plaster. Reinforce the corners of the bench, as they will get dinged and bashed with use. You may want to try a gypsum based plaster nearest the barrel as the metal will shrink and swell with the rise and fall of temperature, as will the clay. For more information on plasters and amendments, see *The Hand-Sculpted House* and *The Natural Plaster Book*, both in Recommended Books.

Feeding and Caring for Your Dragon



Wales, my native land, (which has been described as The Indian Reservation of the British Isles), has a 2000 year-plus cultural tradition of the importance of home and hearth. To this day the national plant is the leek and the national animal the Red Dragon, which graces our flag and is to be seen everywhere. It is well known that every cottage home had a house dragon, a cute little fellow who crouched in the inglenook, snoozing but perpetually alert to the need to start a fire and to warm the house. He is called *DRAIG GOCH*, (which almost rhymes with fried pork).

Rocket Stoves are the modern dragons, the living heaters that sleep in a corner, unless your house, like mine, has no corners. Like any well-behaved house dragon, mine never smokes (unless he's really young and just learning the hazards of smoking); he growls a little (or do dragons really just purr deeply?), but maintains a little warmth all through the cold northern winter, even when he shows no fire. And of course, unlike the rascally Oriental dragons that actually blow fire from their nostrils, all good Welsh dragons swallow their fire, discharging it with joyful flatulence.

LIGHT MY FIRE

If you're accustomed to lighting fires in box stoves, you're in for surprises. Rocket Stoves function almost diametrically opposite to any kind of stove you've ever lit. The wood stands upright, the air goes down, the kindling goes behind the paper and the firewood behind that. The feed tube cools itself so well that I can comfortably sit on the feed barrel in my house. Operation is a brief, very hot clean burn, then you seal the feed for heat stored in the "battery" to slowly warm your home.

First, make sure your draft is leaving the house, not back drafting up the feed tube. You can tell quite easily by blowing out a match close over the feed tube. Watch whether the smoke rises or if it falls into the burn tunnel. If the temperature of the bench gets colder than the outdoor air, a counter flow will carry air from outdoors down the exhaust pipe and through the intestines to exit up the feed tube. This is most likely to happen if you've been gone from your house for a long time in cold weather. Normally, though, you can expect the system to draw air into the stove.

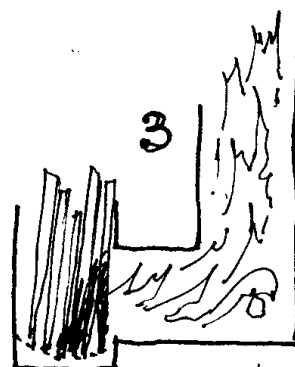
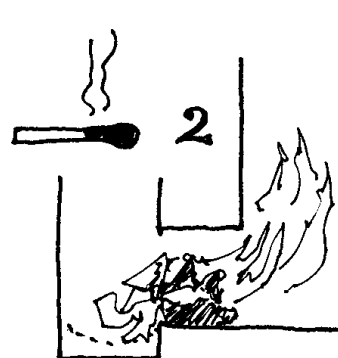
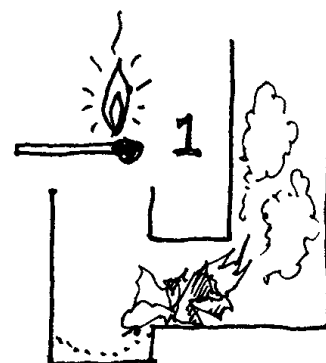
Check your indoor stack thermometer. If it reads lower than the air in the room, you will need to prime the system by putting lighted newspaper into the base of the stack.

Use of Paper and Preparation for Lighting

Remember that it's the heat riser that makes this thing work, not the exhaust pipe. So in normal operation, to heat up the riser quickly, I like to first prepare two or three sheets of dry crumpled newspaper, (not tissue, thick paper, glossy paper or cardboard). With practice, you can get away with two full sheets. Try not to use more, as the clays in commercial paper don't burn and can rapidly build up an ash problem in your tunnels. Then I prepare a handful of very thin, very dry, straight kindling with all of the thin ends together, and the matches. I set them all down on the bench alongside of the stove. *Kindling needs to be tinder-dry.*

If there's any question about the dryness of the paper, kindling, or matches, I generally leave them in a warm place above or right up against the stove overnight so as to be dust dry in the morning. In damp climates such as the Maritime Pacific zone, a kindling shelf or rack above the stove is a good idea, but make sure nothing can fall off it onto the hazardously hot surface of the stove. Safer, perhaps, is to leave paper, kindling and matches on the heated bench.

(1) Now I light one of the newspaper crumples and reach down with it so I can stuff it into the horizontal combustion tube, blowing gently down the feed. I wait until the smoke



from it finds the heat riser and I hear it burning fiercely, then (2) I drop in the other newspaper crumples so that they are directly beneath the feed tube but in contact with the burning piece. If for any reason smoke comes up the feed tube, I just blow again gently to give it the right idea until it's drawing strongly up the heat riser.

Warning:

If you burn large quantities of paper, its lightweight ash may float down the stove's intestines and constipate it. After initial ignition, burn only wood.

Adding Kindling

Kindling must be tinder-dry all through, pencil-thin, straight, split, splintery and long enough that it can't fall down into the burn tunnel or feed tube. As the paper ignites, I very quickly stack a fistful of the thinnest kindling **vertically against the exit from the feed tube** so that the burning newspaper backs up to it. (3) The heat of the newspaper will ignite the kindling, which is burning upstream of it. Then I add more kindling, tight against the opening and upstream of the first load, which as it burns will eat its way back into the new kindling. (4) Now I add thicker pieces of wood until the feed tube is completely full; (5) the fire will chew backwards into progressively thicker fuel. Only the bottom end of the wood should be burning. **Always stoke behind the burning pieces**, load the feed tube from the end away from the burn tunnel and completely fill the feed tube. If you don't, your stove may smoke.

Ideally, as the bottom ends burn off the fuel, pieces will drop by gravity into the feed tube. Often they jam up so you may need to shake them down, sometimes quite vigorously. Logjams can be avoided somewhat by (a) choosing straight fuel without side branches, (b) not cutting fuel so long that it cantilevers itself out of the feed tube and (c) feeding fuel thick end **down** so it doesn't wedge itself into the feed.

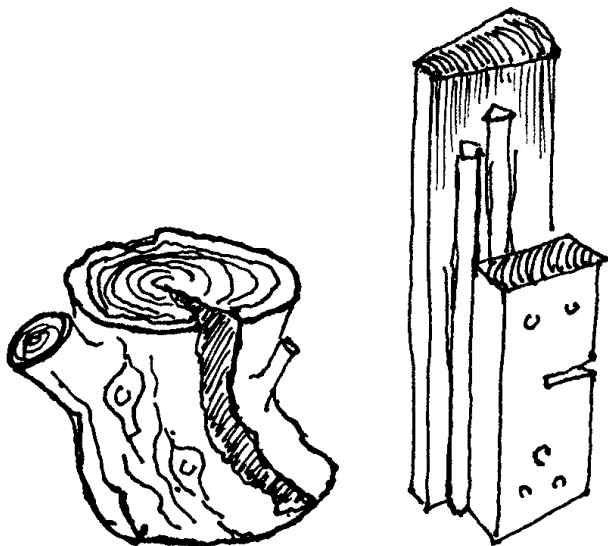
Stoking

You can regulate the power output of the stove and therefore how hot the barrel gets by the thickness of the fuel. If you need sudden heat, use a handful of thin, split, really dry, straight kindling up to the size of a child's wrist. The thinner the fuel, the greater the power output and the faster the stove heats up. Conversely, if you want to be able to leave for a couple of hours and keep the fire burning, you can use thicker—and preferably denser—fuel. There's normally enough heat retained in a brick feed tube to keep one single log burning for a couple of hours. For cleanest burning, fires need to be hot and well stoked. Rockets work best if they are fired at full load for a few hours each day to charge up the thermal battery of the heat storage. As soon as the embers die down, close the lid as tightly as it will go. This stops the exhaust pipe from sucking warm air through the bench and cooling off your mass, and prevents heated air being dragged out of your house. If you choose to build a model without a closable lid, you may need to set some sort of slide damper at the top of the feed tube to regulate how fast the stove burns and also to control stray smoke from escaping. We use fire brick or tile, or a flat sheet of cast iron, which we remove for stoking.

THE FUEL YOU BURN

Keep it Dry

If firewood contains water, the energy produced by burning it is partly used up by boiling that water out of the wood. You lose efficiency dramatically by drying the wood out during burning. The steam so produced can condense inside your flues, rusting them out and dripping from loose joints and inspection holes. So make sure your wood supply is gathered in dry weather and stacked to season in a well-ventilated pile. If cut green, that is, from recently live trees, it should be split open before stacking to allow it to dry out thoroughly, preferably for a full year before burning. In damp climates, store firewood indoors to dry a little more before burning it. Make outdoor wood stacks high with the top covered to keep rain off and the sides open so that the breeze goes through. Thus wood can continue to dry even in



Firewood: the bad and the good.

crooked
short
fast grown
thick
round
thick bark
knots
wet

straight
long
slow grown
thin
split
no bark
fibrous
dry

damp weather. Don't throw a plastic sheet on a woodpile; it may trap moisture and condensation from the ground itself. You could end up with your firewood wetter than when you stacked it. If you have any doubts about the dryness of firewood, measure weight loss of a test sample by setting it on your stove overnight.

Kindling Selection

To test the suitability of deadwood as kindling, examine how strong it is. If it doesn't easily break across the grain, it probably has good fiber and will burn well. Kindling should be **straight, dry, very thin, split, roughly triangular, long enough to stand up in the feed tube, strong** (difficult to break), **fibrous**. It sometimes helps if there's a little pitch in kindling. Conifers such as Douglas fir, pine (except pitch pine), cedar and fir are excellent but avoid larch (tamarack), hemlock and spruce. It's tempting to gather twigs, but they have disadvantages. Twigs tend to be crooked, not straight, and they are covered in bark. Trees grow bark to protect them from fire and to conserve moisture inside the wood. Splitting firewood accelerates drying and helps it burn better.

If you live in town you won't need to buy commercial firewood at some outrageous price. Your stove will run well on dumpster finds, pallet wood, the waste that your local arborist generates or straight branches, twigs and tree trimmings that can be used in length, gradually feeding themselves into the feed tube.

Choosing Firewood

Cutting your own wood, choose the straightest pieces, sawing close to knots to leave long pieces that are easily split from the not knot end. Trim branch stubs down flush.

Commercial firewood is normally sold by the cord (a stack 4' x 4' x 8'), yet the energy

in it is proportional to its weight, not its volume. So try to buy dense firewood. Heavy hardwoods like oak put out nearly twice as much heat per cord as lightweight species such as cottonwood or pine. In a stove with a relatively small feed tube, heavier wood such as oak, ash, beech, birch, madrone or hickory cuts down on how often you need to feed it. Avoid cottonwood, poplar, spruce, hemlock, fir (except Douglas fir), redwood, most pines and cedar (except for kindling).

Because Rocket Stoves work by gravity feed, the wood needs to be fairly straight so it falls into the feed tube without bumps or side branches which might hook it up. Theoretically, a really straight smooth piece of wood can be quite long and should feed itself into the stove automatically, but in practical terms, it's not advisable to use wood much longer than the container around the feed tube or the small barrel containing it. It may burn vertically upwards and fall over, creating a fire hazard or smoke source in the house. Worse, if fuel projects out of the top of an unenclosed feed tube, it can ignite *outside* the tube, flaming up and potentially

reversing the fire's flow. At best, you could be smoked out, at worst, it could set your house on fire.

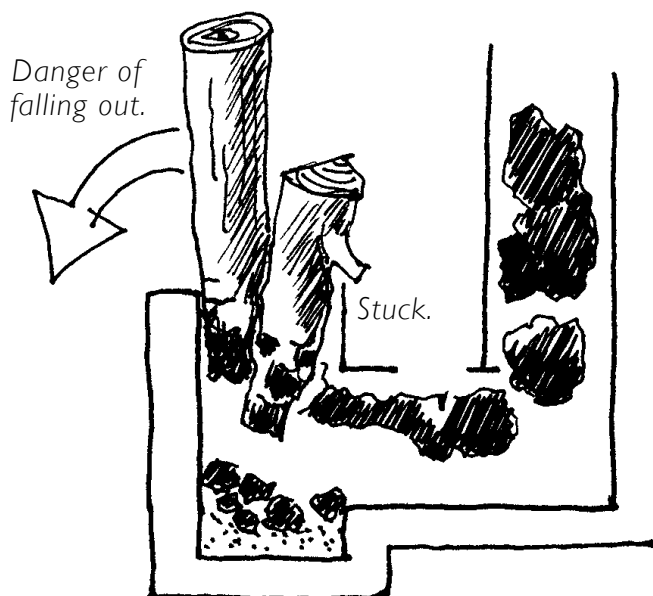
Here are some situations to avoid:

a) Two or more pieces projecting can create a chimney between them, up which the fire can creep against the incoming air. Of special concern would be two pieces of split wood or boards with flat faces facing each other. Even inside the feed tube, try to avoid feeding with flat faces opposing.

b) In pocket rockets, a metal stack can get hot enough to ignite fuel sticking out the feed tube several inches away. In each case, problems can be avoided by *keeping the fuel length shorter than the feed tube* and keeping the lid of the small barrel always on top of that barrel, leaving an air crack if needed, but preventing any back burning.

Kiko Denzer points out that his Rocket will cheerfully burn small diameter wood that doesn't even interest his neighbors with their box stoves. Plantation thinnings and straight branches are sometimes just the right size without any splitting, and they're light enough you can enroll your kids into collecting them.

Woods which are excessively resinous such as pitch pine have trouble burning completely and give off unburnable smoke, which tends to condense inside the flue, clogging it up. Avoid woods impregnated with pitch or with creosote, such as railroad ties. You should also **avoid pressure-treated lumber, and wood that is painted, both of which can contain dangerous chemicals.**



Feed the thick end down.

Maintenance

This is not a maintenance-free stove. The Rocket is a non-standardized experimental and whimsical device, which you will probably build for yourself. Each one has a distinct personality that demands regular attention, monitoring and maintenance. There are a few things you should check on quite regularly. Maintenance revolves mostly around keeping all of the tubes clean, a little like the way eating a high fiber diet will clean out your intestines.

Clean the ash out of the combustion chamber regularly. If you ritualize cleaning it every Sunday morning, for instance, you are much less likely to forget. If you don't, it may gradually clog the throat of the heat riser or, worse, ride on through the system and block another tube which is less easy to clean out. Use something hooked like a potato masher or a kitchen ladle to pull ash out of the burn tunnel, then scoop it out of the feed tube with a cup. Or, after making sure the system is really cool, employ a shop vacuum. First, push your hand down into the ashes to make sure they are cool enough to extract. If you can't keep your hands in them, you could have a dangerous situation. Once, for instance, loading warm ash into a plastic bucket, we ran to the phone, leaving the bucket to melt and the hot ash (containing live coals) to spill out onto a wooden floor. Thankfully, the phone caller had the wrong number or our number could have been up. Take ashes (cooled down) back to the woods where they originally came from.

Inspect the horizontal flue in your heat storage every month or two by opening the clean-out and putting in a small mirror and a flashlight. If ash or soot is building up in the pipe, it can be cleaned by either using a vacuum cleaner or pushing a chimney brush through the system. Not having either, I use a long flexible bamboo cane, freshly cut, with twigs and leaves still attached. If you

use other vegetation, choose something very fibrous and flexible—you don't want it to break inside the duct. Metal pipes are fitted one into the other with the male end facing upstream, so it may be easier to rod out the system towards the stove, not away from it. If you use a cloth attached to flexible pipe as a flue cleaner, make sure that cloth can't fall off inside the flue. You may have real problems getting it out. Clean the vertical stack at least twice each burning season to remove soot and creosote unless you get little result, in which case, once.

I keep a chimney thermometer in my exhaust stack inside the building where I can see it, just above where the pipe emerges from my heated bench. I check its temperature regularly. It's a very accurate probe-type thermometer that measures the temperature inside the tube, not the magnetized type that sticks to the surface. Probe thermometers are a little more expensive but they are more durable and less likely to fall off and break. Because you don't expect high temperatures, it only needs to read to between 200 and 300°F.

The thermometer is also useful because the temperature of the flue gases will drop when your stove needs to be stoked. Just by casual glances at my thermometer, I can see when pyrolysis is no longer happening, which means usually that either the fire is down to embers or the wood is hanging up instead of falling in by gravity. Familiarity with the stack temperature will alert you to inconsistencies in combustion, or anything that might be wrong in the system such as a slowly clogging flue. A stove that normally generates 250°F at the exit flue, which can only be cranked up to 200°F could be evidence that for some reason the draft is not working well.

Cooking on the Rocket Stove

Rocket Stoves for cooking, using the same basic principles described in this book, are used worldwide, particularly in places where firewood is scarce and the cooking is done inside, necessitating a smoke-free, highly efficient stove. This book mostly covers stoves to heat people, with a few cooking options. The world wide web contains a lot of information on Rocket Stoves including lively and timely discussions, research findings and instructions on how to build a number of different designs. Simply feed the string “Rocket Stove” into your favorite search engine.



Photo: Flemming Abrahamsson

Tiny Rocket Stove for making coffee in Flemming Abrahamsson's office (see section drawing, page 75).

Once you have a functioning stove in your house, you'll probably find unexpected uses for it. Calleigh Ferrara gave birth to her baby on their new Rocket fired cob bench (see Case Studies, page 80).

You can use the top of the barrel as a food dryer, using the gentle residual heat after the fire dies down. It's easy to dry things like seeds and sliced vegetables overnight this way. And of course, there's cooking.

If your choice is to have primarily a cooking stove, there's a compromise. More heat to the cooking surface means less to other places, and when you're *not* cooking

that extra heat will chiefly heat the space *above* the stove at a loss of radiant heat from the sides and of stored heat in the thermal battery. Otherwise, if you need chiefly a heating stove, the top of the barrel will be most suitable for simmering or keeping things warm. Now you have a slow cooker for beans or soups, or possibly for toasting nuts, seeds, or foods sliced thinly.

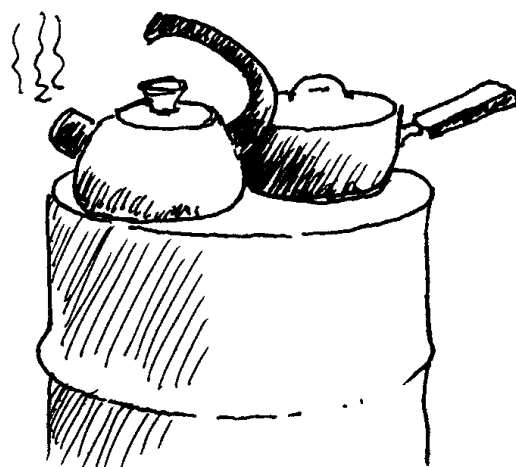
It's also possible to get something boiling on the gas stove, and then put it on the Rocket where it maintains temperature without a vigorous boil. This way you don't lose volatile oils, and you maintain more flavor

and enzymes while saving fossil fuels. My own Rocket Stove is not so good at delivering a fast cup of tea in the morning, or for frying, where you need a much higher temperature, but it makes the best toast I've ever tasted.

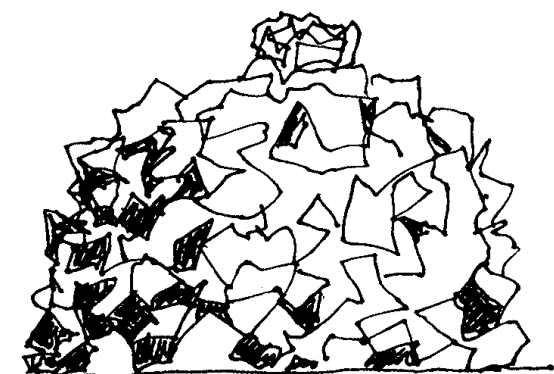
If you keep a teakettle with a quart or so of water in it on top of your stove, you'll have a source of very hot water. Even when it's not boiling, it will be pre-heated and much faster to bring to a boil on a gas or electric cooker.

With larger Rocket Stoves—a 30-gallon barrel or bigger—a removable stove top oven can be used for baking. The best trick I know is to buy a \$1.99 roll of lightweight aluminum kitchen foil and carefully wrap it around to form a little beehive with several thicknesses of foil, shiny face in, to reflect the radiant heat inwards. Tuck the end of the roll over the edge and crimp it together with your hand, then crimp a loose handle at the top. You have an instant oven that will bake good bread, but be sure to support the bottom of the loaf above the barrel top so it doesn't burn. When not in use the oven can be hung up indoors or outside.

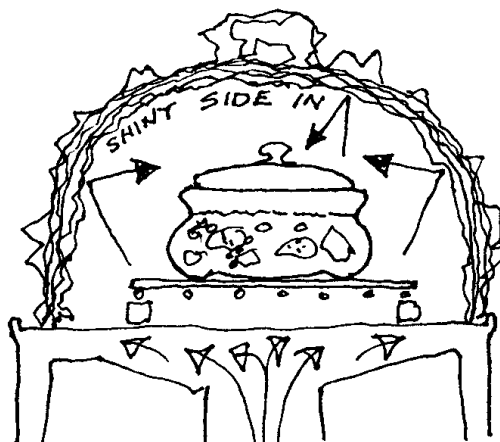
In September/October when there's still a lot of surplus fruit and vegetables available, yet the humidity is up especially at night and the temperatures are dropping, we use our Rocket as both house heater and food dryer. You could set up a multi-rack food dryer with stacked screens that sits on top of the barrel.



Tinker around. Any burning or cooking device needs practice. Can you remember the first time you tried to cook on gas or electricity or a pump-up camping stove? It took time to learn to operate the new machine. So play with your stove a lot. Try improbable things and see what happens. Experiment and let us know the results. You may discover something completely new that nobody had ever thought of. If you do, we'll put it in the next edition of this book.



Aluminum foil stovetop oven



Fire! Fire!

- ★ Don't leave anything in a place where it could possibly fall onto the top of the heat riser barrel or the feed tube. Overhead shelves, wet clothes, towels, kindling, anything plastic or wax or wood or paper. These could all start a fire when you're not looking or produce toxic gas while you're asleep.
- ★ In stormy weather make sure the gases can't back up through the feed tube. Stop stoking the stove a couple of hours before you go to sleep; make sure the coals are all dead, then put the lid onto the feed as tight as possible.
- ★ If you're burning long fuel, don't leave it unattended. It may snag up and fail to feed by gravity, then it can burn up to the top of the feed tube and fall over because it's top heavy. Leave a good wide space around the stove without carpet, paper, or anything that could catch fire, and make sure that long pieces of wood burn down before you leave.
- ★ If you have a tall stack, or a very long horizontal flue, be sure all the joints are air-tight so combustion gases can't seep out into your house. Under no condition should you install a chimney damper; it will constitute a bottleneck that could back up toxic gases such as carbon monoxide.
- ★ Don't let any smoke get into your living spaces. Even tiny amounts are bad for you. If the stove ever smokes, open all the doors and windows. Don't repeat whatever it was that caused it.
- ★ Anything hot close to wood can be a problem. If you build above a wooden floor, leave at least a three-inch air gap under the whole combustion unit, glue aluminum foil down on top of the floor and use a minimum of four inches of mineral insulation under the stove and the whole of the heat storage. Over time, heat can build up at the bottom of the heat storage to a high temperature. Similarly, keep a gap from any wood in the walls, remembering that sheetrock-gypsum board nearly always has wood behind it.
- ★ Firewood needs to be dry, as dry as possible. Wet wood burns badly and gives off water vapor, which may condense to leave creosote somewhere in your system.
- ★ Design for a long run of duct through the heat storage. More than twenty feet total, if possible. Short runs of duct are not able to absorb as much heat as you would wish. Your exit temperature could be dangerously high.
- ★ If you employ metal parts that are painted or galvanized in the combustion unit, burn off the paint before installation, out of doors, and remember the fumes can be deadly.
- ★ Be careful where you burn a Pocket Rocket, they can get extremely hot. Even a five gallon model can radiate at such a high temperature that it can ignite paper several feet away. Site an indoor Pocket Rocket very carefully. Protect children from the metal surface, which can reach over 1000°F.



Burning Questions

Will Rocket Stoves heat every kind of building? They are much more suitable for some uses than others. Keep in mind the trade-offs and limitations.

Heating by these stoves is characterized by quite a lot of convection, a major amount of conduction, but very little useful radiation, except from the top of the heat exchange barrel. The release of heat from storage is slow and gentle over many hours but the stove needs regular attention while it burns.

Compared with a fireplace, which heats you only by radiation and only while it burns, or a metal box stove, which radiates heat from the sides and top but is too hot for conductive comfort, **this is a cuddle-up device.** You can stay warm by being in contact with the storage mass for hours after the fire has died.

The issue is not whether it will heat a building. The building couldn't care less. The issue is whether any heating device provides comfort to the people.

If you live in a big, leaky or uninsulated house, convected heat may be lost before it reaches you. Consider how to get more radiation, less convection and fast response, something you can stand in front of to warm up. You'll use a lot more fuel but that's the price of a house that's big, uninsulated, or leaky. Consider a big Pocket Rocket (see Other Kinds of Rocket) or another type of high radiation stove, with an insulant lid on it, or an efficient wood burning stove.

Rocket Stoves need fairly regular attention and stoking and are better suited to someone who is normally home several hours a day. They are particularly useful if contact heat is arranged (e.g. through the seat for your desk, or where you do phone work or handcrafts or read). And of course, if firewood is expensive and you are trying to put out less greenhouse gas—which is what we all need to do anyway.

Where would I choose not to build a Rocket Stove? Buildings that are irregularly occupied such as churches, meeting halls, etc need to be heated rapidly and don't benefit from long-term stored heat. In large houses with many rooms in very cold zones where heat needs to reach rooms distant from the stove, it might make sense to heat selected rooms by forced hot air. In a work space such as a carpentry shop where one seldom sits down it might be better to have a stove which delivers a lot of radiant heat in place of storing heat, so that you can quickly adjust your comfort by moving closer or further from the stove. In outdoor rooms or living spaces that are not well sealed such as teepees, tents, etc the air heated by the storage would leave the building before you got a chance to enjoy it. Better maybe to put in a stove that delivers high temperature radiation such as a barrel stove or a Rumford fireplace.

Can I run duct work through the floor or interior walls? Almost certainly, unless you already have a poured concrete or a wooden floor. Even in the chilly British Isles, the Romans two thousand years ago heated their villas by hypocausts. A hypocaust is a series of under floor ducts carrying hot gases from a stove. The Romans used sandstone slabs for flooring, set up on stone pillars above a heated crawl space two or three feet high. Today, it might be more convenient to use metal pipes cast into the earthen material or concrete of a floor or laid in sand under brick, tile or flagstone. Remember to put in adequate provision for cleaning out ash or soot, and guard against entry by rodents.

How often do I need to feed it? Fairly often; dragons like to snack regularly. It's one of the delights of the Rocket (for those who enjoy fiddling with a fire). Normally my six-inch diameter system needs attention every 40 minutes to an hour, burning lightweight wood such as alder or maple, but with ash or oak it will happily run a couple of hours without stoking. My 8-inch system needs to be fed every hour to hour-and-a-half on Douglas fir or alder, yet with long, thick pieces of oak, I can sometimes leave it for 3 hours.

Can I leave it to burn all night? It's almost impossible to burn any wood stove all night cleanly. The box wood stoves where you throw in a log and close down the air supply pyrolyze the wood, that is, bake the chemicals out of it. So it smolders all night, generating air pollution. Most of the problems with air pollution from wood stoves come from nighttime smoldering. By contrast, Rockets work well at burning wood fast and clean, and depend upon separate heat storage to keep your house snug. Before you turn in for the night, you let the fire burn out and seal the air supply, then light the stove again the following day.

How long does a cob bench maintain heat? Cushions on the bench will insulate it well. When I rise in the morning I first fold back the bench cushions to allow the thermal battery to warm up the room. Just doing this I sometimes see the room temperature rise 2 to 4 degrees, even after 18–24 hours since the last fire. If I keep the cushions on the bench, it's still warm enough to be comfy a day later. Bigger thermal batteries, such as our Rocket-fired double bed, stay snug two or even three days after a lengthy burn.

How long does the barrel last? Does it burn out? I've never seen one burn out, though we haven't run the same one for more than twelve years. But with all the oxygen used up, so long as you keep it dry, it can't burn from inside nor rust from outside, so it should last a very long time.

But I only have short chunks of firewood. They'll burn fine, but you may need to stoke more often, and the feed tube needs to be quite smooth so they can't jam together and hang up. You will still need long kindling for lighting.

Does it need a direct outdoor air supply? Won't the stove use all the oxygen in my house? Any stove burns oxygen. But it doesn't selectively extract oxygen from your house, leaving you gasping in a room full of nitrogen. It sucks *air* out of the house, not just oxygen. And no, you won't be airless, because as air is sucked down the feed tube, the slight vacuum created in the room pulls in "replacement air" from elsewhere. In very cold climates or very leaky houses this results in drafts, usually from around the bottoms of doors and windows. A separate air vent serving the stove can cut down on these drafts.

How big? A 4-inch pipe should be very adequate. Cover both ends with ¼" metal mesh to keep animals out. Best place? In the ceiling or wall directly above the feed. In mild climates, provided your doors are well-sealed, it may be sufficient to draw cold air down from upstairs, from the many small cracks in a building, through ceiling vents from an attic, etc.

I have read that wood stoves are out-of-date, messy, and a big source of pollution and greenhouse gases. What is the best choice for the environment? While these claims are generally true, woodstoves have been much improved over the past few years, giving off very low emissions and burning efficiently. But there is still a great deal of heat wasted with the conventional wood burning stove. That's why we invented one that is up-to-date, doesn't drop ash on your floor and is extremely efficient. For home comfort, passive solar should definitely be everyone's heating choice. But you may have an existing house that is not solar and can't easily be modified. And, most of us live in places where at least some back-up heat

is necessary, or we may want a hot seat to warm up on. Most other heating options are quite literally terminal for our descendants: oil, gas, electric, (from oil, gas, or nuke), or terminal for other species (e.g. dams on salmon rivers). Wood fuel comes from sunlight and replenishes itself every few years as it grows, reabsorbing the carbon dioxide that your stove gives off.

How can I make the old barrels not look like old barrels? You can surround the barrel or cover it partially with sculptural cob or welded artwork. There may be less toxic stove paints with which you could paint it a cheerful color or you could polish it with sand paper or buff it with a wire brush head on an electric drill. Alternatives to barrels include a cylindrical water tank, or a custom built brick column, which is common in Denmark. European mass stoves are usually covered with decorative glazed tiles.

How soon after building it can I fire up my stove? The best way to get it dry is to put a slow fire in it and gradually heat it up. The beauty of working with a lot of sand in a sand-clay mix is that the sand stabilizes the mix and prevents cracking, so you don't have to wait a long time, just dry it gently.

Won't my kids burn themselves? Probably not. We don't have a single report of a child being burned. At baby height the barrel temperature is quite low—perhaps 200–300°F, much cooler than most metal box stoves. Fuel can't roll out and no coals are exposed, as they are in an open fireplace.

How much time should I allow for construction? What takes the most time is preparations—assembling and organizing materials and tools, designing the stove. When everything is ready, two people can easily build a good stove in a weekend, or in a day with practice. The thermal storage might take longer to complete, depending on the size.

My Rocket Stove oscillates, that is it draws fine for a moment, then the draw reverses slightly as if it's changing direction, then it goes back to drawing correctly again, then chugs and sends smoke into the room again. What is the remedy? Blockage (downstream of the heat riser) in the system is the cause of oscillation. The faster it oscillates, the bigger the blockage. Give the whole thing a good cleaning.

Since the heat riser is doing the work of the chimney, can I let the exhaust pipe exit the building low, remaining horizontal, similar to a dryer vent? Try it and see. It won't always work. If it doesn't work, add a section of vertical stack.

How can I improve my stove's draw? Most importantly, make the heat riser taller and insulate it. Clean out the combustion area and all horizontal ducts. Make sure your firewood's dry. Try to use even dryer firewood. Burn thinner firewood.

Are Rocket Stoves code approved? This stove is different from the burning devices that the fire codes are written for; the Rocket's exit flue is considerably cooler than conventional ones, for example, so concerns about materials used in exit tubes may not apply.

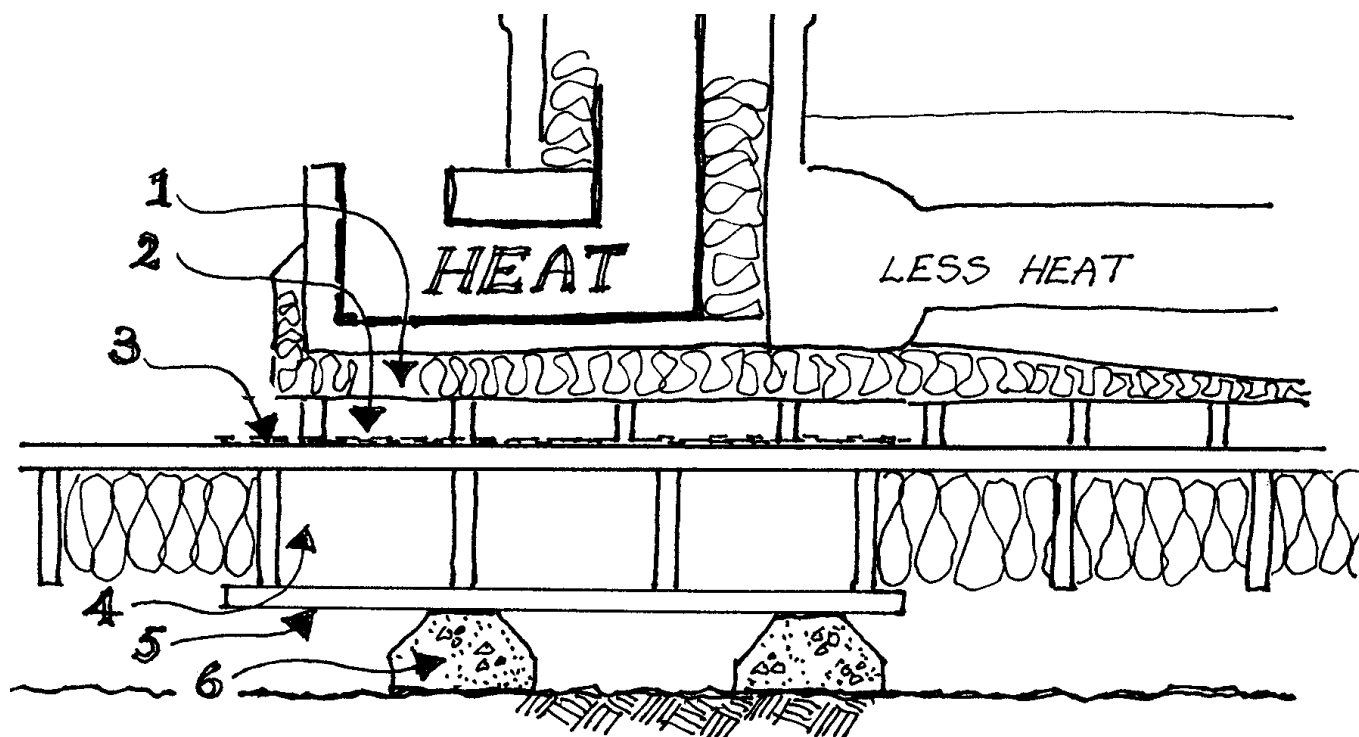
Before installing your stove you should know your local code for wood burning devices. Though you may not follow it to the letter for this type of stove, nor intend to inform the building department, codes sometimes help us make wiser choices. What's important is that you do everything safely. Far more significant than issues of legalities are issues of fire safety and preventing toxic gases in your house. In some areas, this stove may present difficulties with the fire department, as it is not certified.

Remember also, that these stoves have not been in regular use for long enough to determine the real risk of chimney fires, so inspect your chimney often.

But what if you're a renter? I am, and there are Rockets in several buildings I rent. You'll have to practice talking nice to the landlord. Prepare some snappy photos of gorgeous looking sculptural Rocket Stove bench assemblies and talk to your landlords demonstrating that you can increase the value of their house. You could show or give to the landlord a copy of this book. They may go for it. Our landlord graciously conceded provided that we agreed to demolish our stove when we leave and replace it with the same space-consuming black box wood burner that was there before.

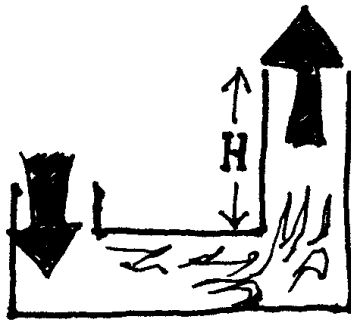
If your rented house has a wooden floor and/or walls, you will need to take appropriate precautions not to burn it down. In the house that contains our office, where we have a three-ton double bed Rocket heated cob bench, the combustion assembly is raised above the floor about 6 inches with clear space

underneath it and insulation is built into the base of the entire stove. We reinforced the floor joists with a stout post in the crawl space beneath the stove. To protect a wall of stud construction or any other burnable material, install at least two inches of high temperature insulation between the wall and the storage bench. Keep the combustion unit at least a foot and-a-half from the wall with an air space in between and face the wall with aluminum foil, shiny side towards the stove. To help reduce temperatures at the wall you could also install a fresh air intake pipe between stove and wall as a cooler. This will also prevent the stove from sucking all the warm air out of your house.

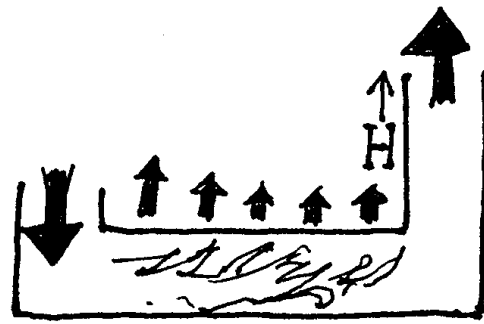


Eight-inch Rocket Stove built over a wooden suspended floor.

- 1. Four-inch mineral-clay insulation, suspended on four-inch brick edge.*
- 2. Four-inch air-flow space.*
- 3. Two layers of crumpled aluminum foil glued to floor surface, shiny side up.*
- 4. Floor insulation removed below combustion unit.*
- 5. Two-inch board for reinforcement.*
- 6. Twelve-inch concrete pier blocks wedged in tight.*

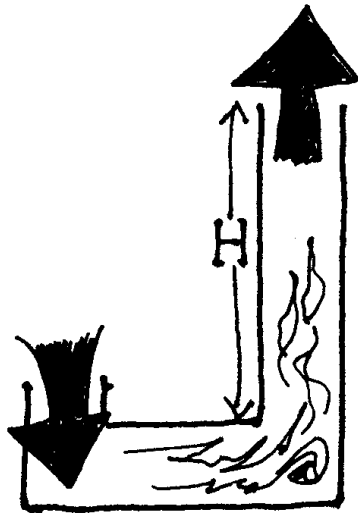


Burn tunnel length equal to heat riser height.

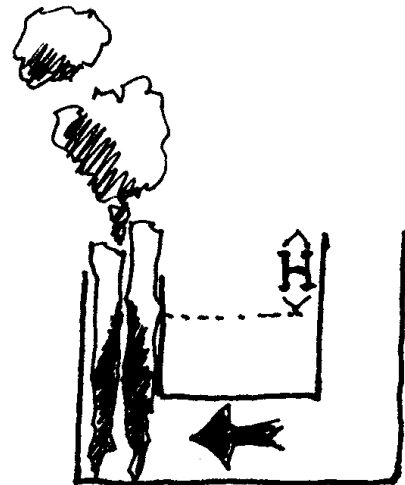


Burn tunnel length is twice that of the heat riser. Half the draft; twice the heat loss from the burn tunnel.

Relative proportions of burn tunnel, heat riser and feed tube.



Heat riser is twice the height of the burn tunnel length: Ideal. Twice the draft.



Feed tube too high. Burn-back can happen with poor draft. Heat riser is effectively shorter.

Trouble Shooting

Stove smokes into the house. There is probably a bottleneck somewhere in the system. Here are some possibilities:

- First, check if you need to **clean ash out** of the burn tunnel. Occasionally something will fall down the heat riser such as mortar from between the bricks.

- Perhaps some wet mud fell into the tube as you sealed the last hole.

- Experimental liners for the heat riser may break up and fall inwards. An example was the ceramic tile drains we tried out in the early days. They can't take the thermal shock so they tend to explode, showering shrapnel down the hole. So **clean out the burn tunnel** very thoroughly all the way to the end.

- If the **feed tube was built too wide**, it has the same effect. You can test by sliding a loose brick or wood block across the top of the feed tube. If all smoking stops when for instance you have it one-third covered, provided there's still a good draft you could make the brick permanent.

- More than once, I've been phoned by someone who, on investigation, found they

had residual **unburned newspaper** in the primer hole.

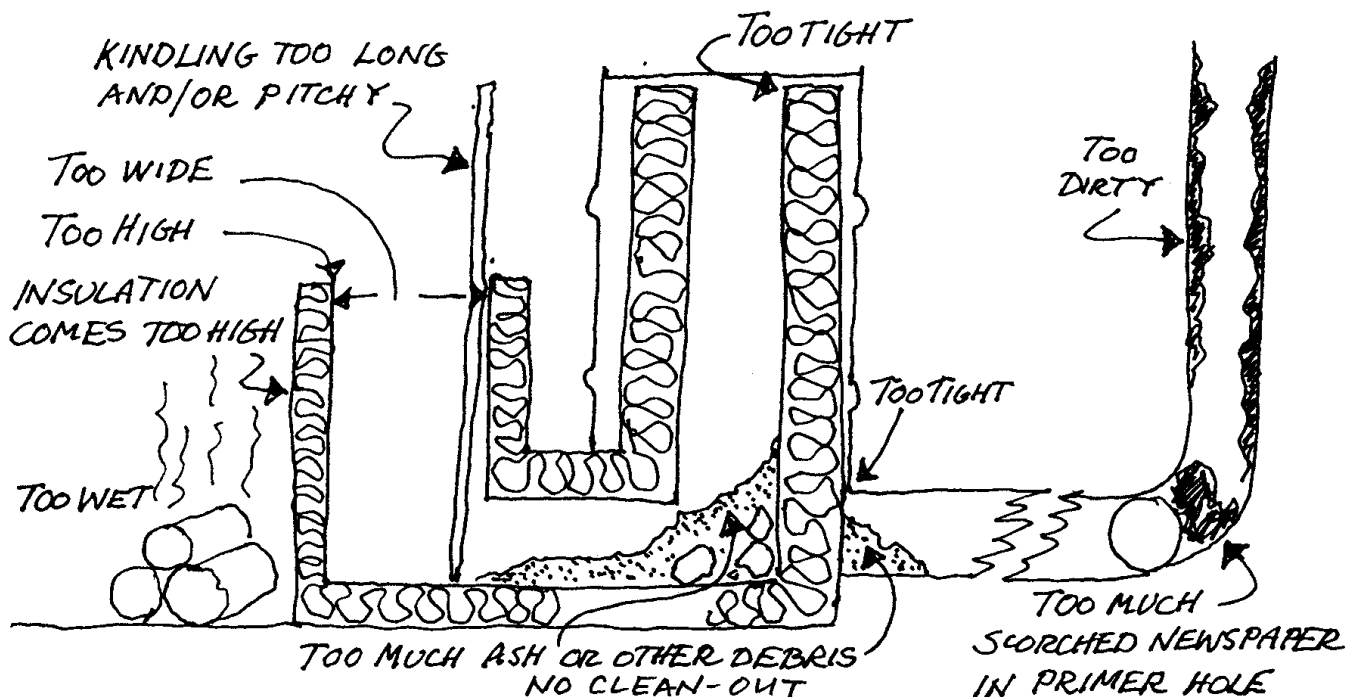
- Once, a dead wood rat was sadly mummified in the tunnel of my heated bench. Another time, following a summer of inactivity, there was a **mouse nest** clogging the exhaust pipe. A piece of ¼" wire mesh over the end of the flue will prevent animals climbing in.

- Unburned carbon can be deposited and can accumulate slowly, gradually building up like black hoarfrost inside the pipes, especially if you burn pitchy wood or conifer bark. Clean it out from time to time.

- The bench was **built with a bottleneck** in it. Perhaps there were too many right angle bends, or a flimsy metal pipe collapsed during construction.

- The space at the top of the heat riser could be too tight; a noticeable hot spot right over the heat riser could be a clue.

- If smoke gradually develops over days or weeks, there could be a build-up of ash somewhere else, probably where the gases exit from the combustion unit into the heat storage. Any obstructions in the stack are



Looking for trouble? Try these places.

at risk of backing up toxic gases, especially carbon monoxide and oxides of nitrogen.

Because the combustion unit is **pushing** cool gases up the stack, whereas with box stoves the hot stack gas itself is pulling gas upwards, be extra careful to ensure there are no obstructions in the exit stack. For instance, a spark arrester on the exit could block with soot, unnoticed, or possibly unburned paper from the primer hole could fly up the stack and lodge there. In either case there's a chance of toxic gases such as carbon monoxide backing up and escaping into the house.

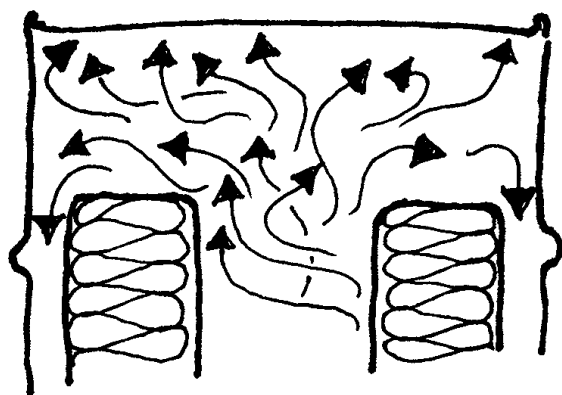
- Sometimes, using **long pitchy kindling** will cause the burn to rise up the feed tube. Fire will seek out the easily flammable dry pitch and creep vertically up the wood towards the top of the wood, sometimes burning outside the feed tube. If you use pitchy wood, keep it shorter than the feed tube. If the fire still burns up the hole, fill the entire feed tube with fuel, constricting the ability of the stove to burn backwards up the fuel. Keep a brick handy to cover part of the feed tube opening if there's a persistent problem, or if the small barrel has a lid, experiment with how far closed it needs to be. If it persists in being naughty, the time-tested remedy of a good shaking is likely to improve things.

- The first time you light your new stove, don't expect immediate success. Don't be downhearted if it smokes like crazy and it's hard to get a draw. With any new masonry stove which is still cold and wet when you first fire it, there will be an adjustment period. Use the primer, fire it up with the driest, thinnest wood you have and be patient. It may take several hours for it to start burning really well.

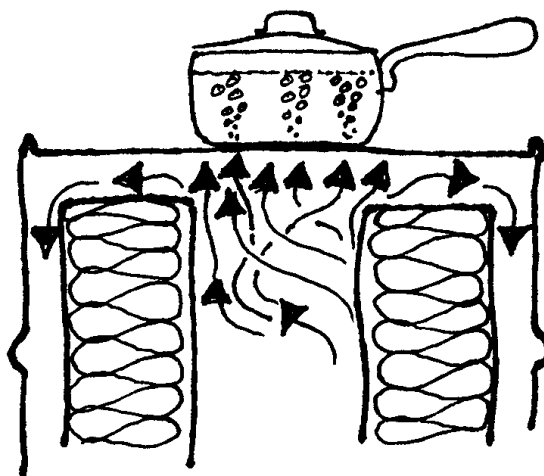
I can't get a quick boil. This means the temperature of the top of the barrel just isn't high enough. Good tea is worth waiting for, but if the problem is a cool cooking surface, it may be that the top of the barrel is too far from the top of the heat riser.

The heat produced is being scattered across the whole surface. You may want to **bring them closer together** to concentrate heat in the center.

For fast cooking, **stoke with thin split wood**, it will burn faster. We've seen Rocket cook stoves get hot enough in the center to glow orange.



Equal heat all over.



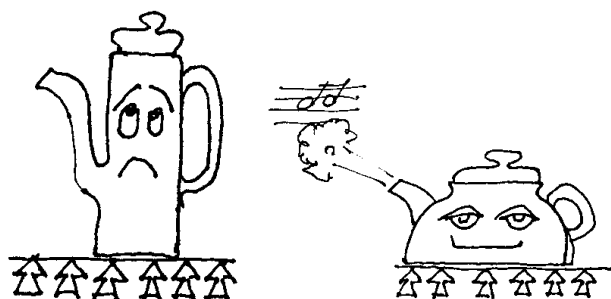
Heat concentrated in center.

When cooking or boiling water, some simple things to remember include:

- Burn dry wood.
- Cast iron or any heavy cookware heats up slowly; stainless steel loses heat slowly.
- Don't put in more water than you immediately need.
- Always **put a lid on** the pot, it can make a huge difference in how long it takes to boil.

- If the pot tends to be sluggish, try laying an insulated, non-flammable pot holder on top of the lid.

- The bigger the surface area of the bottom of the pot, the faster heat can get to it. Tall, narrow teakettles take a long time to boil; use a short, wide pot.



- You could be making tea in an unaccustomed high altitude location, where although the water boils at a lower temperature, there's less oxygen in the air, so the fuel doesn't burn as hot.

Condensation in the exhaust pipe and duct work. Clean burning of even dry wood produces water vapor, but you probably have enough heat in most parts of your pipes to prevent condensation, at least inside the building. Outdoors, an uninsulated metal exhaust pipe stack will condense liquid water at any time the air temperature is low, particularly if your heat storage is really efficient, lowering the exit temperature of the gases to near condensation point. Condensates may be pure water or may contain some creosote. A newly constructed stove takes days to dry out so don't despair if there's a lot of condensate during that time.

However if you experience ongoing condensation in the tubes that are inside your house, there's something seriously wrong. A possible cause is that condensation created **outside** is able to flow down the pipe passing through the wall. The pipe then needs adjustment so that it drops slightly to the outside.

Most likely you are burning wet wood. How can you tell if your firewood is too wet? Easy. Weigh some, straight from the wood stack, split thin as a finger, leave it on the top of the warm stove overnight and weigh it again the next day. If you don't have an accurate scale, you can take a great armful, at least 20 pounds, onto the bathroom scale with you and subtract your own weight. Or if you have only a postal scale, which probably goes to two pounds, use a small sample. You'll get a fairly accurate reading. More than 10 percent weight loss in a night and your firewood was disastrously wet, even 5 percent lost indicates it was too wet to burn cleanly.

Soot/creosote builds up in the exhaust pipe. Wood may be **lying down** in the burn tunnel. This squeezes the fuel together and deprives it of oxygen while letting cold air flow over the top of it. Stand it up, leaning it against the forward wall of the feed tube, letting it drop-feed by gravity as it burns.

Cracking caused by metal parts in earthen stoves. Any junction between dissimilar building materials creates stresses. In places where metal parts are in tight contact with cob, brickwork or stone, heating and cooling create cyclic expansion/contraction.

A common example is a steel barrel heat exchanger enclosed or partially buried in cob or sand-clay. If at all possible, try to leave space for that expansion or use flexible material in direct contact with the metal. Our friend Meka has experimented with using perlite-clay to buffer a wood heating stove from the cob walls surrounding it. Another solution is to welcome the cracks, make allowance for them as is done in urban sidewalks by scoring the surface so that cracking occurs in a predictable pattern. Make sure this scoring is superficial and that the mortar is airtight around the barrel so that gases can't escape and suffocate you.

Drawbacks of Rocket Stoves

Nothing's perfect, except, arguably, Nature herself. Human gadgetry always has a downside. In place of extravagant claims—"the wood stove you always wanted" (how do we know what you wanted?) or "This stove will solve all your heating problems" (it almost certainly won't)—we wanted to address aspects of Rocket Stoves that people have found difficult.

Stoking needs to happen quite often, whereas you can fill a big box stove with wet wood and smolder it overnight. With practice, straight, long dense wood and good luck you can feed a 6-inch system every half to three hours, an 8-inch every two to four hours. You can't keep it alight and burning clean all night, so it needs to be lit fresh each day, and in a few cases, twice a day.

Long straight wood works better. What if your firewood supply is all curved, short, knotty, branched? Well, self-feeding by gravity gets difficult, so you might need a different design of feed tube, horizontal perhaps with a grate beneath and a closed door. We need more research from the knotty hardwood zone.

Too much work splitting wood. In practice, a 6-inch system won't take wood thicker than your forearm, an 8-inch system won't take wood bigger than your knee. If you don't enjoy splitting firewood, or if your firewood is difficult to split, burn small roundwood, or design a bigger diameter system. A 10-inch flue can have an 8" x 10" feed tube, and could take wood up to about 7 inches. A 12-inch system (which we haven't tried yet) could probably stand a 10" x 12" feed. Big diameter systems are more suited to big heat storage, long heat extraction tubes and multiple flue pipes, for instance for floor heating.

Key parts need frequent replacement.

In the combustion chamber, temperatures are very high (up to 2000°F) and thermal stress is intense. Thermal stress means the rate of temperature change is high. Also the hottest spot constantly moves around as the fuel burns and settles. Steel parts in the feed tube or burn chamber disintegrate by slow combustion and ceramic parts such as brick crack, spall and crumble. The fastest damage is often in the bridge covering the burn tunnel and around the base of the feed tube where the burn tunnel begins. It would be useful to find a more durable material. Perhaps castable ceramic or cast iron would perform better. More research is needed.

Ash clean-out is not always easy. Cross sectional sizes in the combustion area are fairly critical so stove performance suffers from ash buildup. Easier clean-out might solve the procrastination factor. My own process goes like this: (a) As I clean out ash, I tell myself, "Get it out quicker next time!" (b) I burn my stove quite a lot in cold weather. (c) Every few days I remember I need to clean out ash. Each time other priorities get in the way, or I can't be bothered to look for the clean-out tool, or last night's ash is still too hot to handle, or I loaned out my only metal bucket, the one I can safely load with hot ash or it's dark, or it's Thursday, or there's a letter "R" in the month. (d) My stove gets gradually harder to light. I blame everything except ash buildup such as wet wood, bad luck, bad weather, my own incompetence, etc. (e) Stove occasionally smokes into my house. Remedy? Keep the lid on the feed barrel, shake the fuel down more often, anything but empty ash. (f) Finally, I give in, find tool and bucket, kneel on a cushion, empty an almost clogged system. An 8-inch system can yield 2 to 3 gallons of ash. Time taken? About ten

minutes, including redistributing ash, cleaning tools. (g) Tell myself, “Get to it quicker next time!”

I think you can see the remedies. First, have a ritual clean-out day, say every Sunday morning before lighting it. If necessary, put it on the calendar. Second, keep the clean-out tools and ash bucket in an easily accessible place. Third, try to remember that most smoking or hard to start problems are caused by an obstruction, usually of ash.

Rocket Stoves need a sophisticated operator. Rocket Stoves are an invitation to be involved. Choice of fuel is an art, both when selecting it and as you feed it piece by piece. Here’s a stove that continuously reminds you of the diversity of Nature. If you screw up, fail to pay attention, or work too fast, the stove punishes you with smoke in your house or it’s hard to start or too much stoking, splitting or cutting wood. Not a stove for people who rent their house, unless they have real interest in the process. Also not so good for guest houses, hotels, or situations with rapid turn-over of residents. And finally, in just a few cases, they just plain don’t work. Of conventional box stoves you could probably say that they *mostly* don’t work, so don’t be alarmed. We know of only three non-working examples of Rocket Stove. Two were built by neophytes whose symptoms were impossible to diagnose by phone, so perhaps we can discount that. But the third was a demonstration stove built at a workshop. How embarrassing! With every adjustment we could conjure up to try, it still won’t work well. It backdrafts, filling the whole house with smoke, and we just can’t figure out why. Don’t let any of this discourage you. There are hundreds of rocket stoves in operation. Most of them without a glitch.

Slow response time. This is another major issue with the rocket mass heater. If the house and bench get cold, it can take a while to heat them up again. In climates where heating needs are intermittent, the system works less efficiently.

The fire is difficult to see. If you’re used to the visual magic of armchair fire gazing, you may find it difficult. You can however watch it from above, and there’s the compensation of **listening**. Rocket Stoves are an audial feast. Burning strongly, they can roar, in fact like a little rocket, and the intense temperatures snap and crackle the firewood. Subtler is the gentle thud every so often as a piece falls down the feed tube, when you hear the burn respond immediately. We’ve heard reports that this sound was what people liked best of all. “It’s instructive. I can attend it by sound prompts.”

Conversely, the thuds and shufflings remind your subconscious that the stove still has fuel. When they stop, you will gradually notice it. As with little kids in another room, it’s when they go quiet that you have to check them out. As long as there’s noise, everything is okay.

Do you really need to see the fire from your couch? Turn off the lights and watch dancing patterns on the ceiling. You’ll rest in peace.

Adaptations & Other Kinds of Rocket

We have given you a very specific recipe for making one particular model of one size of one kind of Rocket Stove with minor variations. This is like a recipe for chocolate chip ginger saffron cookies with 143 grams of butter, 212 grams of flour, 96.7 grams of honey and exactly a quarter of a pinch of salt. In other words, we've tried to faithfully give you the instructions to build one stove which we know works well.

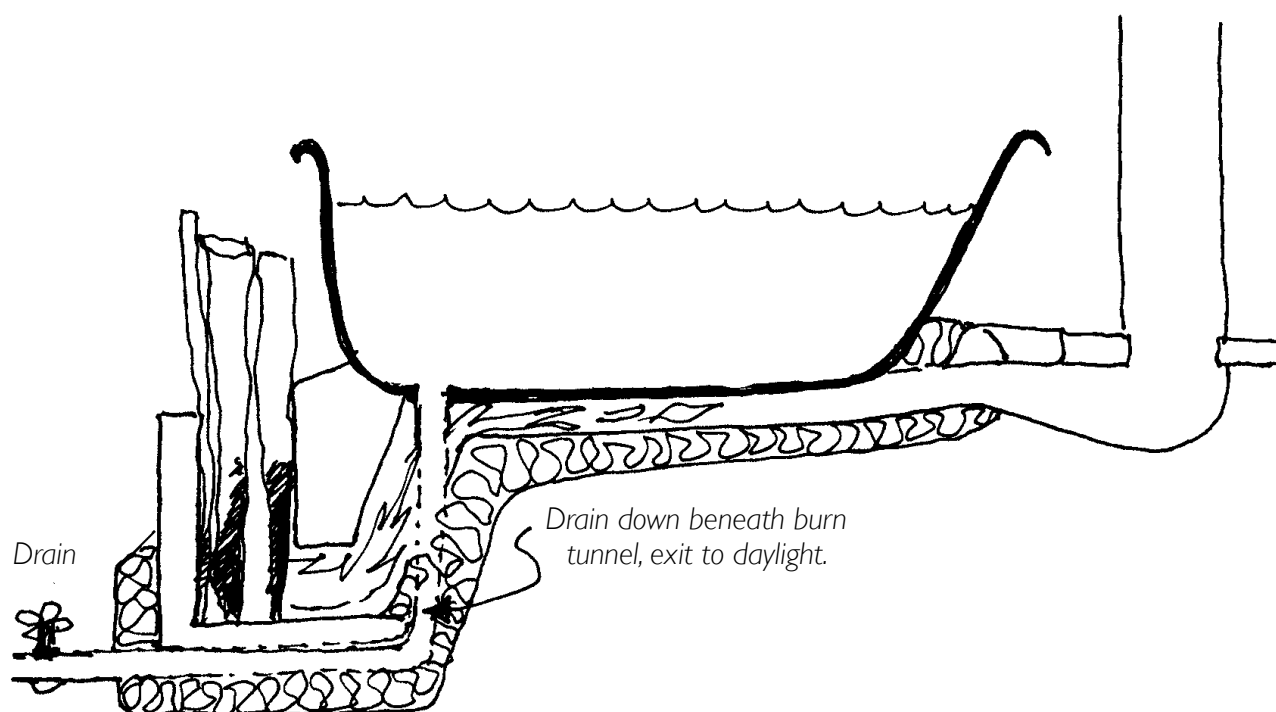
Now you're wondering if there's any flexibility in the measurements, proportions or materials. Already I can hear you asking "But what if...?" "What if I don't have any mason's sand? Or if I can only find 7-inch pipe? What if your stove doesn't fit into my house? What would happen if I wanted the bench higher? Can I heat my walls or floor, or build a stove for a completely different use, such as heating a workshop? Or a teepee? An ice-cream parlor?" When we change one variable, it changes everything else, so you will want to know the significance of changes you may make. As with many aspects of physics, a linear scale-down is not normally followed by the same scale-down in area or volume. A fire twice the size doesn't do everything twice as much as one that is half the size. But we can make some predictions about how well variations will probably work and from experience we can warn you about some things that definitely do not.

Start by consulting *Dementia* and *Proportia*. Almost certainly if you choose to make the heat riser higher the stove will burn faster, whereas if you choose to make the exhaust pipe higher it will have very little effect. If you make the heat riser shorter you will come to a point where it doesn't work at all, but we don't know exactly where. You would just have to try it. The longest heat storage flue we have seen is over 30 feet and it performs excellently, so we can speculate that a 55-gallon barrel with an 8-inch flue can push hot gases 40, 50, probably 60 feet. Beyond that is more speculation.

We also know that heat is lost more rapidly from hot objects than cooler ones. So the most critical part to insulate will be the surroundings of the burn tunnel. The stove we describe in detail heats people in a small house in a fairly mild winter climate quite effectively. For a bigger house or a colder climate (or colder people) you might try to scale up the whole unit, making the entire digestive tract a bigger cross sectional area and making the heat riser taller.

For heating a greenhouse you can run your exhaust pipes through the floor to minimize wasted space and maximize the amount of heat storage placing it as low in the building as possible. But with a greenhouse stove, moisture is always present and you would be advised to build with flues that won't rust, using for instance brick, stainless steel or aluminum.

THE ROCKET HOT TUB



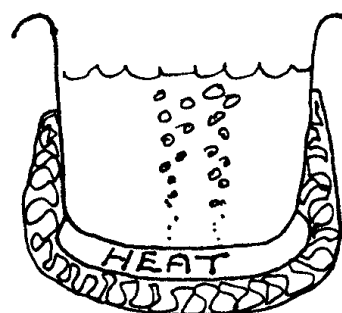
Hillside Rocket Hot Tub

If you have an old cast iron bathtub, you can fairly easily turn it into a one-person makeshift hot tub. It may need to be under a roof to protect the cob parts from rain.

Take an old clawfoot bathtub, twenty or so used bricks, and a few feet of chimney pipe. Dig a trench the length and width of the tub, fairly shallow. A gap 1½" to 2" deep is ideal, the full width of the tub's bottom. Line it with pyro-insulant (we've used a ratio of 1 clay-slip to 6 perlite). Set the tub down carefully over its trench, and seal the sides with insulation. To drain the tub, attach a vertical drainpipe straight down through the insulative trench floor and discharge away from the area, perhaps to thirsty plants downhill of the tub. Dig a pit just in front of the drain end of the tub, a foot deeper than the trench, and construct a brick feed tube in it. Connect the tub to the feed tube with a perlite-clay fire tunnel, lifting the tunnel floor steeply so the hot gases collide with the tub's floor. A few inches from the head end, a

brick base holds up the exhaust pipe, which is worth insulating, though that's not essential.

Use a floating bubble-wrap cover or an old closed-cell foam camping pad that fits the tub tightly, or the water as it heats will simultaneously cool by surface heat loss. You will also need a bum-saver, a wooden board to insulate your butt from the hot iron beneath. Always make sure that you have at least ten gallons of water in the tub before firing or you'll crack the enamel. And, don't even try a fiberglass bathtub; the smell as it melts is atrocious.

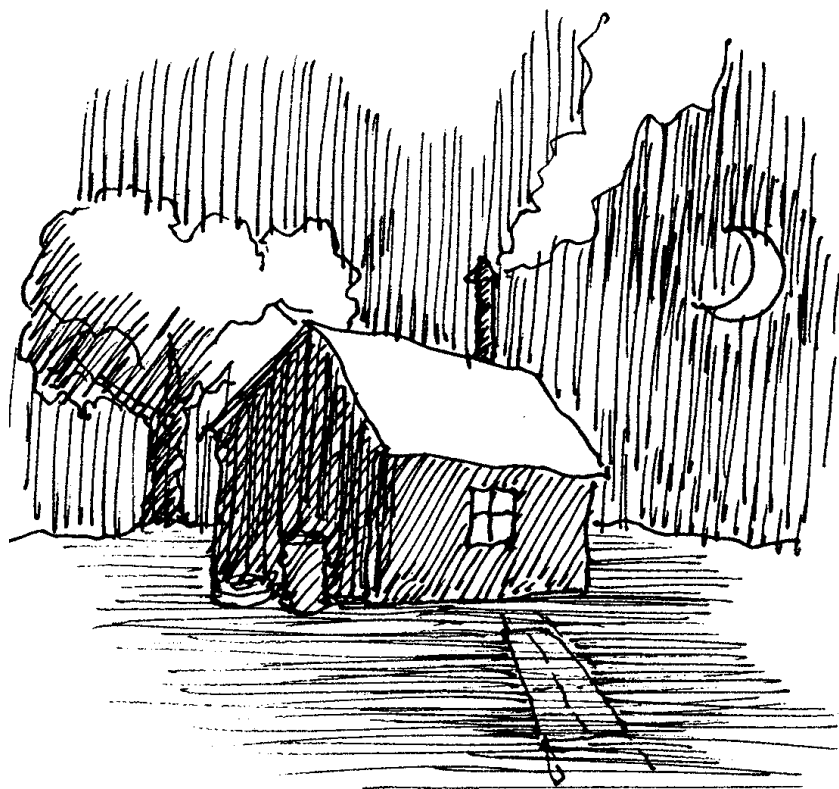


Note wide tunnel and insulation placement.

Depending on how you rank the distinguishing features of a Rocket Stove, some of the following examples of other kinds of Rocket Stoves could be seen as Something Else. They have some Rocket characteristics, but not all, they lack heat storage, for example. Although they burn extremely clean, they do so at the cost of wasting heat up the stack. We thought it worthwhile to include them though, as they may stimulate further tinkering.

DETROITUS AND THE POCKET ROCKET

Shortly after Larry and Sandy bought their farm, and long before they built the house there, he and I were working all day in the rain. There was no shelter, it was midwinter and we got soaked and chilled. As darkness came on, we packed our tools and drove back to the pickers' shack Larry and Sandy had rented on another place. Just the time for a hot shower and a mug of cocoa in front of a blazing fire!



We had the cocoa, but there was no shower in the shack and no easy way to warm up. California farmers clearly felt little need at that time to provide comfort for their seasonal workers. We were blue with cold; the cocoa didn't help that much. Finally we switched on the gas stove and sat with our feet in the oven. After a while, Larry looked

at me and laughed. "This is ironic," he said. "Two of the world's experts on improved stoves sitting with their feet in a gas oven. Why don't we build a wood stove?" So we bundled up and went back out into the pouring rain with a flashlight.

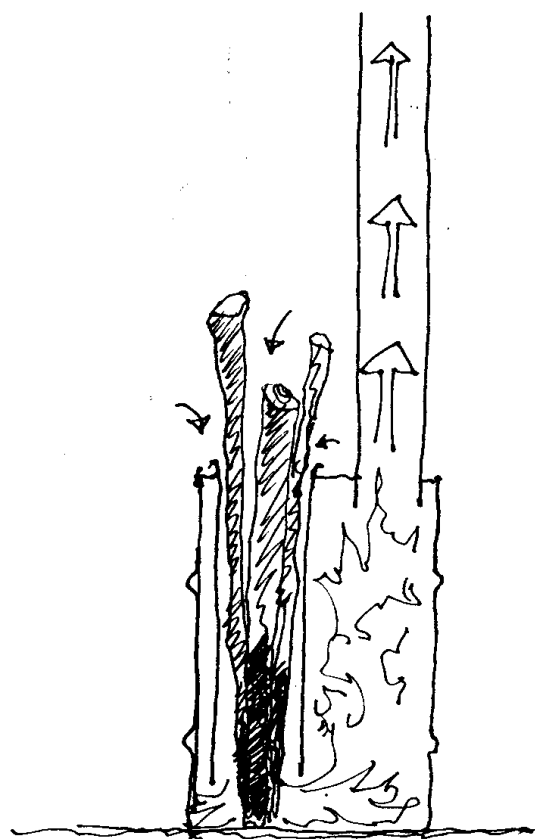
Like many California farms the place was rich with junk piles—"Detroitus" as David Eisenberg calls it.

We found a 55-gallon barrel and assorted lengths of rusty stove pipe and took them back with the vague notion, I suppose, that we could build a barrel stove by banging a door into one end of the barrel, laying it flat and poking a flue into the other end. But somehow we screwed up. The frigidity of the night must have affected our brains. Both holes ended up at the same end of the barrel. So we stood it upright, connected the flue to one hole and poured burning kindling down the other. It took off instantly, roaring loudly. Little did we know we had invented the Pocket Rocket. But then we didn't care much; it was just too comfy, slowly rotating our steaming bodies and sipping hot cocoa.

The stove that Larry Jacobs and I made was an ancestor of Rocket mass heaters. How they work has to do with the fuel and the incoming air both being preheated because the feed tube is actually inside the burn chamber. They are similar in that there is an abrupt 180-degree bend at the bottom of the feed tube, there is gravity feed and the feed chamber is separate from combustion. The high temperature of the combustion

chamber and the stack drags in fresh air at high velocity. Pocket Rockets waste a lot of heat up the stack so it's good to use a small diameter pipe but they are incomparable for delivering foot-level radiant heat quickly out-of-doors in even the worst weather.

We later played with the idea at an alternative kid's school in England, scaling it down to as small as a three quart paint can with a bean can for a feed and a 2-inch downspout for the stack. We taught workshops to suburban housewives on how to make a 5-gallon Pocket Rocket with a tire iron and a rock in about 25 minutes if you're stuck at the side of a road near a landfill.



Pocket Rocket

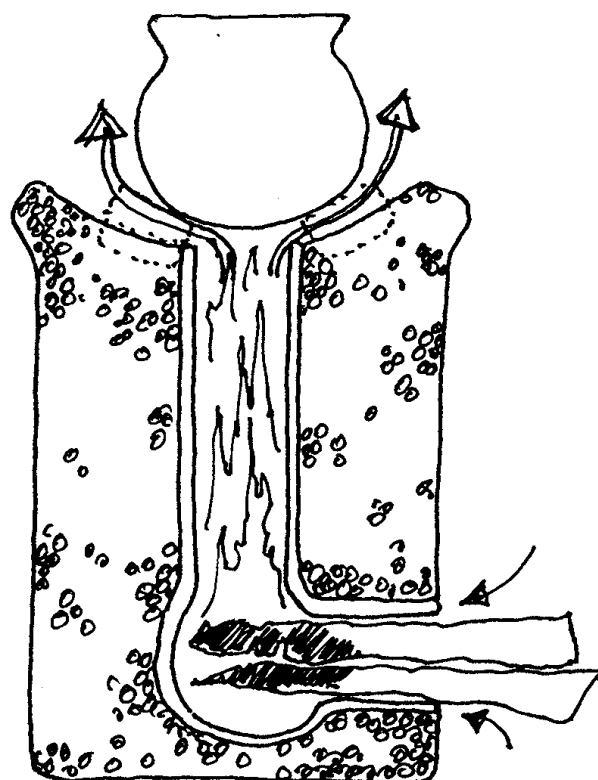
Our dream was that they could be taught to homeless people to get fast heat on windy street corners by burning scrap lumber out of dumpsters.

Recently, Tracy Johnson made a truly Pocket-size one with a beer can and two pieces of 1-inch steel pipe. "Hard to keep it going though," she says.

Note also that the greatest heat output is from the *bottom* of the pocket rocket

and it can get alarmingly hot. We've had them cherry red all-round and hot enough for the can to buckle up like a concertina: a dangerous source of heat radiation that can ignite flammable objects at 2 and 3 feet distance. Be sure to keep the kindling, paper, furniture, etc. at least three feet away or surround your pocket with a safety wall of brick, cob or polished aluminum.

THE GUATEMALAN COOK STOVE: ESTUFA ROCKY



Estufa Rocky

In the late '80s my work as a trainer for the Peace Corps caught the attention of the Guatemalan Minister of Agriculture. He thought that a clean burning wood fired cook stove for the urban populations, especially in Guatemala City, could reduce the devastating deforestation happening all around the capital city. At that time more than a million people did their daily cooking on little open

campfires inside their homes, particularly the recent settlers in the huge squatterments that filled the steep ravines surrounding the more formal parts of town. Daily, huge trucks brought massive loads of pine firewood in from the mountains. It was sold in street markets or in corner stores at a substantial price. Families were spending up to one third of their meager incomes on cooking fuel. For some people the choice was to cook or to buy food; they couldn't afford both. As with anything the government wants, everything had to happen quickly, so suddenly I had a staff of five and a lab in Guatemala City and 12 days to come up with a stove that would cut firewood use in half.

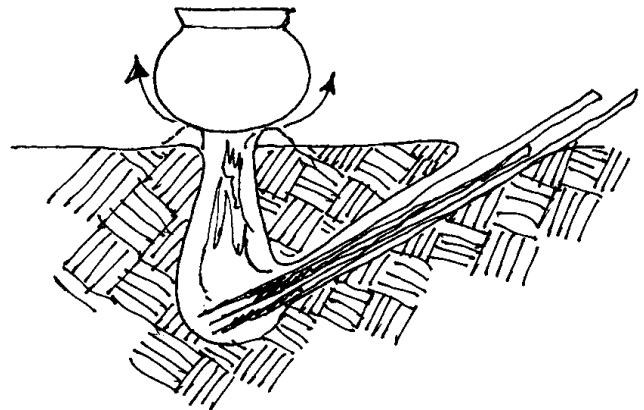
The device we developed cut fuel use by more than 50 percent and was the fastest cooking stove of the hundreds I tested in those years. Its core was a terra-cotta elbow 4 inches in diameter which created a heat riser about 20 inches tall and a horizontal feed tube about 10 inches long. The elbow was cast into a lightweight pumice-concrete cylinder and cooking happened on top of the heat riser. We made no attempt to get the small amounts of smoke it produced out of the house. At a budget of US\$4 per stove there was little room for refinements.

The Minister of Agriculture, delighted by the results but a pragmatic realist said, "What do you mean 'Rocket Stove?' That sort of title will never fly in Guatemala. We will call it *Estufa Rocky!*" ("Rocky" was the name of a series of movies which were very popular in Guatemala at the time).

Most of the users loved these stoves. Not so much for their firewood savings, (who counts firewood anyway unless you have a scale and a laboratory?) but because they cook really fast. It is a marvel to people who normally cook on an open fire to be able to keep the fire going with only one stick.

THE BENGALI PIT STOVE

In the heavily populated delta of the Brahmaputra, rural people lack many resources and are desperately short of cooking fuel. Long before Rocket Stoves were around, the people there developed underground stoves using similar principles.



The Bengali Pit Stove

Combustion happens in a flask-shaped pit about a foot-and-a half deep. The fire is fed with tiny pieces of sticks and agricultural waste through a diagonal tunnel, which intersects the bottom of the pit (see diagram). Dry soil is quite a good insulant, so the burn is very hot. The cook pot is suspended on three little clay hills equally spaced around the rim of the pit.

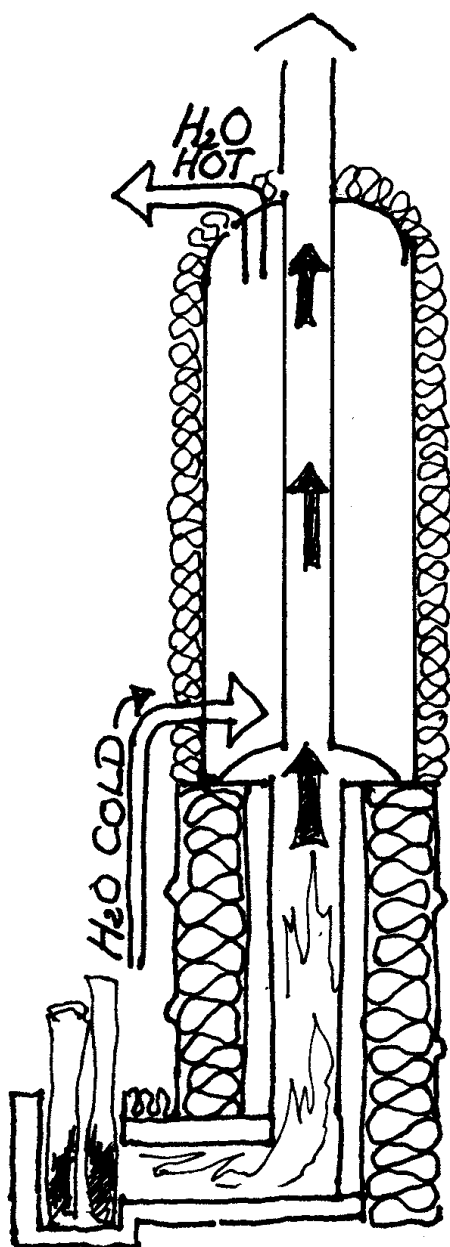
These stoves are extremely efficient in the amount of fuel used and the speed with which they cook, and they have a great advantage over fires or stoves above ground. In a very hot climate, waste heat radiating from a cooking fire can add to the cook's discomfort. Nearly all of the pit stove's heat goes into the pot.

You might try this one next time you go camping, or even in your backyard. The investment is minimal and the rewards are high.

HEATING WATER

A frequent question is “What about heating water?” Nothing conclusive, but we’ve tried a few things. You might do the same.

Our first attempt was a 60-gallon gas heated water tank (from the dump, for free) mounted atop a 55-gallon standard Rocket. The exit gases roar up the heat riser, then straight through the tube in the center of the tank. The tank is insulated, and the barrel is stuffed with loose perlite all around the brick heat riser.



The general idea of a water heater mounted atop the heat riser of a Rocket Stove.

Things we learned:

1. A three-inch flue is too small; it takes 1½ to 3 hours to get up to shower temperature. At the North American School of Natural Building this works okay because most evenings there is demand for ten to twenty showers and the 60-gallon tank yields about that many if you keep stoking between showers.

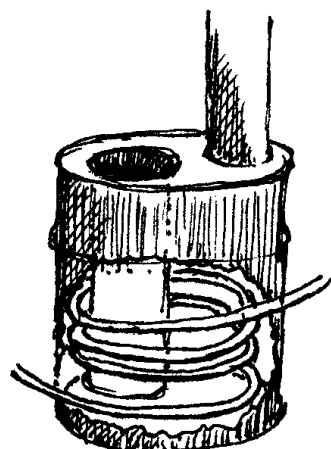
2. The whole contraption is very high, about ten feet with the exit stack, seven or so without it.

3. Sixty gallons of water in a steel tank weighs a quarter of a ton. It feels precarious so high up. What could happen if the support barrel tilted, collapsed or rusted through? How would it do in an earthquake, and would you have to run for your life naked and soapy?

4. Loose-fill perlite settles over time, so the top few inches of the barrel are now very poorly insulated.

As part of Cob Cottage Company’s ongoing research project, Ernie Wisner is using a coil of twenty feet of half-inch copper tube wrapped around a triple-wall stainless steel stove pipe/heat riser. It feeds into a standard water heater tank. Early results look very promising, though with a bigger pipe, say ¾", you could expect a much faster heat-up.

For instant hot water, a coil of ½" copper pipe in a Pocket Rocket delivers very hot water within minutes. Easy to make, very little fuel, but you need to be there to feed it and to make sure the water stays flowing.

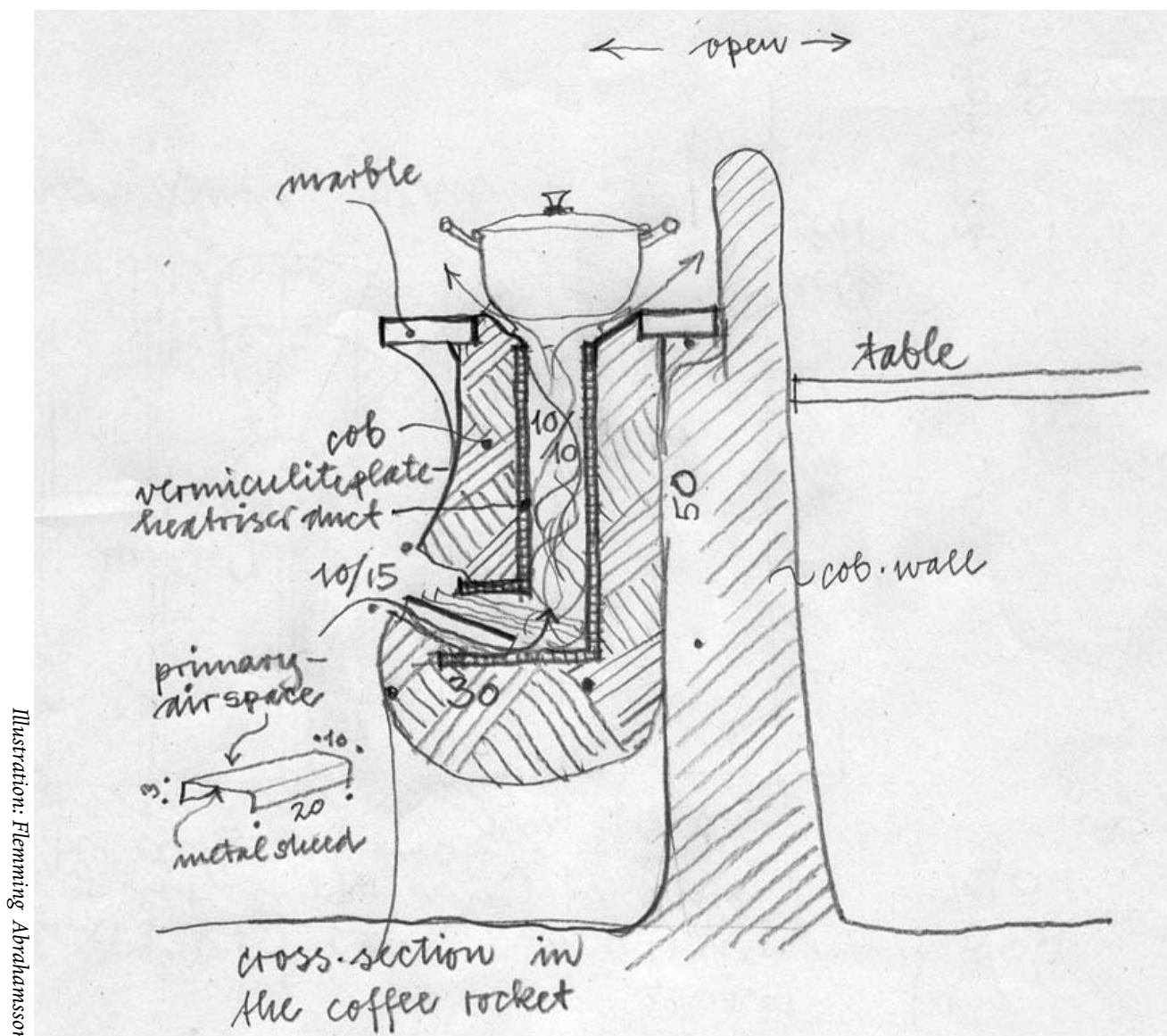


Instant hot water.

THE COFFEE ROCKET

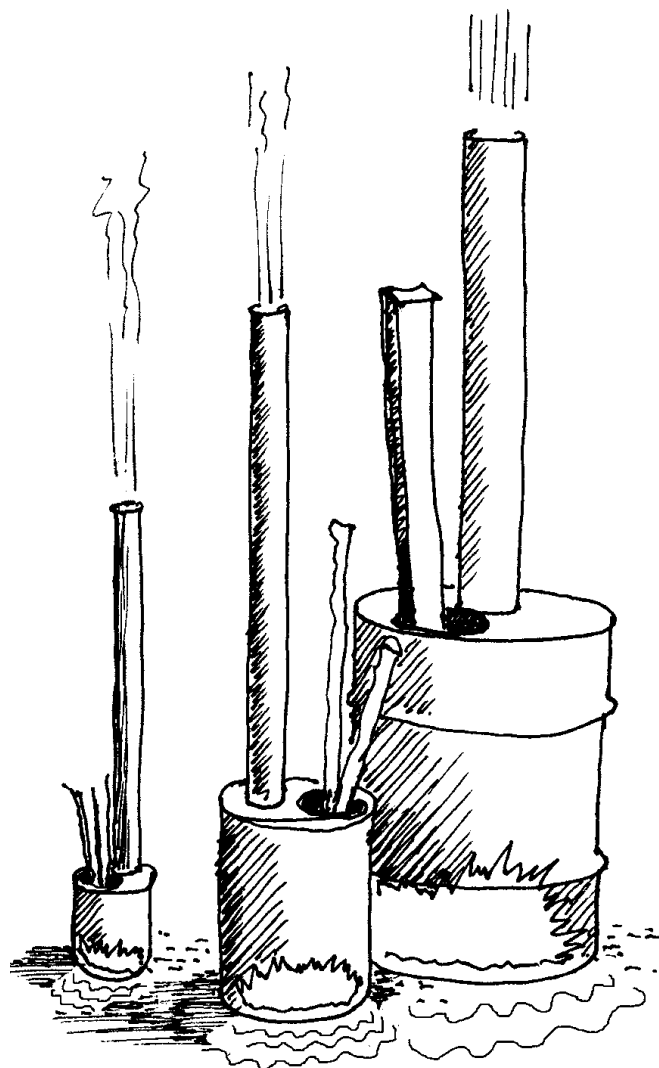
In the office of our Danish partner, Flemming Abrahamsson, among the stylish Scandinavian furniture and beautifully drawn plans on his desk sits a little thermal fiberboard box recessed into the surface of the desk (see photo, page 56). When clients come to discuss the architecture of their buildings, Flemming asks, "Would you like some coffee?" He puts the coffee pot on top

of the box and sticks a match in its mouth. His Coffee Rocket boils a liter of water in four minutes, easily outdoing gas or electricity and produces so little smoke that it has no need for a chimney. It's made of low-density, high-temperature mineral fiberboard, which you can buy by the sheet and cut with a handsaw.



Dimensions are in centimeters.

HOW TO MAKE A POCKET ROCKET



Pocket Rockets come in many shapes, sizes and styles. The type pictured is an outdoor radiant heater. It's made from cheap materials that are often found in the waste stream. Because of its high chimney, it has a relatively clean burn, but of course what heat isn't absorbed by a human directly off the radiant barrel is sent to the heavens. The emissions are low, though, making it a nice way to get warm around a fire in the city, for example. It requires very little wood to operate. It is also easy to make.

This recipe is for a Pocket Rocket with a five-gallon burn chamber (using a 5 gallon can or pail). It's possible to make one in any size. The pipe sizes will be proportional. For example, a 25-gallon drum works well with an 8" x 25" feed tube, and a 4" x 66" flue pipe. These measurements are fudge-able. It's the proportions that matter.

MATERIALS:

5-gallon metal can or pail with removable lid, clean of finish paint or residue
4 inch x 60 inch pipe (preferably not galvanized)
6 inch x 12 inch pipe (not galvanized, flat black stove pipe is preferred for both)
Sheet metal scrap of at least 4 inch x 4 inch (or something similar: steel pie pan, vegetable strainer, steel pot lid, etc)
Newspaper
Firewood: dry, thin, straight, long
Plenty of tiny kindling

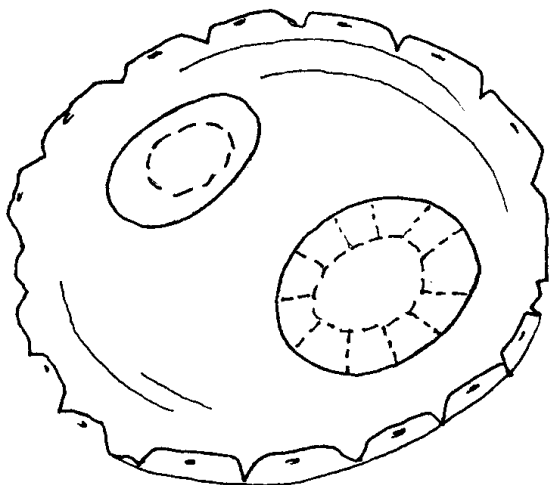
TOOLS:

tin snips
hammer and nail
hole saw
pliers
felt-tip marker

SAFETY GEAR:

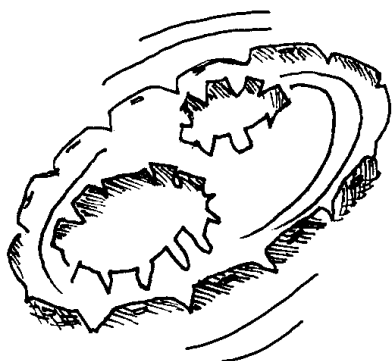
leather gloves

Remove the residues of paint and the pail's contents (see a note on safety, below). Remove the rubber gasket, if there is one, from the inside of the lid. The feed tube and the flue pipe are both attached at the same end of the burn chamber (the can or pail) in the lid. Trace the outline of the two pipes onto the lid with a felt marker (or nail, etc), placing each pipe towards the outer rim of the lid so that there will be plenty of material left in the lid itself to support the pipes (see illustration, following page). In order to create a tight fit for the pipes, draw a circle that is an inch all-around smaller inside the original one.



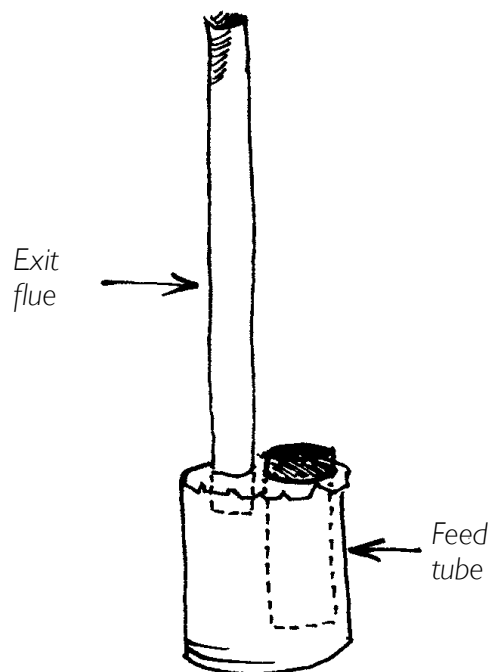
The flip-side of a can lid with large and small pipes traced onto it.

Start the hole in the center with a hammer and nail, chisel or other sharp object. Then from the starter hole, use tinsnips to cut out the inner hole. An easy way to do this is to cut in a spiral pattern from the center out to the inner marker line. Do the same for the other pipe. Now you have a can lid with two holes which are both too small to accommodate the pipes. Using tinsnips, cut tabs about an inch wide, radially from the hole's center out to the pipe's actual line. These tabs will hold the pipes in firm and tight and allow much more control and adjustment when fitting them. Using pliers, fold the tabs almost to right angles pointing into the can. Now you have a dangerous frisbee.



Can lid with tabs cut out and folded back.

The shorter, bigger pipe, which is the feed tube, will hang inside the can, almost to the bottom (see illustration). The long exit flue pipe will sit into the can only a few inches,



just enough to hold it steady. Put the lid on the can and friction-fit the two pipes into position, making adjustments to the tabs as necessary so that there is a nice tight fit.

Operation Light the corner of a piece of crumpled newspaper and push it down the feed under the area of the flue. Flames should be drawing up the flue pipe. Slowly feed more burning newspaper to burn at the bottom of the feed tube. Add a little more newspaper then a few pieces of kindling, standing upright in the feed hole. The object is to keep the draft going in the same direction: into the flue. Add more fuel. You can regulate airflow into the stove with a piece of sheet metal a little larger than the pipe. There are many ways to enhance the burn quality. Experiment!

A note on safety. A lot of the pipe out there is galvanized. Its melting point is 787°F, but it offgases at a lower temperature than that. We like to just avoid galvanized pipe.

Most barrels are painted. This paint must be burned off in a bonfire to remove it. Who is downwind (including you)? Wear robust leather gloves, and stay out of the smoke.

Research Needed and Experiments

In the year and a half since the first edition was published, considerable experimental work has been done. All by amateurs, some of it with surprising results. We now know more about geometric relationships, proportion and ways to heat water, for example. But as with any good research, more questions than answers are generated. This remains an exciting field, wide open for low-cost research by anyone with a little time and creativity. Cob Cottage Company will continue to be a clearing house for new information and will happily put researchers in touch with one another.

Experiments with **bigger stoves** with **bigger power outputs** might be interesting. So far, most Rocket Stoves have been built with 6-inch or 8-inch diameter exhaust pipes. They might necessitate more durable, high-temperature materials, such as castable ceramic, fireclay-fiber mixes, or fireclay-insulant mixes for the combustion zone.

How far horizontally can a Rocket Stove push hot gases? Our own greenhouse stove works well with 36 feet of exhaust flue and no vertical stack. What would it take to heat sixty or a hundred feet?

Less work in splitting firewood and less frequent attention are desirable. Ways of creating a bigger feed chamber would help a lot.

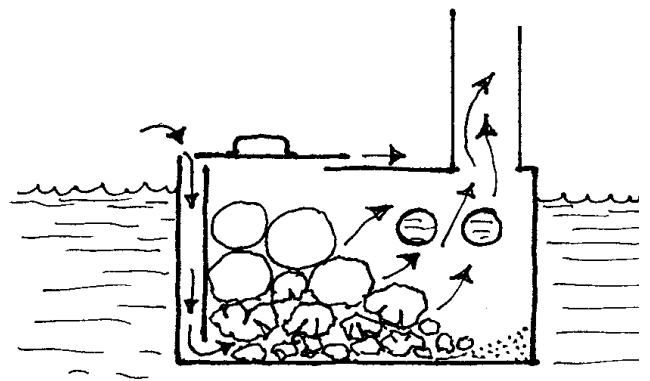
A submersible Rocket Stove for heating hot tubs? In the 1980's, an enterprising inventor in a physics laboratory at the University of Alaska came up with a welded aluminum wood stove called the Snorkel, specifically designed to heat a wooden hot tub. It had some similarities to the Rocket but the fire chamber was not separated from heat storage so the combustion temperature was too low for a clean burn. Someone inventive should be able to improve on that.

Saunas and sweat lodges could well be Rocket powered. There is a lot of interest in this.

What about a Rocket with the fuel loaded vertically in a closed loading stack, with the **air inlet on the side at the bottom** of the feed tube? It might be that you could expose the air vent as a very small window of very hot fire visible in the room, heating the feet by direct radiation. For chunky or curved fuel, would a horizontal loader be worthwhile? What disadvantages would it have?

Castable pre-assembled kits would make building these stoves more accessible to more people.

A foolproof self-loader to guide fuel into the feed-tube could help with the use of longer wood or very short wood such as wood chips, pellets or sawdust, and should protect from burning pieces falling out of the stove.



The basic Snorkel concept.

Increased durability of key components. In particular, the bottom of the feed tube and the bridge over the burn tunnel.

Home-made fireproof insulants, e.g. clay-sawdust, clay-wood chips, clay-paper fiber, etc.

Better Pocket Rockets. More durable feed pipe, safer surfaces, less stack heat loss, their use as cookstoves. All are promising, as is a wider range of applications. For instance can a Pocket Rocket be a mass heater? Or, how could we store the heat produced?

How about a Rocket Stove that runs on **clean construction waste and forest thin-nings**? If your access to burnable fuel is from forest restoration thinnings, or from the cut-offs from carpentry projects, what would your Rocket Stove look like? We'll be working at this one over the next year, as many people find themselves in this position, wishing to cut down on flammable materials in their forests, or wishing to rescue fuel from the waste stream.

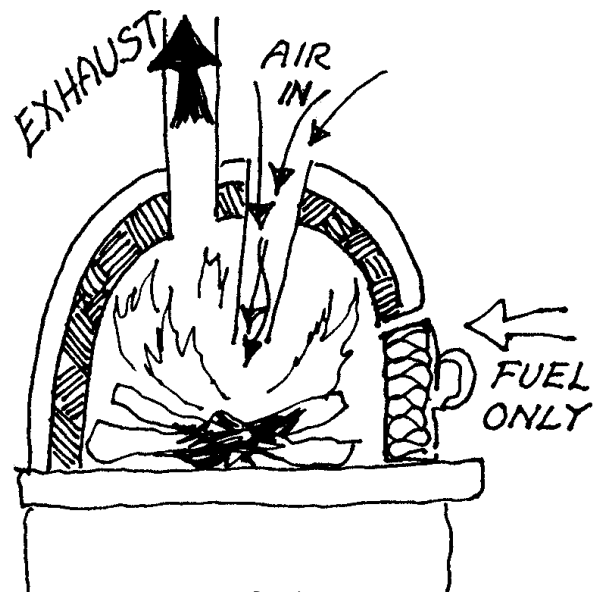
Hypocausts means underfloor heating by hot gas. They were used 2000 years ago in the chilly British Isles by the Romans. Normally they used sandstone slabs for the floor, suspended on sandstone pillars about three feet high. Now that underfloor "radiant" (hot water or electrical) heating is popular, this may be something useful to explore.

An underfloor Rocket Stove for melting aluminum. Shannon Dealy is currently finishing up and testing an aluminum forge in his cob workshop. Firewood is fed horizontally into an outdoor feed tube. The burn tunnel passes through the cob wall, and the heat riser is two barrels stacked and welded end-to-end to create enough draw for the temperature required to melt aluminum (1200°F). Four manifolds, made from square steel tubing, guide the cooling gases through under-floor pipes in the shop, making it so

warm in there that when Shannon fired it up to dry the floor, it did more than dry, it drove him out!

Beehive ovens normally bake really well, but burn really dirty. Shortage of oxygen and low surround temperature, coupled with no effective chimney, are a bad combination for clean burning. A little experimental work by Jim and Tyra Arraj hints at possibilities for a better bread oven with cleaner burn, greater efficiency, and fewer neighbors calling out the fire truck.

The Arrajes installed a short removable chimney, which creates suction that hurtles pre-heated air down the down-draft pipe onto the fuel. The oven door is kept closed except when adding fuel.



Beehive oven.

Case Studies

TOM & CALLEAGH live in a cob house they built at a community in the mountains of Northern California. Their home is extremely remote. In winter, it's an 8-mile hike with a four thousand foot climb to the nearest drivable road.

After building the cob house and living in it for a year or two, we'd both had plenty of time to think about a central heat source for the house. The idea for a mass heater bench came up, but I had doubts about building a mass heater that would actually work. My mind always came back to the tried and true 'airtight wood stove' option: compact efficient and familiar—or so I thought!

In February 2002, we participated in the Pyromania workshop with Cob Cottage Company. There we learned about cob fireplaces and construction, but most importantly for us, we experienced for the first time sitting on a warm, cozy and very functional wood fired mass heater bench—three of them, in fact! After this experience, I immediately threw the airtight wood stove idea out the window. 'Air-tight?' Wood stoves are anything but efficient. Convenient, perhaps. Familiar, yes. But

efficient? No. They are smoky wood hogs that pump most of their heat up the chimney.

Seeing a working mass heater bench in operation and experiencing its comfortable qualities totally converted me. It is extremely efficient, reaching 90 percent combustion, and almost all heat made is then stored in the cob mass bench, to be slowly released over days!

As for our own bench, it takes about four hours to get totally warm. From a 4-6 hour burn time once a day or every other day, we can maintain a comfortable temperature in the house of about 65°F, even on cold days. The heat from the bench isn't as radiant as a metal stove, but when you get close or sit down on the bench, bring your book and your tea because you will want to stay!

Calleagh: The first real use of the bench was during my labor in late October of 2002. We were birthing at home and we wanted it warm. I ended up using the heated bench as support during our daughter's birth. During her infancy, we slept on a futon on the floor next to it with Shirleen up against the bench because it was cold and frosty (in the 20's) at night. I consider a heated bench an excellent resource for a newborn. I did have to watch it though. More than once while napping on the bench, she got too warm (over time the heat rises through the cushions). I dubbed it the 'overheat-her' bench.

Now, we put all of our clothes under the cushions at night before we go to sleep. The next morning we wake up and start our day with warm clothes! What a luxury in the winter!

—TOM FRAME



Photo: Tom Frame



Three examples of cob buildings that have stood for several centuries in southwest England.



Photo: Catherine Wanek

*The fine craftsmanship of Flemming Abrahamsson.
His office, at right, has a gorgeous stove and bench,
pictured below, left. Bottom right: A Rocket Stove powered
staircase, sculpted out of cob. You can just make out the
staircase through the window of the office. Photographs
this page by Catherine Wanek.*





Above: The Rocket Mass Heater with bench at lower right in the home of Ianto Evans and Linda Smiley has been in use for over ten years. Dry firewood, split thin and cued up in the sun, small feed barrel and heat exchange barrel nestled in cob.
Below: The continuation of the bench above. Note the thermometer about half-way up on the exposed vertical stack.





Above: Chris Reinhart's Rocket Stove. Note that the barrel is exposed quite a bit to maximize radiant heat. Below: Kirk Mobert's Rocket Stove with cooking surface on top. There are two cold air intakes below the metal door. The cob bench box keeps firewood dry.



A ROCKET-FIRED WOOD KILN

In Canada, Jay Naydiuk, who owns a small private lumber mill, built a drying kiln. He used an 8-inch Rocket system with an 8-foot long sand-filled wooden trough for the heat storage and it exhausts to outside the building. A small squirrel-cage fan is moved along the lumber stack at regular intervals to ensure hot air is dispersed equally throughout the pile.

Last year he dried ten thousand board feet (about 25 cubic meters) of his own lumber in batches of about two thousand in a 12 x 20 foot shed about 8 feet high. It took a month with the stove burning about ten hours a day.

Jay's stove has a welded half-inch steel cylindrical burn tunnel and heat riser. To get the extra power of the 40-inch tall heat riser, he added a third of a barrel in height by mounting a 55-gallon drum on top of another one-third of a barrel, which he had cut the bottom out of. It got so hot that the pipe **glowed** orange he says. The kiln temperature ran up to 130°F (though he built the stove at -20°F).

As if its remarkable power output and use isn't enough, it's actually a mobile stove. The whole thing is built in a big pan made out of a 120 gallon oil tank cut in half horizontally so he can drag it out of the building if he needs to. What this means is that his setup is fairly lightweight compared with brick ones with their weighty permanence.

Air supply is from a side vent at burn tunnel level. The feed tube is a capped load chamber sealed with a metal bucket. Jay burns two-foot bolts of his own mill waste that would otherwise be unusable: fir, birch and aspen, but he says larch (tamarack) and lodge pole pine give the best heat. He made his load chamber oversized so even with his 40-inch heat riser the stove doesn't always burn completely clean. The burn tunnel was insulated with wood ash and he felt that its incomplete

combustion might have to do with that ash settling and compacting.

He clearly loves his stove, though. He likes the amount of attention it demands. "You have to tickle it," he says. "Rocket Stoves make people feel good. This is a stove for where people abound, where there's community. At one of the first firings of the stove, Trish needed a fireplace poker. I made up an apple crisp and put it on top of the stove on a grate with my big stainless steel mixing bowl over it for an oven. While it was cooking, I forged a poker out of a piece of steel. Then I took the poker and the apple crisp up to Trish's house. That stove makes the best apple crisp I ever tasted."

His application of the Rocket Stove as a lumber dryer is only one of many similar drying applications he feels the system could take on with its gentle heat, from nuts and other edibles to pottery.

He is so enthused by his prototype that he is replacing it with a bigger, ten-inch flue size model. The heat storage will be much more extensive and his plans for the new one include insulating with high temperature mineral wool similar to a fiberglass bat. The horizontal pipe will run the entire length of the building with the pipe doubled back, a total of thirty or forty feet. He intends to put the heat storage into a cob-filled trench in the ground to make his lumber stacks more accessible.

DONKEY'S ROCKET

Kirk Mobert and his family live in a hybrid, natural home-to-be on the California coast in Point Arena. Kirk's story is interesting for a couple of reasons. Not only does his Rocket Stove act as an oven, a stovetop cooker and a heater, he built it without the benefit of this book, having only seen a Rocket Stove during a visit to The North American School of Natural Building. Kirk says, "I invented it as I went along, building from the bottom up. At one point I got hung, the idea is a simple one but it can be hard to visualize fully. So I called Ianto in a panic one night and he gave me the ten minute synopsis. 'The chimneys in the stove, dude.' That was it, everything pretty well clicked after that."

Kirk's stove begins with an oven door made by a metal worker friend. The burn tunnel is massive and can handle several logs burning horizontally. Beyond the burn chamber there is an ash-drop or pit, which burning coals and wood eventually slip into. His fireplace is a horizontal loader with a wide mouth, so the fire can be seen and enjoyed with the front-feed door open. Below the main front door there are two small sliding gates that act as air intake regulators. With the gates open, cool air flows below the length of the burn tunnel, getting a preheat from above before entering flame. The core of the burn chamber is what Kirk calls fireclay cob, "I took fireclay and just made cob with it." The heat riser was cast using refractory cement, poured into the gap between 8-inch and 10-inch cardboard tubes.

From the heat riser top, gases drop down to heat an area where wood waits to dry and a small bench, and finally leaves the system and runs through stovepipe, heating a greenhouse before leaving the building. Weekly maintenance involves "a really long rake-looking thing—a hoe—that fits down the air intake tubes. Occasionally, ashes pile up and block the airflow, so I shove them back to where they're out of the way, adding to the insulation in the back of the stove." For

longer term maintenance there is a clean-out for the stove at the back, on the greenhouse side. A cob plug is wiggled out, ashes are removed and put to use in the greenhouse or straight out the door to the gardens beyond.

Results from Use: The Rocket Kirk made is a wonderful example of taking the principles that make the Rocket Stove work: geometry, proportion and materials, and orienting them to one's own needs. Although now that he has more information, he would do a few things differently, such as try to reduce the temperature of the exit gases. Other nuances of the stove have come with much tinkering; there are spots on the stove which are showing signs of extreme heat stress. The stove is showing cracks and Kirk looks forward to "chopping into it and rebuilding sections again." A work in progress.

THE REINHARTS

Chris and Jennifer Reinhart live in a handmade cob and straw bale cottage in the bumpy part of Indiana, near Bloomington. After their first stove was built, they experienced so many problems with smoke inside their home that they rebuilt it using wisdom gained from their first attempt. Their diligence, imagination and inventiveness have paid off. Here is Chris Reinhart's story in his own words.

Firing off a few of my observations, feelings, and ideas about the Rocket. My back and bottom sides are being warmed by one right now, as I lean against the vertical stack leading up the wall and outside. Jennifer is cozied up over by the barrel and we are both on laptops. I love the feeling of satisfaction that comes from building the device that keeps Jennifer, our son Ethan, and myself warm and cheerful through the winter months. The sound of the Rocket is reassuring: "The heat is on," it says and also tells me when to feed it. Many people who visit the house are more intrigued by the stove than by the walls made of mud and straw, and some have been

encouraged to go out and build their own. There's no reason not to, as the materials can be picked up about anywhere. Our Rocket Stove cost less than \$100 total and took two weekends to put together; one for the stove, one for the heated bench. When we rebuilt, it took a day to take the stove apart, and a day to put it back together.

This is the second incarnation of the stove and it was built pretty much "by the book."

We had some downdraft problems during the typical stormy fall our first year. Lots of smoke-outs left us feeling rather put out and the first solution we have looked into was the Vacu-Stack (available at chimney

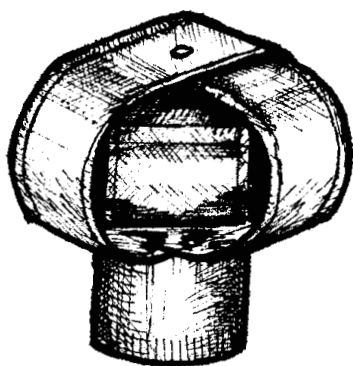
the house. It works great, but to the tune of over \$150. This is what we are currently using, with plans to implement the "old-timer's" way of doing things which is three stovepipe T's attached together so that wind blowing in is more likely to keep blowing out rather than turn two corners to go down the pipe into the house. We chose the Vacu-Stack option and saw immediate relief of our problem. With the other changes mentioned in the stove, we have not experienced the problem since then, though it's still too early to tell if it is forever relieved.

When we rebuilt the stove we insulated under and around the tube with perlite contained by brick. Although in planning for the insulation cavities I neglected to plan for an ash pit, which I had built into our first stove. I regret this, because I enjoyed the convenience of an ash pit at the bottom of the burn tunnel. On Jenn's suggestion we began using the shop-vac to clean out the burn tunnel, and it works amazingly well. I always feel that the stove burns best the first few fires after cleaning it.

Perhaps the most significant changes were the added insulation to the feed tube and the change in dimensions. In our first stove, only one side of the horizontal burn tunnel was insulated because it was not planned into the stove.

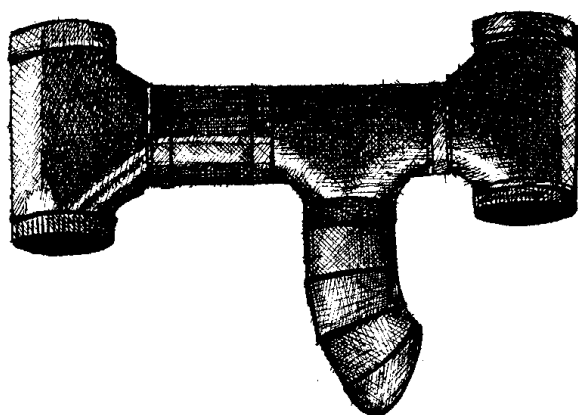
I changed the dimensions mostly because I used different bricks than in the first stove. In our original stove, we noticed the first and second bricks over the burn tunnel kept breaking and I replaced them three times during our first winter. In our second stove, I replaced the salvaged brick pavers of the burn tunnel that we initially used with fire brick, and thus shifted the dimensions slightly. The entire "J" was 7" x 7" in our first stove and 7" wide by 6" high in the second. The new one gets hotter faster, and the J-tube stays hot for much longer after the fire burns out which makes for effortless start-up for the next fire. I have no quantitative data about the differences between the two, though.

Illustration: Chris Reinhart



Commercial product: arrangement of baffles creates "suck" as wind blows through.

supplies and online). It is a stovepipe cap that creates suction as high winds blow into it, so it actually draws more in the wind instead of allowing the gases to be blown back into



*D.I.Y. Solution: Three T's and a coupler prevent wind from blowing down the flue.
Illustration: Chris Reinhart.*

The bench is built of masonry with sand-clay mortar. Urbanite, scrap bricks, sandstone from the creek, and the locally abundant scrap limestone were used mish-mash and built around the flexible stainless steel 8" pipe that a masonry stove-building friend of mine donated.

As for design improvements, partway through building the bench I realized the heat storage capabilities would be improved by building in an open channel between the masonry of the bench and the exterior foundation wall and cob wall. It seems this would slow heat loss to the outside wall and increase the amount of heat going into the mass floor and out into the room.

I like to have the wood split fairly small, 2"-3" in any direction. We have hotter fires with several small pieces rather than a couple of larger ones. Some may consider this excessive splitting a drawback. To me wood splitting is like hitting golf balls or any other focus-oriented physical pursuit. When splitting wood, one knows immediately when one's focus wanes. We burned a cord of wood last year, and that was before the



Chris laying the foundation for the stove. The burn tunnel of brick rests on a bed of perlite. Note Chris is building his first layer of brick and insulation sub-floor level. You can see the completed stove on page 84. Photos, this page, Christopher Reinhart.

building was well sealed around windows, doors and ceiling, and it was a moderately cold year by local standards. I imagine we'll use the same amount or less to heat our 200 round feet this year.

As with any type of fire, it's possible to become hypnotized, and sometimes I find myself squatting in front of the fire box staring into it, with all the crackling and popping of a hot fire and the roar of gases crashing into each other.

—CHRISTOPHER REINHART

BERNHARD MASTERSON

Four years ago my partner Le and I decided to embark on a journey toward a greater connection with the natural world: the seasons, gardening, and reducing our need for cash. Since that dream began we have built ourselves a snug 450 square foot hybrid strawbale and cob cottage outside Portland, Oregon. We heat with the sun and a wonderful Rocket Stove.

This is our first winter in the functionally completed house and we are thrilled our dreams are coming true. No longer do we come home in the evening to a cool house and push a button to turn on the furnace, but instead come home to a house that is still comfy and fire up the Rocket Stove. We have a greater awareness of the seasons because we are more involved with actual heating of our house. Every couple of days we get the opportunity to appreciate the weather when we go out to get firewood. I try to take a moment each time to just open my senses and soak in the experience of being outside.

Weekdays we are home in the evenings, and by the time baths are finished the Rocket bench is toasty for bedtime reading. On the weekends we really become cats and look for as many ways as possible to spend time on the bench.

Rocket Stoves are renowned for their efficiency and we surely are pleased with the efficiency of our own. On days with no

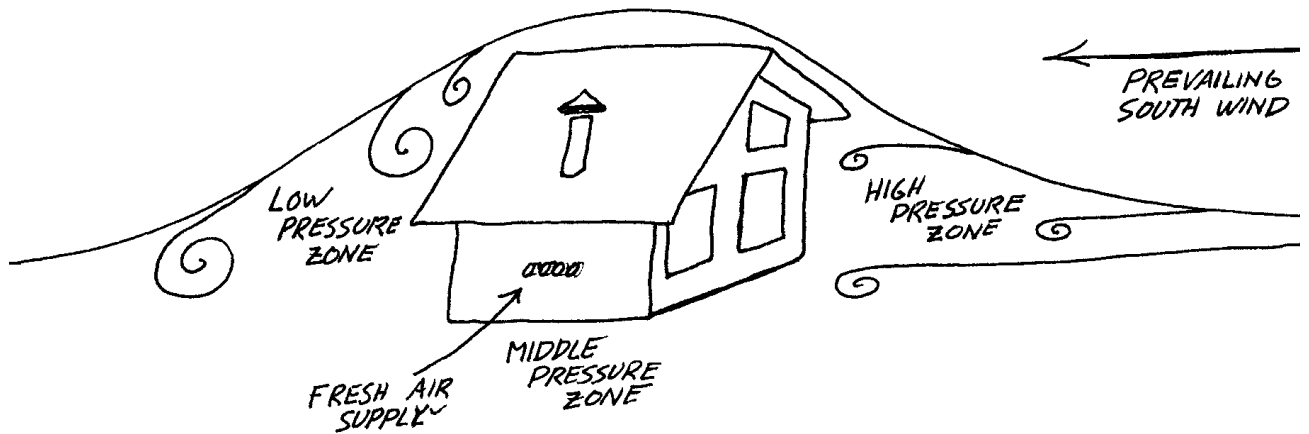
sun we run our stove two to three hours in the evening, burning about a five gallon bucket full of wood. For regular winter temperatures of 35 to 50°F, this keeps our house at a comfortable 60 to 65°F.

When the weather is windy and colder, 20° to 30°, our house loses about seven degrees a day. This means that in the burn time we have each evening we don't quite make up the heat loss. So in a given 24-hour period we may lose a degree. This doesn't bother us because even by the end of the week our house is still 55° when we get home and 60° when we go to bed, and the bench is always a warm place to hang out. There is also the unexplained feeling that our mud house is warmer than a conventional house at a given temperature. Our weekday burn time is limited because unlike a traditional box stove, we shut down the stove completely and put on the damper before bed. This keeps the heat in our bench from being pushed out of the house by the stored heat in the heat riser.

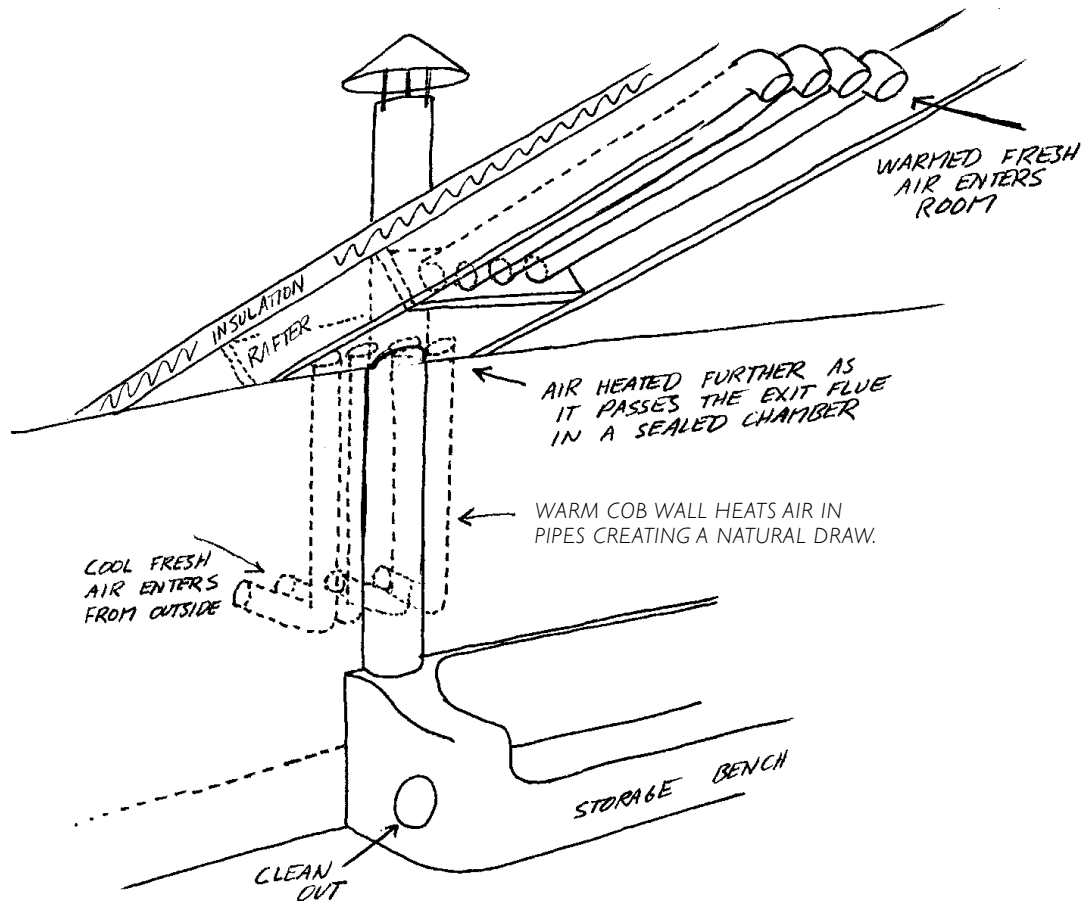
In designing our stove we chose to keep the top of the barrel low so that we could easily put large pans of water on the top for heating. The three gallons of water we heat on the top of our stove each day we use for dishes and recharging bath water.

Using a 55 gallon drum with a removable clamp-on lid allowed us to build the drum into the wall between the living room and bathroom and still have access to the heat riser for cleaning. The radiant heat in both spaces is wonderful. We have however discovered a couple drawbacks to the clamp-on lid. One is that the bung holes and rings formed in the lid limit the space we have on top of the stove for pans. A second is when we are running the stove really hot the lid expands and pops up slightly which is a little startling when it is covered in pans. Perhaps next year I will try fabricating a new lid from a thicker sheet of steel to solve these imperfections.

I still think the removable lid is a net gain. To seal the bung holes and lid I removed the rubber gaskets and replaced them with



Our other common wind comes from the north, and pressure zones reverse. The flue still exits in a neutral pressure.



By putting the flue exit and the fresh air supply on the same side of the house, pressure variations between the inside and outside due to wind are balanced. This reduces the load that the J-tube heat pump works against to push combustion gases from the house. The cross-sectional area of the four-inch PVC pipes matches that of our stove's feed tube.

aluminum foil “ropes.” This worked well and the aluminum did not degrade at all in the first year of our stove’s operation.

Installed in our bench are two six inch diameter ducts for increased surface area for heat transfer to the thermal mass. Our bench is about sixteen feet long. I feel if it was longer we would get more heat out of the exit gases as flue temperatures range from 170 to 250° F as gas exits the house.

The ducts in the bench vary from two to four inches from the surface of the bench, which although not designed that way, turns out to be an asset. We can move around from hotter to cooler parts of the bench depending on our comfort. The two inch spot may be a little on the thin side since it can get quite hot, but it sure reduces the time it takes to proof bread when we set loaves on the bench to rise.

The first stove I built is in a drafty workshop. When we have strong winds hitting the side of the shop where the flue exited it tended to backdraft. I discovered that I could solve this problem by opening up a window on the same side of the shop to balance the pressure in the shop with that on the upwind side. So for our house stove I put a fresh air supply on the same side as the flue to equalize pressure. This has worked well and I built a sort of heat exchanger with the flue to take the chill off the incoming air.

One of my neighbors laughed at our funky stove and the small size of our woodshed as we were building. Now when he comes to visit, his favorite place is on the Rocket bench. And he is envious that we can collect and split our season’s supply of fire wood in two days since we heat our house with about a cord of wood. Less wood chopping means more time on the bench, and that is always a good thing.

—BERNHARD MASTERSON

KIKO DENZER

Here are Kiko Denzer’s notes about the technical issues of three different rocket mass stoves, followed by a really clever adaptation for a small shop heater based on the principles.

Modular rocket design for a small cabin:

I wanted a small, lightweight stove for a 10 x 22 wood cabin; something that would hold more heat than the old cast-iron wood cooking range and that wouldn’t create such a risk of chimney fire, or drop bits of coal and hot ash out the holes in the rusted tin that formed the old firebox. I found a heavy metal box 22" square and a 19" maple sugar barrel, then set the box on steel and wood legs off the floor, and built a 6" stove. The very small firebox works very well. I wrapped the bottom third of the barrel, and a short length of flue in cob. The flue exits horizontally through the wall of the box, makes a 180 degree turn back to the stove, and then a 90 degree turn up and out the roof. The chimney was existing, otherwise I’d have thought about sending it out horizontally through a wall. In fact, I might still do that. The exit vent/bench is made of square adobe bricks and stone tiles.

Exit vent/bench made of square adobe bricks and stone tiles: I wasn’t coming across much metal tubing, and an odd combination of bench and foundation design didn’t leave room for a round tube in places. So I cast adobes and used them to form the vent tunnel under the bench. I had some big slabs of limestone and soapstone, so I used them to span the adobe walls for the seat (also didn’t want to risk having the seat crack if someone jumped up there too hard). Mistakes: the adobes were rough, and I didn’t smooth plaster them as I built the tunnel (I was thinking extra surface area might improve heat transfer, but the extra drag is noticeable in the stove’s operation). I also should have made some thinner adobe “tiles” to give myself more room to make the turns in the bench. As it is, one section of the bench where the turns got too tight had to

be bypassed in order to maintain good draft. I had also thought that the top tiles would be easy to remove for clean-out, but they had to be covered with cob to fill gaps, and removal would make too big a mess. Clean-outs in the sidewall of the bench were and are good, however.

Insulative mixes: I've used several different insulative mixes for casting burn tunnels, including refractory cement (expensive) and pumice, as well as a clay-sawdust mix fortified with Portland cement (cheaper, but also softer). It seems that any lightweight aggregate makes a very soft material that degrades much faster than hard firebrick so it's not an experiment I've pursued further. The sawdust clay mix however (without any added Portland) made a fine insulator for the riser—all the sawdust burnt out, leaving a very lightweight clay foam. The foam is very fragile, but held up fine until I rebuilt the stove. When I touched it, it collapsed. If need be, it could perhaps be made stronger by using purer clay (fireclay?) and perhaps thicker slip.

gap between exchange barrel and insulated heat riser, I just extended the chimney in three long sections connected by 180 degree turns—a big radiator to provide heat fast with a small amount of fuel. The firebox is the same cross sectional area as the 6" system, but adjustable so I can burn a very few very small sticks, quite slowly, and have the heat from them instantly, which is more of what I need in the shop environment. Also good for cleaning up scraps from wood projects.

—KIKO DENZER

FLEMMING ABRAHAMSSON

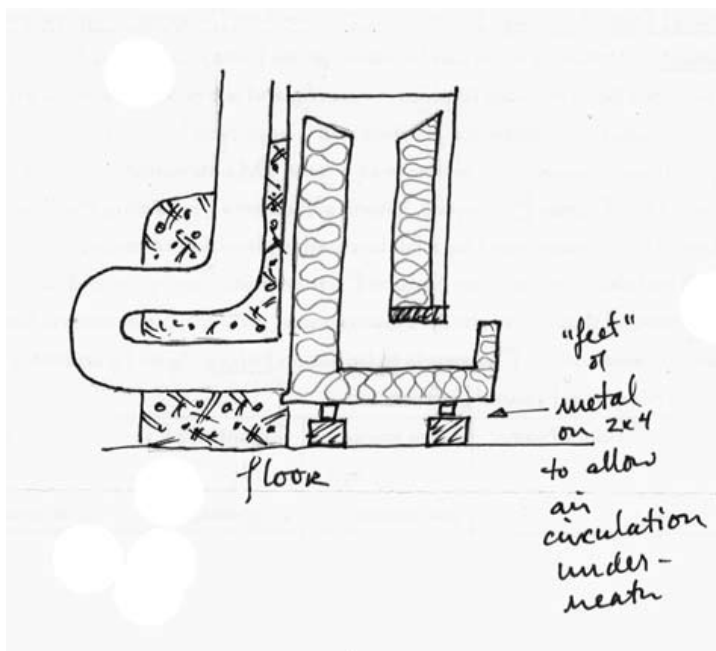


Flemming Abrahamsson is an ecological architect, building contractor, master mason and master thatcher. He is famous in Scandinavia for his brilliant ecological designs. See pages 82 and 56 for examples of Fleming's work.

We had the pleasure in 1997 to have the first cob building workshop in Denmark.

At the workshop there were many skilled craftsmen and other masons who in their daily work built masonry stoves. The meeting between Ianto and the other pyromaniacs immediately inspired a whole lot of experiments with fireplaces and ovens.

None of us who live so far north with a cold winter have ever forgotten this session.



Another example of adaptations based on Rocket Stove principles: I just made a little Rocket radiator for my shop/studio: Basic design is the same, but instead of directing the flow of hot gases through the narrow

From this workshop the ideas about cob, baking ovens, bench stoves, and Rockets spread like a fire to all of Denmark.

The first bench stove in Denmark was built in cob with an oil drum as heat riser with a 5-meter long exhaust pipe in the bench. The exhaust pipe dives into the clay floor after it travels through the bench. Then after another 2 meters, it comes up in the middle of the house in an 8-inch round flue. Ianto and I measured 1000°C (1800°F) in the combustion chamber and 32°C (90°F) in the top of the chimney—the rest of the heat was kept inside the house.

Another project we did was for the public schools in Copenhagen. They have a common place where they train the school

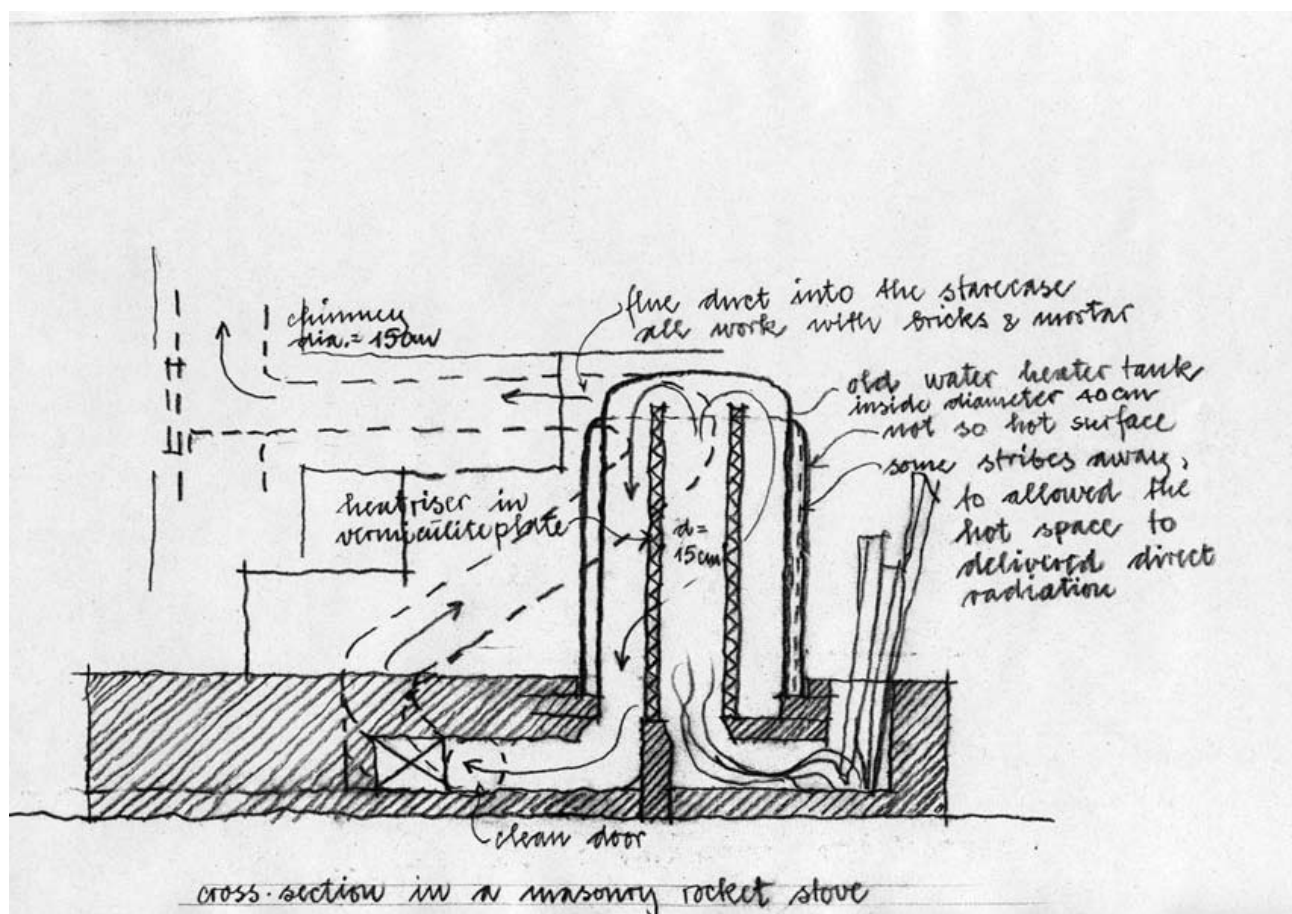
children in physics and chemistry. Here they demonstrate industrial production of energy such as coal, electricity and natural gas.

The children decided very quickly that they should also demonstrate how firewood is used for energy. So we built a Rocket bench stove and a baking oven. From these stoves, the hot gases, instead of being lost up the chimney, will be used to heat a hot air balloon.

In another classroom we built a 3½ ton Rocket masonry stove, which heats the room and a water-heating radiator—so that the children understand where the heat comes from.

—FLEMMING ABRAHAMSSON

Illustration: Flemming Abrahamsson



Glossary

Here you'll find our definitions of some of the terms found in this book.

burn tunnel – horizontal duct connecting feed tube to heat riser.

cob – mineral-fiber composite building material made of clay soil, sand, water and straw, smeared together damp to cohesive consistency.

combustion unit – all parts of a Rocket Stove that enclose fire.

cord – unit of firewood measurement, a stack of four feet wide, four feet high by eight feet long.

duct – pipe, any shape, that carries gas or air.

exhaust – all ducts downstream of the combustion unit.

exit flue – leaves the building, or carries exhaust gas out of the stove.

feed tube – vertical shaft into which fuel feeds itself by gravity.

flue – any duct that carries hot gases.

heat riser – internal chimney carrying burning/burnt gases up from the burn tunnel and pulling air through the feed tube.

heat storage – heavy masonry mass through which exhaust gases pass, heating it.

hydrocarbon – any chemical comprising only hydrogen and carbon.

hypocaust – under-floor heating system of ducts carrying hot gases.

Lorena stove – cookstove system using a sand-clay block which is excavated to accommodate fire and cook pots.

kindling – thin, easily ignited wood used to get a fire going quickly.

pyrolysis – chemical decomposition of fuel by heat but without oxygen.

Rumford fireplace – high efficiency open fireplace built to a fixed geometry.

specific heat – the amount of heat a material will store, proportional to water.

squatments – neighborhoods that evolve by squatter takeovers.

stack – vertical duct carrying gases.

thermal mass – comparative term describing total ability of a body to store heat.

thermal battery – heavy construction designed to store heat for long periods.

Urbanite – broken up concrete slabs, e.g. from driveways, sidewalks, etc. used in construction.

More Information

RESOURCES ON PYROMANIA

Cob Cottage Company. Take Pyromania workshops, find updates to this publication, access the brain trust of Ianto Evans on Rocket Stoves and other things related to Natural Building and find the very best Natural Building books available at the mail order bookstore:

Box 942

Coquille, OR 97423

Phone: (541) 942-2005

Website: www.cobcottage.com

For technical advice and anecdotal commiseration, or to tell us about the stove you've built, contact us:

Ianto through Cob Cottage, above.

Leslie: www.rocketstoves.com

We have on hand a list of fellow pyros who have built these stoves and take great pleasure in thinking and talking about fire. They can perhaps answer some of your questions or come to your site to give advice. Some will charge a fee, some will not. Perhaps you'd like a workshop at your site, or for your group or school, etc. Contact us for referrals.

Leslie Jackson teaches workshops in Pocket Rockets to schools, natural building groups, sustainability fairs, etc. Traveling with all of the materials to build a Pocket Rocket, and leaving a few Rockets behind, her demonstrations get people thinking about fire and efficient wood burning.

You may order copies of this book, download the digital version, find local Rocket Stove builders, workshops, further case studies and many detailed photographs of the insides and outsides of Rocket Stoves at:

www.rocketstoves.com

BOOKS ON NATURAL BUILDING AND WOOD BURNING

★Evans, Ianto, Linda Smiley and Michael G. Smith. *The Hand-Sculpted House: A Practical And Philosophical Guide To Building A Cob Cottage*. Chelsea Green Publishing Co. 2002.

★Smith, Michael G. *The Cobber's Companion: How to Build Your Own Earthen Home*. A Cob Cottage Publication. 1997.

★Kennedy, Joseph, Michael G. Smith and Catherine Wanek, Editors. *The Art of Natural Building*. New Society Publishing Co. 2002.

★Evans, Ianto. *Lorena Owner-Built Stoves*. Volunteers in Asia. 1980. (reprint).

Soderstrom, Neil. *Heating Your Home with Wood*. Harper and Row. 1978.

Shelton, Jay. *The Woodburner's Encyclopedia*. Vermont Crossroads Press. 1976, etc.

Barden, Albert and Heikki Hyytiainen. *Finnish Heating Stoves: Heart of the Home*. 1988.

★Denzer, Kiko. *Build Your Own Earth Oven: A Low-Cost, Wood-Fired Mud Oven; Simple Sourdough Bread; Perfect Loaves*. Hand-Print Press. 2000-2007.

Lyle, David. *The Book of Masonry Stoves*. Chelsea Green Publishing Co. 2000.

Orton, Vrest. *The Forgotten Art of Building a Good Fireplace: The Story of Sir Benjamin Thompson, Count Rumford, an American Genius*. Yankee, Inc. 1969.

★Chiras, Dan and Cedar Rose Guelberth. *The Natural Plaster Book: Earth, Lime and Gypsum Plasters for Natural Homes*. New Society Publishers. 2002.

★Denzer, Kiko. *Dig Your Hands in the Dirt! A Manual for Making Art out of Earth*. Hand-Print Press. 2005.

★Ludwig, Art. *Principles of Ecological Design*. Oasis Design. 2003.

★Ludwig, Art. *Create an Oasis with Greywater. Your Complete Guide to Choosing, Building, and Using Grey Water Systems*. Oasis Design. 1994-2006.

★Ludwig, Art. *Builders Greywater Guide. Installation of Greywater Systems in New Construction and Remodeling*. Oasis Design. 1995-2004.

★Ludwig, Art. *Water Storage: Tanks, Cisterns, Aquifers, and Ponds*. Oasis Design. 2005.

★Kahn, Lloyd. *Home Work: Handbuilt Shelter*. Shelter Publications. 2004.

★Kahn, Lloyd and Bob Easton. *Shelter*. Shelter Publications. Second Edition. 2000.

★Available by mail from Cob Cottage.

ABOUT COB COTTAGE CO.

Our inspiration comes from direct observation of Nature and from the wisdom of traditional cultures. We are committed to deconsumerizing, to reducing the flow of cash resources and waste, and helping others to do the same. We work with a wide range of natural materials.

We conduct hands-on research on natural building methods and materials, testing our own buildings by living in them.

Cob Cottage Company runs the North American School of Natural Building, the first permanent teaching center for Natural Builders in the US.

Through **practical trainings** in natural construction, we help empower ordinary people to build their own houses at moderate cost. See our website at cobcottage.com for a current workshop list.

By mail and phone, and through publications and tours, we supply information, support and inspiration for people to make healthy choices about buildings.

Our **“Pyromania!” workshops** are for those in love with fire. Learn how fire burns, what makes combustion efficient, how to build the ultimate in snug, energy-saving campfires, stoves, and fireplaces for cooking and comfort, all hand-made at almost no cost. We burn and evaluate several models, as well as build one or two. Cob Cottage Company is the only group offering such workshops (that we know of) and they often occur spontaneously and fill up quickly. Keep an eye on the Schedule of Workshops in the Cob Cottage Company website (at cobcottage.com) and let us know if you'd like to be placed on a Pyromania alert list.

Dozens of cob demonstration buildings all over North America are now open to visitors.



Ianto Evans is an applied ecologist, landscape architect, inventor, writer and teacher, with building experience on six continents. He teaches ecological building and has consulted to USAID, World Bank, US Peace Corps and several foreign governments on improved cook stoves, fuel supplies and kitchen technology. Ianto developed the Lorena stove in the 1970's in Guatemala—the first really successful widespread self-help cook stove. He has thirty years experience with research promoting and building woodfired stoves. He was a founder of Aprovecho Institute, Cob Cottage Company and the North American School of Natural Building.



Leslie Jackson is a natural builder, an educator and a musician. She is an independent publisher, helping writers by playing several roles (from

collaborator to editor and from coordinator to layout designer) in order to see a book evolve from the dream to the shelf. Between book projects, she gives workshops in Rocket Stoves and natural building subjects and consults for the local natural building community. Leslie lives at the juncture between high and low tech in Oakland, Ca.

AFTERWORD



In late Fall, 2005, Ianto gathered three of us together to prepare for this edition: Two hand-picked pyromaniacs, Kirk “Donkey” Mobert, Ernie Wisner and myself. For two weeks, Kirk and Ernie tinkered, built, broke, brainstormed Rocket Stoves and drank copious amounts of coffee that was brewed on obscure woodburning inventions that Ianto has been collecting. I asked questions and wrote and drew. We were occasionally interrupted by pin-point questions from Ianto, who mostly puttered in his vegetable garden. It was much like the Pyromania! workshops at Cob Cottage in its spirit of play and inquisition, but it was more like a retreat in its absolute immersion. We ate, drank, talked, dreamt and breathed fire. At the end of the time, we were left with more questions than we sought to answer and we were left with the conclusion that the key to a good stove is to test *a lot* to get the results you want. Also, this stove isn’t just for pyros and scientists. With an understanding of the principles, shapes and materials anyone can build a good Rocket Stove and take charge of their heat and comfort.—Leslie Jackson

THANKS

We're only certain of a few things in life. Apart from the inevitability of death (taxes are somewhat optional), we're sure of one fact: we will have forgotten to mention some people who helped a lot. Sorry. If you let us know, you'll go in the next edition.

So, in no special order:

Linda Smiley

Bart Trickel

Kiko Denzer

Bernhard Masterson

Flemming Abrahamsson

Bjarne Wickstrom

Pat Loomis

Michael G. Smith

Tim Kring

Robert L. Arson

Susan Kleihauer

Hop Kleihauer

Tom Frame

Calleagh Ferrara

Art Ludwig

Shannon Dealy

Larry Jacobs

Elke Cole

Coenraad Rogmans

Larry Winiarski

Dennis Kuklok

Nelson Flystrap

Meka

Kirk "Donkey" Moberg

Ernie Wisner

Chris Reinhart

Jack Stephens

Jay Naydiuk

*Cob Cottage Publications,
2004, 2005, 2006, 2007*

Appendix E.2: Batchrocket.eu

Batchrocket.eu ^(/)

Search ...

 (/nl/werking)  (<https://batchrocket.eu/en/workings>)  (/fr/fonction)  (/es/funcionamiento)  (/it/work) 
(/slo/work)  (/pl/workings)  (/ru/working)

English menu

[Introduction \(/en/\)](#)
[Workings \(/en/workings\)](#)
[Building \(/en/building\)](#)
[Designs \(/en/designs\)](#)
[Applications \(/en/applications\)](#)
[Contact \(/en/contact\)](#)



(<http://creativecommons.org/licenses/by-sa/4.0/>) Batch Box Rocket by Peter van den Berg

is available under the Creative Commons Attribution-ShareAlike 4.0 International (<http://creativecommons.org/licenses/by-sa/4.0/>) license

Workings, how and why

What is a wood fire?

During the combustion of wood the organic molecules are decomposing into smaller pieces. Eventually those become gases, known as woodgas, and are the source of flames as they burn. The results of complete combustion are: heat, carbon dioxide (CO₂) and water.

([read more](#))

Mixing

Woodgas is extremely combustible, explosive even, when it's hot enough and thoroughly mixed with fresh air. This mixing doesn't occur spontaneously, it is achieved because of the highly turbulent conditions generated by the batch box design in the port and riser.

([read more](#))

Mixing and turbulence in the Batch Box

In the world of Rocket Heater builders the name of that short insulated internal chimney is called a "heat riser". In the Batch Box Rocket the tall and narrow opening at the bottom side of the riser is called the "port". The combination of riser and combustion chamber is called the "core". The way turbulence is invoked is significantly different from a normal wood stove.

([read more](#))

Heat

Another environmental factor is just as important as fuel/air mixing: maintaining high temperature during combustion. This shouldn't be taken lightly. During development temperatures as high as 1200 °Celsius (2190 °Fahrenheit) have been measured in the riser. Higher temperatures result in cleaner combustion... and can also be a challenge for construction

materials selected to be used!

(read more)

Cautions

It has been found experimentally that the respective ratios between the sizes of the combustion chamber, the port, the riser and the air intakes for good combustion are quite specific numbers. A relatively small change in dimensions that change the tested ratios could be enough to disrupt the correct functioning of the heater. Also, a proper chimney is very important.

(read more)

Exhaust gas measurements

The measurements that eventually led to the final Batch Box Rocket are done with a digital gas analyzer, the Testo 330-2. This device measures in real time during every "testrun" the temperature of the exhaust gases, the oxygen level (O₂) and the content of carbon monoxide (CO). These measurements provided the necessary feedback so we could understand empirically how to improve combustion - not just a guess.

(read more)

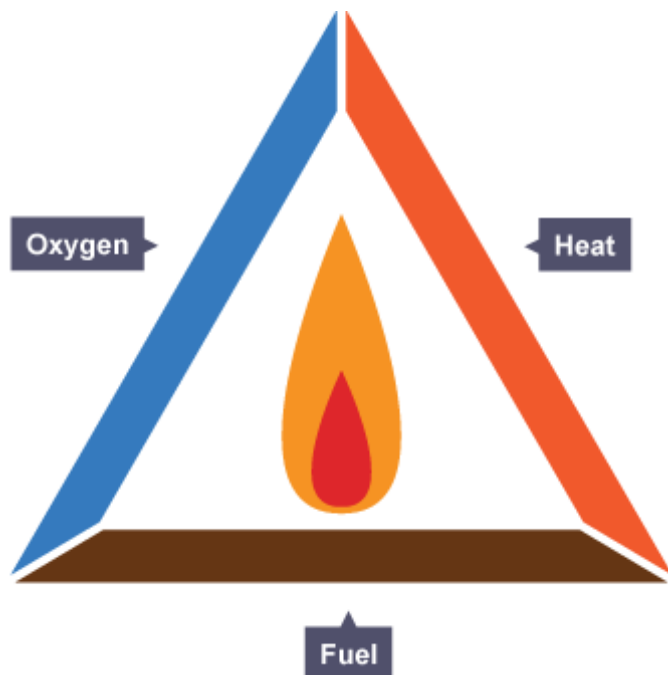
Air streams in the port

Since 2012 a lot more is known about what the air flows in the port looks like and what their respective function is.

(read more)

How does wood burn in a fire?

The fire triangle shows the three things needed for a fire to start and keep going.



The complete combustion of wood (which is made up of hydrocarbons) results in the following: the hydrogen atoms combine with oxygen to make water vapour (H₂O), the carbon atoms combine with oxygen to make carbon dioxide (CO₂), and the maximum amount of energy is released.

These same end products are found in natural gas burners.

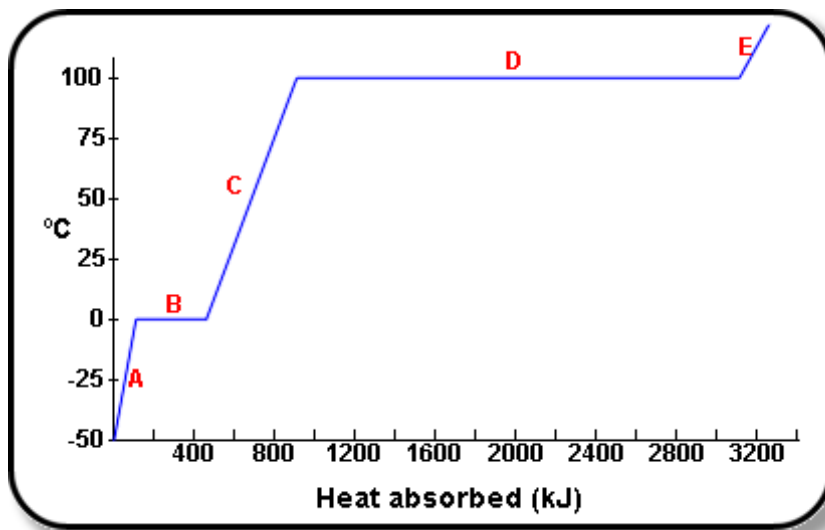
Lessen or remove one of the sides of the triangle then combustion will not be complete combustion but rather incomplete combustion. Water vapour and carbon dioxide are still produced, but two other products are also produced: carbon monoxide (CO), a colourless toxic gas and particles of carbon, which appear as soot and smoke. Additionally, the maximum amount of heat is NOT produced.

On the surface, burning wood does not seem too difficult, place some small dry branches with paper, put a match to it and the fire is started. Once we have the fire, to have it burn cleanly takes just a bit more thought and effort. We need higher temperatures than the few hundred degrees of a small fire and we need to 'keep it under control', not let it grow excessively. By insulating the combustion chamber and even more important, the heat riser, the heat generated from the fire is kept 'within the fire' maintaining a high combustion temperature which aids in more complete combustion.

The result of these 'new conditions' (very high heat, 'Goldilocks' (https://en.wikipedia.org/wiki/Goldilocks_and_the_Three_Bears#Literary_elements) air supply'-not too much, not too little, juuust right) will be a smokeless fire. Whilst being simple aims, a lot of effort was required to find the parameters presented here that achieve this smokeless fire. **To understand why there is no smoke, it must be realised that smoke is simply unburnt fuel, nothing more, nothing less.** In fact, up to 60% of the available energy of wood is found in these combustible gases. So smoke is not 'just a nuisance' which affects a large area in the outside environment, it is factually 'money up the chimney' in a very real sense. Money Up In Smoke!

Quite literally, apart from around one percent ash, the entire content of wood can be converted into heat**, and as such smoke is only an indicator of incomplete conversion of fuel into heat. These heaters, as described earlier, have very high temperatures of combustion, so the smoke is very hot in the combustion chamber and in the heat riser. We combine pre-heated air with that smoke which results in spontaneous combustion of the smoke. Even the rightly feared carbon monoxide -a deadly poison- is in fact simply unburnt fuel (recall above that in complete combustion CO is not a product of wood burning). CO has no odour of it's own, so when "town gas" which contained up to 8% CO was used for heat well into the twentieth century mercaptan (a foul smelling substance) was always added to the gas, simply to alert people to any leaks or unlit burners. The point remains though, CO is a fuel (and used as such in town gas) and all of the wood's energy content can be extracted if burnt correctly.

** Whilst this is strictly true, a few points must be understood to put this into a real world context. These heaters will not be used in a laboratory with pure oxygen, they will be used at home with ambient air. Even weather conditions will vary and influence the burn. Most importantly, all air dried wood will contain some moisture. This needs to be driven off before combustion of the wood can take place. To boil off water takes a tremendous amount of energy as shown below.



The graph shows how the temperature of water rises as energy is added. (it starts from below freezing point which we will ignore. Unless the wood you use is itself below freezing!) As energy is added (the horizontal axis), the temperature rises along the straight line C, for every 'bit' of energy added there is a corresponding rise in temperature which is why it is a straight line.

When the water reaches boiling point (100 °C at sea level) it no longer gets any hotter (seen by line D, it is horizontal even though energy is still being put into the system) During this stage, the energy being absorbed by the water is not making the water any hotter, but rather is making the water change from 'liquid to gas', and this takes place with no change in temperature. Line E will ONLY begin once all of the water has become steam.

Unless we have a condensing boiler, that energy required to turn the water to steam is lost from the system, and into the atmosphere. So, in real world practice, these are some of the losses that do and will occur. **The *very*important *point* to be taken from this is, NEVER burn anything other than dry wood.** Now you know why.

The following video is a fine example of the flammability of smoke.

How to relight a candle using the candle smoke



[Back to top \(/en/workings#top\)](#)

Mixing and turbulence

Strangely enough, wood itself does not burn. It is similar to petrol, petrol itself does not burn. If you are quick enough you can douse a match in liquid petrol. It is not recommended that you try it, as most likely the match will ignite the mixture of petrol vapours and oxygen just above the liquid petrol. Once that is understood, it is clear then that it is wood 'vapours' mixed with oxygen that are the substances that burn. Heat causes the chemical components in the wood to break down into smaller, flammable components which then combine with oxygen (in the presence of heat), in turn releasing more heat which causes the cycle to continue. A pure woodgas flame should be blue, hard to see in sunlight. Because there's also glowing carbon dust carried with the flame the colour is red, orange or yellow, the higher the temperature the lighter the colour. When there's a lot of gas in the flame and a tiny bit of carbon it could appear as yellow-purple.

Once it is understood that it is the substances released from the wood by heat that combine with oxygen, we can see that complete and thorough mixing of these substances with oxygen is needed for complete combustion. In practice this is the most important objective to achieve and the most difficult. A column of smoke rising from a fire will most likely burn on its 'outer surface', the interface between the smoke (fuel) and the oxygen rich air. Inside the column of smoke there is very little oxygen hence no combustion. It finally leaves as smoke (unburnt fuel) because even though it eventually meets enough oxygen it has cooled enough that combustion does not occur. Recall that there are three conditions necessary for combustion, fuel, oxygen and heat.

The common method used in combustion heaters to induce this oxygen and fuel mixing is to inject fresh air (usually not pre heated) into the fire from multiple locations. A lot of air is needed for this conventional wood burning system, which is a serious disadvantage because it will lower the temperature of the fire, one of the three conditions needed for complete combustion. In metal stoves this cooling of the fire is not regarded as a disadvantage but rather an advantage, as the temperatures that can be reached from a wood fire are great enough that the steel, even stainless steel, will be destroyed in a surprisingly short time frame. The combination of an oxygen rich and carbon poor environment coupled with high temperatures will corrode the steel very rapidly. As a result, during every burn severe spalling at the metal surface will occur at the hottest spots.

The heaters described here are designed to maintain the hottest burn temperatures possible -far greater than metal heaters can withstand- and ensure proper mixing of the fuel gas and oxygen by methods described in the following section.

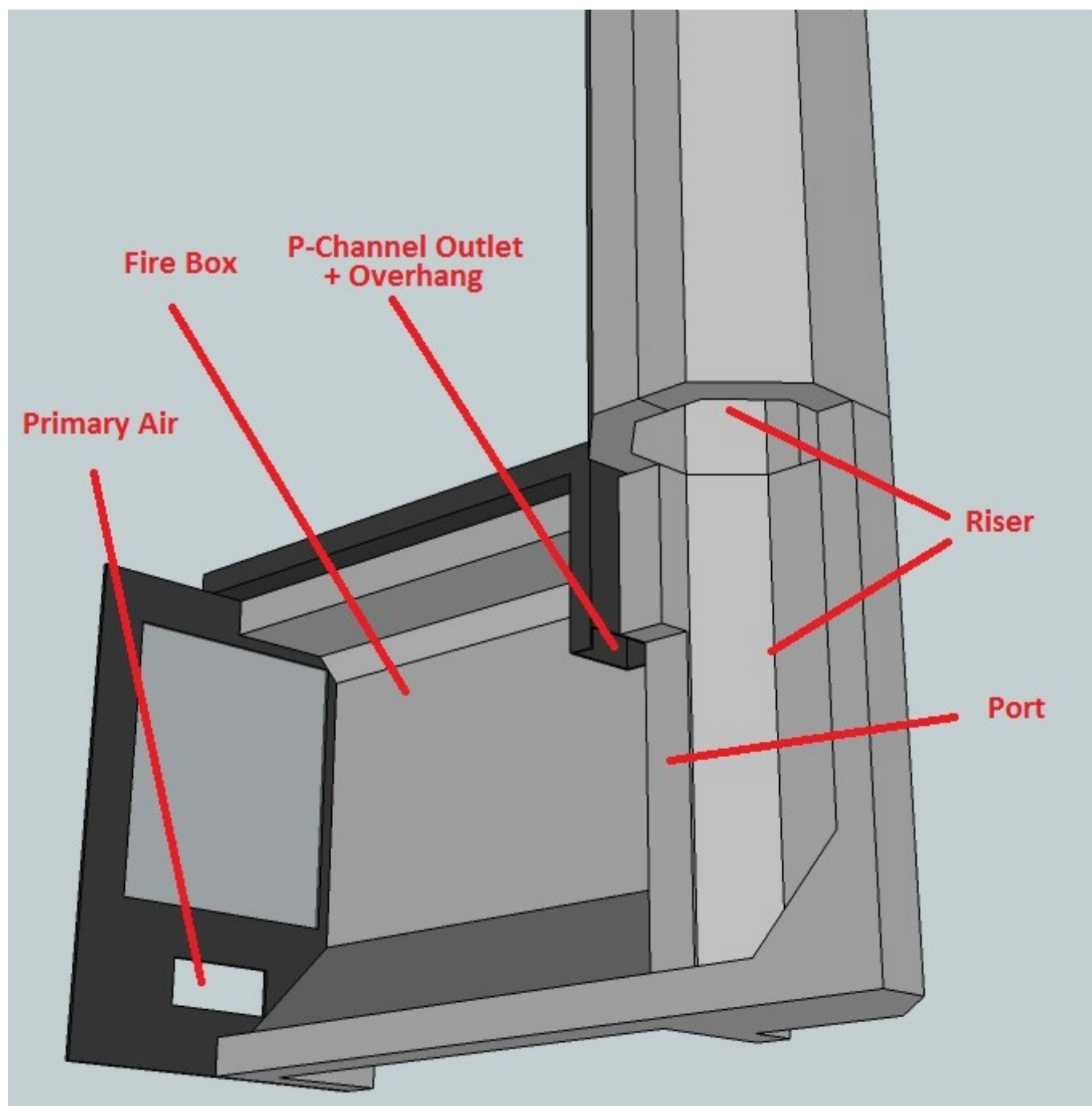
[Back to top \(/en/workings#top\)](#)

Mixing and turbulence in the Batch Box Rocket

The mixing of wood gas and oxygen in the batch box heater is achieved by the carefully designed geometry of the combustion core and the correct positioning of both the primary and secondary air intakes. These critical dimensions will be given later. The arrangement of these building components is quite simple and shown in the 3D cutaway illustration below. The combustion chamber which is longer than it is wide vents to the rear, where a vertical insulated 'chimney' is placed. This is the heat riser referred to above. The function of the combustion chamber is naturally to combust the wood, the function of the insulated heat riser is to allow the final (and complete) combustion of any wood gas produced from the wood fire. From the preceding sections we now understand what is needed to have that complete combustion, fuel (the wood gas), heat (from the fire and from the combustion of wood gas itself. Note again that especially the riser is heavily insulated, ensuring as little heat as possible is lost from any combustion process) and oxygen.

Note particularly the connection between these two elements of combustion chamber and heat riser, a high and narrow opening between the two. This is known as the 'port'. It is actually 70% cross sectional area of the cross section of the heat riser (the cross sectional area of the heat riser is one of the 'standard dimensions' in these heaters, namely a dimension from

which other dimensions can be scaled). The port itself is 72.34% of the riser's cross section area, but due to the overhang of the secondary air p-channel this is reduced to 70%. This sudden narrowing in the path of the gas stream has a very important function, as the **same** amount of gas is flowing through the system at all times, when it comes across (or passes through) a narrower opening, it must then speed up at that point (remember, the same amount of gas is passing through at all times and all places). The result of that speeding up at that exact point is that the pressure at that point lowers.



The picture above shows a cut-away view of 1/2 the combustion chamber and the lower heat riser.

Now referring to the diagram, secondary air is delivered through a hollow tube (shown in black at the top of the combustion chamber) connects the external air directly to the point of lowest air pressure in the system, the opening of the port. This form of secondary air intake is known as a P-channel and is one of the early innovations I created that noticeably improves combustion.

This then causes air (or more properly oxygen) to be introduced into the gas stream as it enters the port. As can be imagined, we now have the three conditions needed for combustion, fuel, heat and oxygen. The wood gas is already extremely hot, there is an awful lot of heat in this location, all we need now is the final complete mixing of the oxygen and wood gas. One last point to be noted now, as the secondary air being introduced into the port has to pass through the steel pipe located on top of the fire, it has been pre-heated on it's journey to the port. This pre-heating of incoming air assists in keeping the combustion temperature high.

The thorough and complete mixing of the wood gas and oxygen occurs as the mixture passes through the narrow port and into the heat riser behind. As the gas flow speeds up through the restriction of the port and then slows down abruptly when it reaches the **larger** space behind the port, a massive pile up in the gas flow occurs as the still fast moving molecules

passing through the port slam into the suddenly slowed molecules in front of them. This creates considerable turbulence and is continuous as long as the velocity of the gases are higher in the port than in the riser, the large majority of the burn time. These conditions cause the flammable gases to mix into a swirling double vortex in first a horizontal plane and then an ascending double corkscrew as it rises within the heat riser as it exits the system.

The ascending double corkscrew forces the gases to take a much longer path (and hence take longer time) than if they were to go straight up. That this longer travel occurs within a well insulated, extremely hot environment allows the mixed fuel and oxygen to readily combust.

The speeding up of gases as they pass through a restriction is known as "**the venturi effect** (https://en.wikipedia.org/wiki/Venturi_effect)", a law of physics first described by **Daniel Bernoulli** (https://en.wikipedia.org/wiki/Bernoulli's_principle) in the 18th century. The highly chaotic conditions created by this arrangement can be seen in this short video filmed looking down the heat riser and directly at the exit of the port, where the massive pile up occurs and the double vortex/ascending corkscrew is formed.

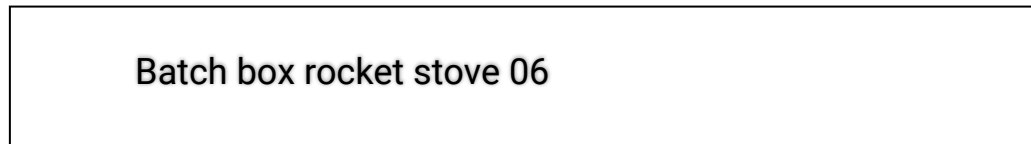


The rather unique way these heaters create the turbulent conditions required for complete mixing of oxygen and fuel has other favorable results for combustion efficiency. The metal box heaters' blunt sledgehammer approach means lots of air was introduced. This extends the life of these heaters but as noted reduces efficiency. Because the preheated secondary air in the batch box heater is introduced into the best injection point for complete mixing to occur, we do not need anywhere near the same amount of introduced air as metal heaters. So the total cross section area of the combined air intakes is smaller than would be expected in a normal box stove. These smaller than expected air inlets are perhaps even more surprising when it is seen how quickly the fuel is consumed in these heaters.

One last explanation of why 'excess amounts of cool air' is contrary to good efficiency. The essential component in air for combustion is oxygen. Any other component in air is only a passenger, it contributes nothing to the combustion but only serves to cool the fire (they are known as ballast gases. Just as on a ship, ballast is only excess weight and not cargo). As you can see these heaters, by careful use of geometry and taking advantage of natural laws, we introduce the right amount of oxygen to the exact spot required for complete mixing and combustion.

Maybe we can extend this idea of 'goldilocks air'. Not only is it not too much or too little air, juuust right, it is also in juuust the right place.

These heaters generate a typical noise, a low rumbling (but strangely comforting) sound. In fact, it is this characteristic sound found in all of these variants of heaters that gave them the name 'Rocket Stoves'. The short video that follows gives an indication of this characteristic sound, this particular example is in a metal housing so has more of a 'ring' to it, builds that employ masonry or brick housings the timbre changes to a less ringy, lower rumbling sound that is not offensive at all.





[Back to top \(/en/workings#top\)](#)

Lots of heat

Both the firebox and heat riser are insulated heavily, with particular emphasis on insulation of the heat riser (where the temperatures can be the greatest). This enables the whole to more quickly reach optimum operating temperature and enhances the combustion of the woodgas/oxygen mixture which is of course the basis of heater efficiency.

[Back to top \(/en/workings#top\)](#)

Important point

It is important to realise that the shapes and dimensions of the combustion unit are quite critical. Variations from these are effectively untested. Your proposed variation may have hit upon a winner, but without testing no-one will ever know). The specific values of 'tightness' of these ratios of design dimensions and ratios is quite logical, they are responsible for what's going on in there.

To achieve the goals of this heater (smoke free highly efficient combustion that can be followed and built by others) it is important that the developed and tested dimensions are followed quite closely.

A proper chimney is required, a chimney is the 'engine' of any wood combustion heater, and is the motive force that creates sufficient draft for clean combustion. As discussed above, the air inlets are smaller than 'expected' and as such are perhaps more easily affected by variations from the design given here. **Ratios of the design (/en/building#dimension)** are to be found in the "Building" section. When the flue temperatures rises (and hence the draft) the air inlet can be decreased, or larger pieces of wood used. Larger more 'chunky' pieces of wood have less surface area than a similar weight of 'finely divided' wood.

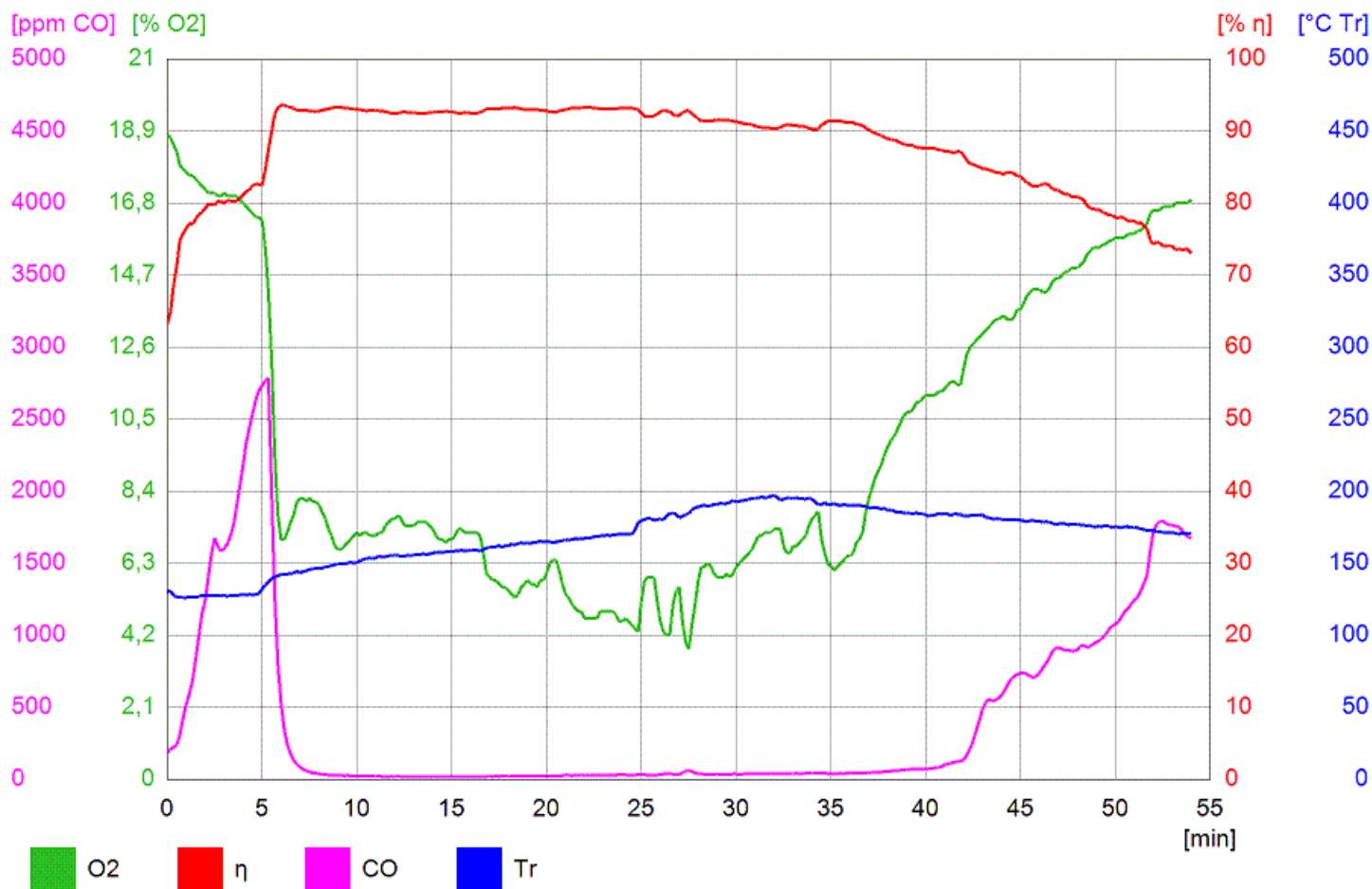
These heaters burn the fuel load without the need for restrictions in the air supply or any other measure used to 'slow the burn down for longevity' as done in conventional wood stoves. It should be clear by now that for maximum efficiency and cleanliness of the burn those types of incoming air restriction measures only harm that goal. And so to harness or profitably utilise the heat created we need a large radiating surface or a sufficiently large mass to absorb and slowly release the stored heat. These different approaches will be covered later.

A curious phenomenon of these heaters is the time taken to burn a load. It turns out (rather counter-intuitively) that full load of wood combusts in about the same time as a half load of wood (or other ratio), from lighting to glowing ember phase. So it can be seen that a full load of wood delivers a surprisingly large amount of energy in a given time. Hence we need ways to harvest this heat which will be discussed in the following pages.

[Back to top \(/en/workings#top\)](#)

Results

In the last four years (2012 thru 2016) I've executed hundreds of runs on the core presented here, and am satisfied a stable dependable combustion heater has been designed. The Testo 330-2 is a gas analyzer which measures the flue output and from that data calculates the efficiency of the burn, and can be connected to a computer as I have done to generate its own line diagram and spreadsheets.

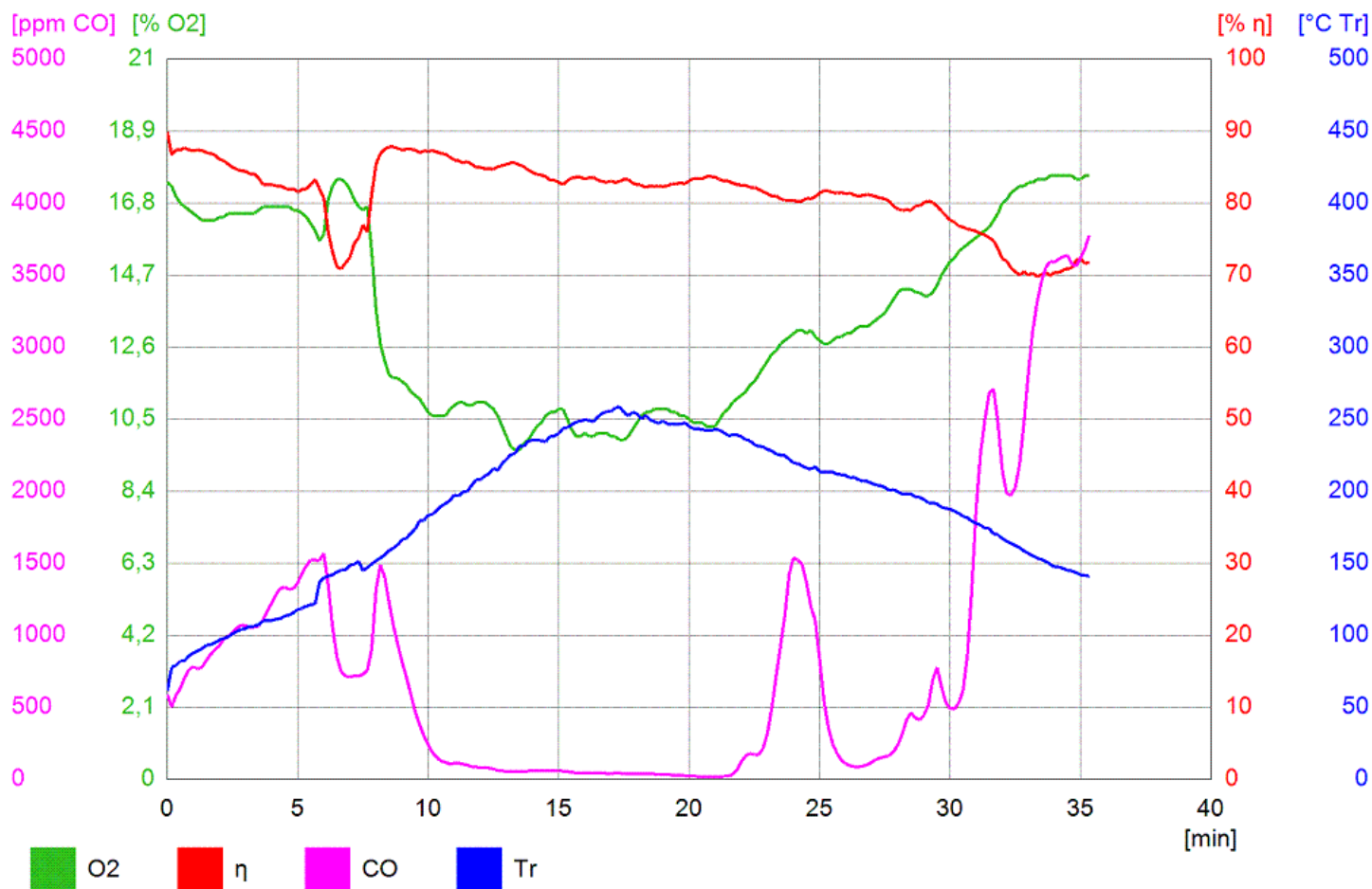


The test shown in the above diagram has been run in a warm heater, as can be deduced by the starting temperature (measured in the flue outlet, in degrees Celsius, represented by the blue line). As mentioned earlier, a 'hot' (already up to working temperature) flue will have a correspondingly strong draw, and so in this run the fire developed quickly. During the run the oxygen level (green line) dropped below what I consider as the border between optimum and non optimum (6% O2). Below that figure runs the chance of higher (purple line) CO outputs (as insufficient oxygen is present). That did not happen in this case as can be seen, so whilst that risk is present it is clear that excellent burns can still be obtained. From all of the earlier discussion given on combustion it can be seen/understood that the oxygen levels, and the flue temperature are directly linked to the efficiency of the burn. The efficiency is shown by the red line.

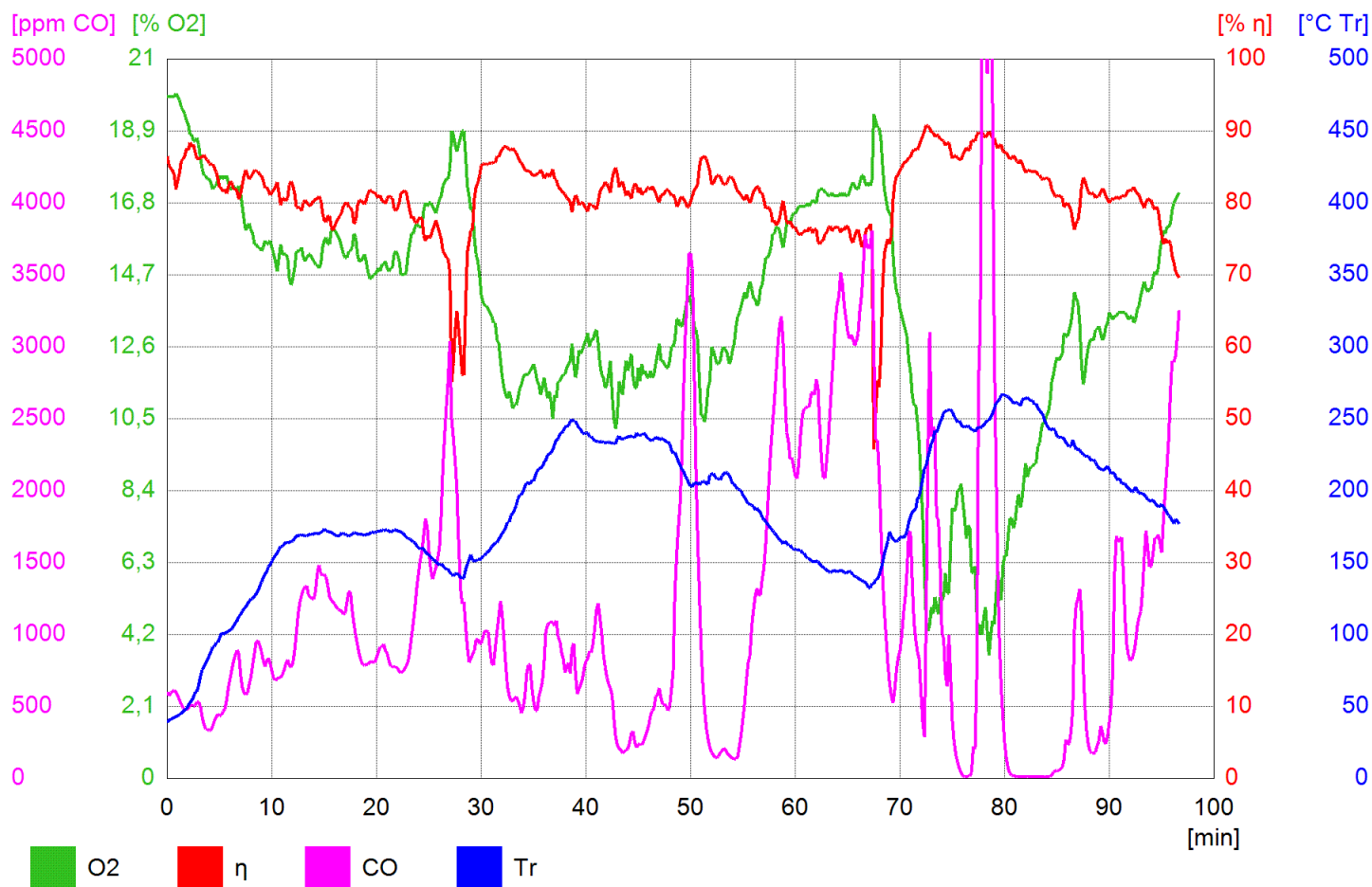
When the oxygen content does not drop below 10% with a correspondingly low flue temperature of 80 °C (176 °F) the efficiency will be higher than shown in the above graph. However lower exhaust gas temperatures means less draft and can have repercussions on combustion because of lower flow velocity through the system.

These graphs that show the inter-relationship between the various parameters of the burn are a graphical way to understand the 'Important Point' made above, that it is doubtful that a departure from the descriptions given here will result in a more optimum heater. Of course it IS possible, but highly unlikely. The interactions within the heater are very complex, and any change has to be evaluated by actual measurement by testing similar to that shown here.

The above graphic is of course a very nice one and for this reason not very representative. A somewhat more normal looking diagram which is generated during development in 2012 could be this one:



Comparing the graphs we can learn a few things (like why the Testo is absolutely essential in knowing exactly what happens during a burn) and see how this burn is more representative than the "cherry picked" stellar example just above. As you can see the extremely low CO levels (pink line) which indicate complete combustion does not occur quite so soon as before, nor does it last as long. Also observe that the Oxygen level (green line) does not go as low, but is still at a very nice level. The oxygen measurement is known as 'excess O₂'.



The above is the graphical representation of a very ferocious burn, roaring, joggly and bumpy and occasionally also smoking. Recent developments came to a close with much better results, this will be discussed in the "Core designs" chapter.

[Back to top \(/en/workings#top\)](#)

Working of the air streams

August, 2020

Since the start of development in 2012, how the batch box rocket works has become much clearer. That the BBR has good scalability (readily enlarged or decreased in size) suggests the presence of underlying fundamental principles.

Eight years later there are some conclusions to be drawn, supported in some respects by people who better understand aerodynamics than ordinary mortals. Those conclusions are based on observations made by multiple builders and developers on different continents. In no case are the following conclusions scientifically substantiated, they are only plausible.

1# The current explanation of why such a hot and fierce fire can be attained is attributed to the pressure difference between the front and rear of the fire chamber. The port acts as a venturi, explained earlier in this chapter. In that venturi the air velocity is greater and the pressure correspondingly lower than at the front where the air enters. That differential pressure is always greater than the draft of the chimney, the port acts as an amplifier. The larger the difference, the brighter the fire, similar perhaps to a fan blown fire. That is also why the time that elapses from ignition to the glowing phase with half a batch under the same conditions is almost the same as with a full batch. That full batch produces a larger fire, a stronger negative pressure in the port and therefore also a faster combustion. It is not the case that a quarter of a load also takes as long, apparently there is a limit. A very hot and clear fire delivers the most complete combustion.

2# When the riser is viewed from above, it is clear that the stream of fire through the port appears to be narrower than the port itself. The speed of that flow is also greater than what can be expected based on what is visible in the firebox. This has to do with the square edges of the port. This point was discussed extensively with Dr. Larry Winiarski * during a workshop in Warsaw, July 2015. Some builders had already chamfered or rounded the edges of the port a number of times, in an attempt to make it more attractive. If that chamfer was large enough, about one-third or more of the port's depth, it was sufficient to destroy complete combustion in almost all cases. The end result is black smoke from the chimney, just because of the all too smooth curves.

Possible explanation of this phenomenon: sharp right-angle edges cause a lot of small turbulence along the walls of the port. That wall turbulence also slows down the flow along the walls. In the middle of the port the speed remains high, which makes the current seem narrower to the eye. Due to the delay on the left and right, the flow splits easily and the two flows curl, creating the double vortex. The residence time in the hot riser is extended this way which allows more of the wood gas to combust.



Thus the port should always have two right angles and should open up in the center of the riser.

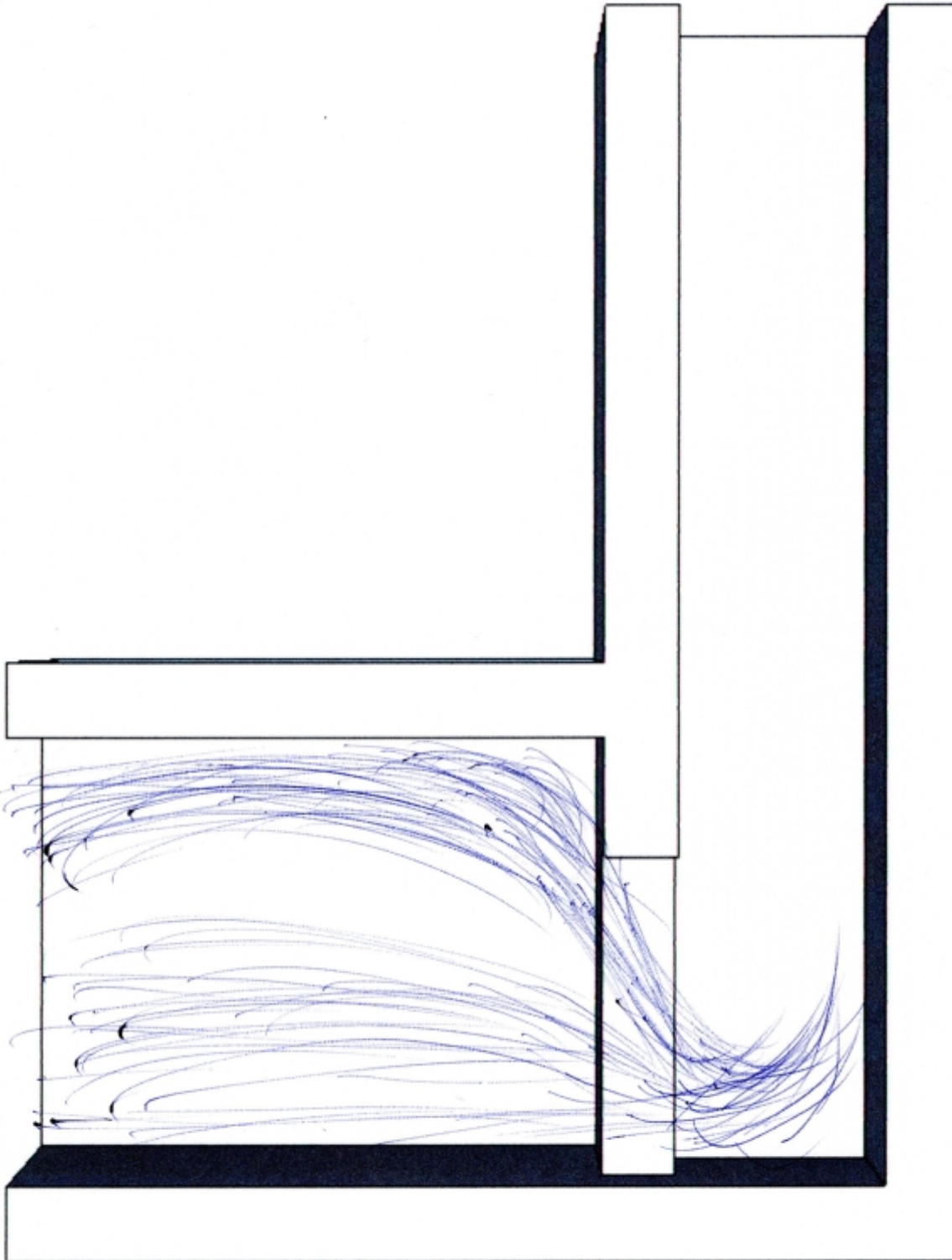
For example, it is tempting to build a sidewinder in such a way that the back wall of the firebox is flush with the wall of the port. This situation does not meet the conditions outlined above and the properties of the batch rocket may be worse as a result. If the port is not built in the center of the riser but on one side, a single vortex is created. The residence time in the hot environment of the riser then becomes shorter, which in turn affects the quality of combustion.

3# A well-functioning batchrocket shows a horizontal flame, especially at the beginning of the combustion when the afterburning starts. And that flame appears in the bottom half of the port while the top half is completely empty to the eye.

Especially in the early stages of development, some batchrockets were built where the port had the full height of the firebox rear wall. Even though the width was made smaller to compensate, the result was always bad to worse as opposed to using the currently common piece of wall above the port.

In addition, with open systems (see **Applications (/en/applications#opensystems)**) the phenomenon occurs that combustion without a door and without secondary air supply is still very good. Yield is lower but by not more than 4% or 5%. Also in this variant the flame tend to ignite very low in the riser.

The explanation for all three of the above phenomena probably lies in the flow of air passing over the fire towards the port. Because the air above the fire gets very hot, it flows unimpeded along the ceiling. At the rear wall, the current is bent down and accelerated by the venturi action as soon as it enters the port. The greater the air speed at that moment, the less easily the flow changes direction. Until the stream encounters some obstacle that forces it to go another way, the air through the openings between the pieces of fuel in the firebox together forms such an obstacle. The flames in the firebox are blown to the rear and the flow of air from above forces it down. In a closed system, a p-channel or floor channel provides additional air at exactly that location.



An open system takes advantage of this effect, allowing sufficient fresh and hot air to enter the port and riser in an aggressively turbulent environment. So it is clear that a port the full height of the firebox does not work properly, the hot air from the ceiling simply passes straight into the riser without creating any down-forcing turbulence. And lastly, this may also explain why an object like a piece of wood sticking into the port can destroy the desired complete combustion. The currents are disrupted and the aerodynamics of it all change completely. By withdrawing that piece of wood, the entire system will revert back to proper functioning again within a minute.

Please be aware that a heater with no door isn't recommended inside a house. Due to the fact that in essence it is an open fireplace, it could spill smoke inside the living room. Also, no door means the heater can't be closed which could be dangerous while people are asleep. In case the fire isn't completely out, deadly carbon monoxide could spill out of the heater due to weather changes for example.

*Larry Winiarski is widely regarded as the creator of the original rocket stove. Created as a more efficient alternative to traditional open fires in many developing countries and refugee camps where cooking is done on a wood fire.

Back to top (/en/workings#top)

(<http://info.flagcounter.com/Pckc>)

 US 36,429	 NL 17,002	 CA 6,828	 GB 5,372	 RO 2,963
 FR 31,367	 AR 12,714	 ES 6,813	 RU 3,518	 AU 2,693
 PL 22,403	 BE 7,745	 IT 5,962	 DE 3,211	 SI 2,562
Pageviews: 544,550				
You:  NL Newest:  TG				

Appendix F Internet sources

CYCLONE BAZOOKA X

Een cycloon-raketkachel die gebruik maakt van een cycloon-warmtestijger (patent aangevraagd) die een geheel nieuwe structuur heeft met een mooier en mooier verbrandingsontwerp. Hoe je lucht gebruikt, verandert de raketkachel drastisch! Een raketkachel van de volgende generatie die zowel verbrandingsefficiëntie als duurzaamheid op een hoog niveau bereikt.



Elke vorm heeft een betekenis, en door ze te combineren komt de voorstelling verder naar voren. De betekenis van de vorm die de verbranding prachtig ontwerpt, is zo eenvoudig mogelijk verpakt. Er zijn veel technologieën die niet zichtbaar zijn. En we moeten nog iets weten. Raketkachels zullen nog meer evolueren!

Klik hier voor vragen → info@firecyclone.jp

Waarom is het een cycloon?

Dit om het verbrandingspad in de warmtestijgbuis zo lang mogelijk te maken. Door dit te doen, verkrijgt u een verblijftijd en verwarmt u de vlam met de vlam. Het brandt eigenlijk in een spiraal, met vlammen en lucht die elkaar overlappen als een millefeuille. Maar het gaat niet alleen om draaien. Je moet hebben wat je nodig hebt om te weten wat je wilt doen.

Waarom heeft de warmtestijger deze vorm?

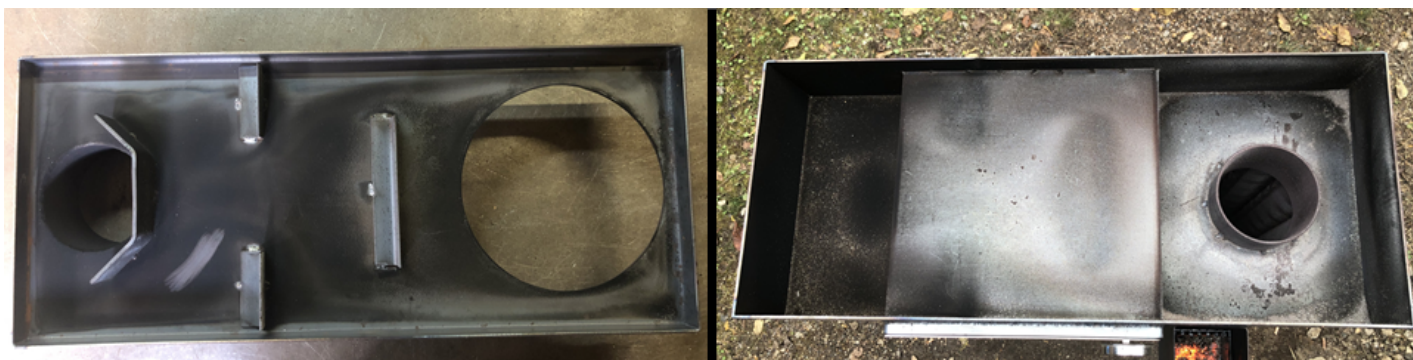
Tot nu toe hebben we alleen al meer dan 100 prototypes van warmtestijgers gemaakt en herhaaldelijke verbrandingstests gemaakt. Dit betekent dat we meer dan 1 ton staal hebben gebruikt. De reden waarom het zoveel moeite kost, is dat je het pas kunt begrijpen als je het daadwerkelijk verbrandt. Productie kan niet alleen in de geest worden voltooid. Na herhaalde verificatie ontdekte ik dat er gebieden zijn die niet kunnen worden bereikt door de vormen van standaard stalen materialen te combineren.

Waarom geen isolatie gebruiken?

Omdat het niet meer nodig is. Ik zeg niet dat raketkachels geen isolatie nodig hebben. Het is niet langer nodig voor deze cycloon-warmtestijger die we hebben gemaakt. De nieuwe cycloonverhitter heeft ook een luchtlaag aan de buitenkant van de vlam. De luchtlaag wervelt tussen het staal en de vlam. Het brandt spiraalvormig in de wand van de wervelende luchtlaag. De buitenkant van de warmtestijger is een kamer die de verbrandingslucht voorverwarmt. Hierdoor worden zowel verbranding als duurzaamheid op een hoog niveau bereikt.

Als je aan gezond verstand twijfelt, zal de wereld zich meteen uitbreiden. Ik denk dat gezond verstand geen doel is, maar een richtlijn om het te overtreffen. Het is echt opwindend om verschillende manieren te proberen om verder te gaan dan wat zo wordt gezegd.

Probeer de toekomst te achterhalen door CYCLONE BAZOOKA X daadwerkelijk te gebruiken.



Het warmteafvoeroppervlak wordt vergroot door uitlaatgassen boven en onder de oven in de hete tafel te laten passeren. Bovendien wordt door het toevoegen van een weerstand aan de binnenkant warmte teruggewonnen en wordt de uitstoot van deeltjes uit de schoorsteen verminderd.



Afmetingen kachel ① + ②

(breedte)

225 mm x (diepte) 415 mm x (hoogte) 750 mm gewicht ① 13 kg ② 12,3 kg

hete tafel ③

(breedte) 700 mm x (diepte) 300 mm x (hoogte) 860 mm (indien gemonteerd)

gewicht ③ lichaam 15,6 kg Bovenplaat 7,6 kg Poten 2 kg

Afmetingen ovenoven

(breedte) 290 mm x (diepte) 300 mm x (hoogte) 55 mm

Roestvrijstalen pizzaplaat met thermometer 1,6

kg Korrelmand 3,4 kg

Cyclon bazooka X set 220.000 yen (exclusief btw)

* Diameter schoorsteen 120 mm (apart verkrijgbaar)

* Voor levering zijn aparte verzendkosten vereist.

Toepassingen: voor buitenactiviteiten en rampen

Het wordt ook gekocht door universiteiten, overheidsverenigingen en marathonverenigingen voor gebruik bij rampenpreventie en buitenevenementen.

Klik hier voor vragen → info@fireyclone.jp

Video van het gebruik van CYCLONE BAZOOKA X (3e verbrandingscyclon raketkachel)

サイクロンバズーカ X 2020 [3次燃焼サイク...



サイクロンロケットストーブで8Lの湯沸かし...



[Keer terug](#)

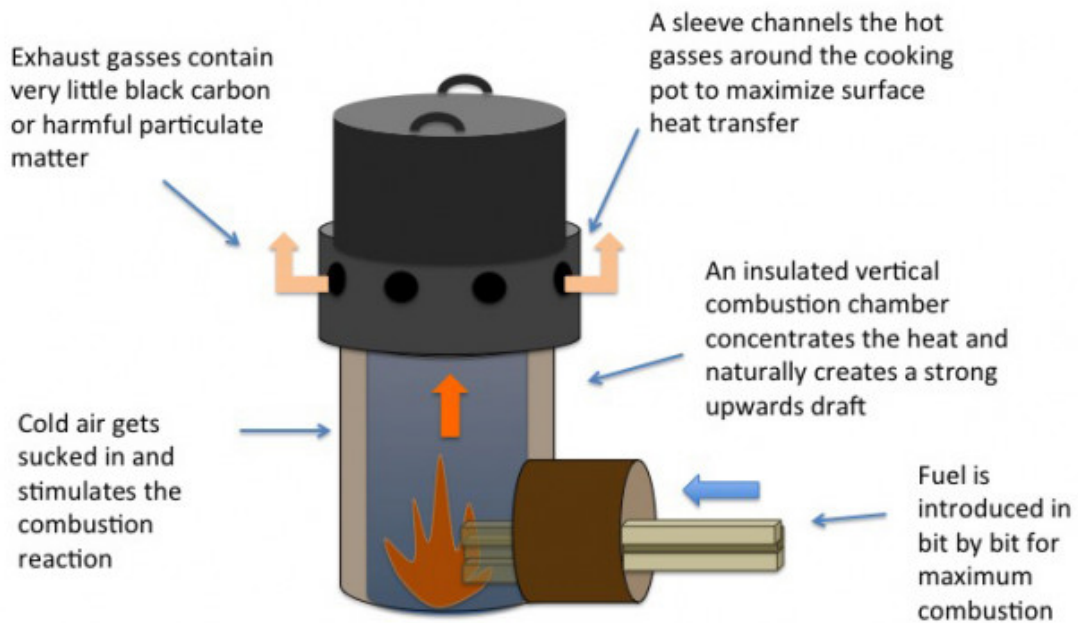


INSPIRING STORIES TO MOVE THE PLANET FORWARD



Fires of the future: Meet the Oregon innovators fighting global pollution with rocket stoves

What's in a Rocket Stove?



JACOB LEBEL
Umpqua Community College
f

March 04, 2017



Known as the "Grandfather of the Rocket Stove"

We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. More info

OK, I agree

Decline

Raised in old mining camps that ran exclusively on giant sawdust burners, Winiarski spent his childhood building fires as a Boy Scout and his adult career investigating wood powered cars and jet engines. But it is his invention of a clean burning and super-efficient combustion device that has perhaps had the most positive impact on the lives of thousands of people in rural and developing countries.

The story of the rocket stove began in 1979, when Winiarski, a Ph.D. graduate in mechanical engineering, was working at the EPA. After his wife died in a freak traffic accident leaving him with three sons to raise, Winiarski made what he called a religious vow to dedicate the rest of his life to doing the right thing.

"I said 'Lord I can't handle this but if you somehow help me get through this, I'll try to devote all my expertise, time and talents to where it will do real good in the world,'" Winiarski said.

His search for a cause brought him in contact with Aprovecho — Spanish for "to make best use of" — a non-profit based in Cottage Grove, Oregon, that was focused on improving cookstove technology for the approximately 3 billion people worldwide that still cook indoors over an open fire or traditional cookstove.

According to the World Health Organization, over 4 million people die prematurely due to indoor air pollution from cooking or heating with wood, animal manure, or coal.

"You go into places into places in South America and then they don't even bother cleaning the walls because the next day it will be all be black again. The cobwebs are like stalagmites of creosote," Winiarski said. "And the women has the baby on her back and they are breathing this all the time."

Drawing on his childhood experience with efficient fire-making as well as his years as an engineer and scientist, Winiarski set about developing a set of basic stove design principles to improve combustion efficiency which became the origin of the rocket stove.

The key, Winiarski explained, is the insulated vertical combustion chamber which concentrates the heat and also produces a strong upwards draft from the warm air being drawn upwards. Another major component is that the fuel (usually wood) must be introduced bit by bit so all of the material burns efficiently without overloading the



Dr. Larry Winiarski is a Corvallis, Oregon, engineer who invented the first rocket stove design. (Photo courtesy Aprovecho Research Center)

We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline

These simple innovations put Aprovecho Research Center on the frontlines of a revolution in clean cookstove technology. **Studies** indicate that rocket stoves can reduce the amount of fuel used by 39% to 47% compared to an open fire, and can reduce emissions by about half what is produced by an open fire or traditional chimney stove. In many developing countries, using less wood is directly linked to decreased deforestation and the increased efficiency means that less CO₂ gets released into the atmosphere. The higher temperatures inside a rocket stove also drastically reduce black carbon, a particulate component of wood smoke that is a large contributor to climate change.



Aprovecho's for-profit branch, Stovetech, mass produces and distributes rocket stoves like this model around the world and in the U.S. for emergency preparedness and camping purposes. (Jacob Lebel)

Despite its many benefits, Winiarsky has never attempted to patent his rocket stove technology, insisting instead on open sourcing his basic principles to be shared, adapted and improved by stove makers and entrepreneurs around the world.

"I'm so proud that I've created local businesses for people that do a good job on the stoves," Winiarski said.

Andrew McLean, chief operations officer at Aprovecho, explained the importance of having the rocket stove design be fluid and adaptable to fit regional cooking styles.

"In China all they want is high heat all the time because they are using a wok. In Mexico they're boiling beans; so a low simmer for a very long time and they also need a griddle for tortillas," McLean said.

"In Africa, they have a huge pot they're making a very thick porridge in and they're pounding the top of it all the time so they need a very durable stove that won't break down from all the force."



We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. More info

OK, I agree

Decline

around the world such as Nepal, India, Senegal, and China. Local rocket stove manufacturers can come to these labs and have their rocket stove prototypes tested for their efficiency and emissions level using the same technology which Aprovecho developed and uses in Oregon.

A poster of some of the international Aprovecho field stations hangs in the lab in Cottage Grove, Oregon. (Jacob Lebel)



Laboratory Emissions Monitoring System developed by Aprovecho Research Center uses hoods with sensors connected to a computer to measure different molecular and particulate emissions. (Jacob Lebel)

Every summer, Aprovecho also hosts a “Stove Camp” in Oregon where students and researchers from the international labs come and learn how to operate the testing equipment such as the emission monitoring hoods. Representatives of the U.N. High Commission for Refugees and the World Food Programs have attended these events in past years.

“This has advanced far beyond what I would have hoped for or I could have imagined,” Winiarski said.

But he’s not done yet. Besides his ongoing research into garbage incinerator and dehydrator designs, Winiarski is also working on an improved prototype of the rocket stove that uses double vortex directed airflow in the chimney to improve mixing of oxygen and fuel molecules and push the stove’s efficiency to new records.

We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline



Several different kinds of rocket stove prototypes in the Aprovecho lab. (Jacob Lebel)

Tags:

[rocket stove](#), [clean cookstoves](#), [heating](#), [storyfest2017](#)

How do you move the Planet Forward? Tweet us [@planet_forward](#) or [contribute](#) to the conversation with your own story.

Related Content Hub:

[Planet Forward Storyfest 2017 Entries](#)

[Read more](#)

[Our 2016-17 Planet Forward Correspondents](#)

[Read more](#)



136

RELATED CONTENT

Podcast: How did a boy from Manhattan become a scientist who made the rainforest his life's work?

We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline



Zachary G. B. Smith

Planet Forward Podcast

Learning to think like a river: Stories of the Amazon



Tomasz B Falkowski

SUNY College of Environmental Science and Forestry

Begin the journey to the rainforest with Storyfest 2017 winners



Planet Forward Staff

Planet Forward

2017 Planet Forward Summit



We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline

Six Storyfest 2017 winners heading to the Brazilian rainforest



Planet Forward Staff

Planet Forward

Meet the Storyfest finalists: 22nd Century



Planet Forward Staff

Planet Forward

Meet the Storyfest finalists: Visionary



Planet Forward Staff

Planet Forward

Meet the Storyfest finalists: Left Brain



We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline

Meet the Storyfest finalists: Right Brain



Planet Forward Staff

Planet Forward

Meet the Storyfest finalists: Innovator



Planet Forward Staff

Planet Forward



TRENDING

Essay | How COVID-19 changed my practice of environmental ethics

Cate Twining-Ward

Planet Forward Senior Correspondent | The George Washington University

'This cool thing in the world': A conversation with game designer Elizabeth Hargrave

Greta Hardy-Mittell

Carleton College

5 reasons why MENA countries are so affected by climate change

Liat Wasserman

We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

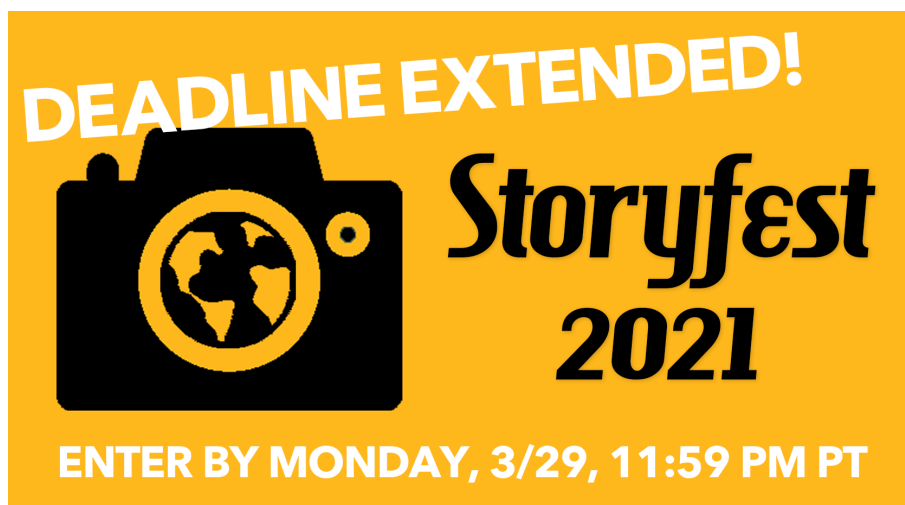
OK, I agree

Decline

Lizzie Stricklin

The George Washington University

[SEE MORE](#)



We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline



GET OUR NEWSLETTER

Sign up for the Planet FWD newsletter and get inspiring stories to move the planet forward!

Email *



Ik ben geen robot

reCAPTCHA
Privacy - Voorwaarden

* = required field

Submit

A PROJECT OF

We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline

School of Media & Public Affairs

THE GEORGE WASHINGTON UNIVERSITY

ABOUT US

CONTACT US

SHARE YOUR STORY

ABOUT THE CONSORTIUM

Climate

Energy

Food

Green Living

Water

All Topics

About

Consortium

We use cookies on this site to enhance your user experience. By clicking any link on this page you are giving your consent for us to set cookies. [More info](#)

OK, I agree

Decline



Post Reply

Bookmark Topic

Watch Topic

New Topic

permaculture forums

growies

critters

building

homesteading

energy

monies

kitchen

purity

ungarbage

community

wilderness

fiber arts

art

permaculture artisans

regional

education

skip

experiences

global resources

cider press

projects

Forums: [rocket stoves](#) | [wood burning stoves](#) | [rocket mass heaters](#)

Help required with mini rocket stove

scott
dimelow

Posts: 17

posted 4 years ago

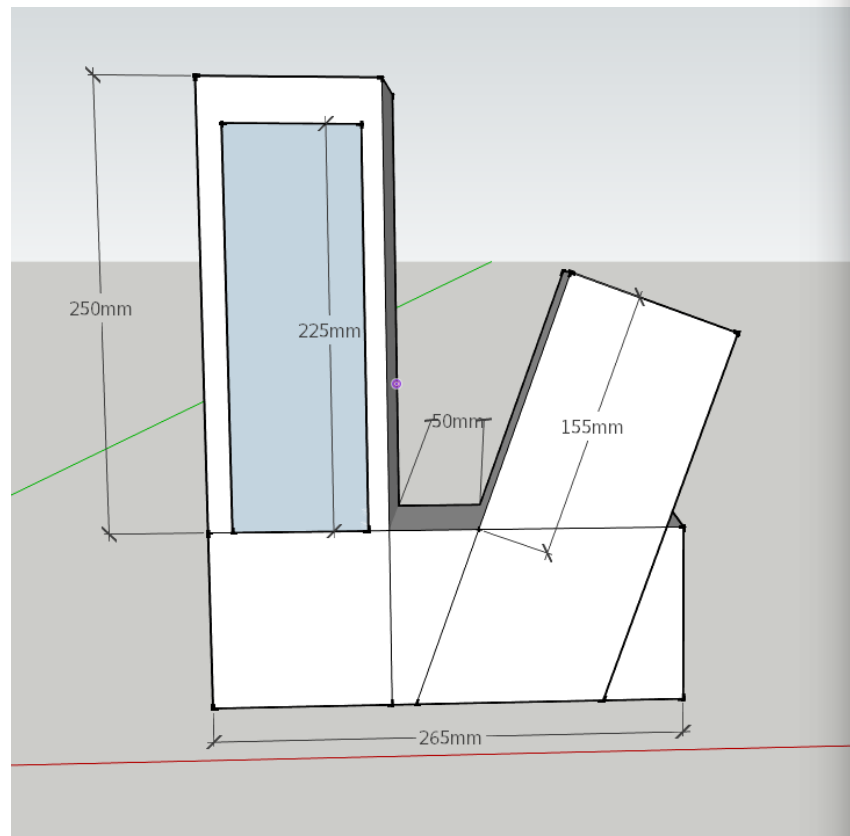
1 +1 Quote Report

1

Hi all, I'm new to the forum and looking for some help please.

I'm making a rocket stove for my live in van, which is primarily used for heat, although I probably will use for boiling kettle etc.

I'm having issues with my design, and I'm pretty sure it's either the flue size and/or the heat riser. Although it seems to draw well enough, the flames do start to move up the wood. This in turn means it burns down really quickly. I'm also getting lots of smoke, which does disappear but only when the wood has burned down sufficiently. As soon as I refill it, the smoke starts again. I've been chopping the pieces quite thin too, between 10-20mm. The flue is 50mm tube.



It's primarily constructed from 100mm box section, it's not clear from the images but the heat riser is 75mm box section. I was aware before starting, that the height of the riser should be more than the feed chamber. The bottom section used to be 100mm box section too, but I reduced it to 50mm high to try and solve the problem. I thought the burn chamber may have been too deep.

reply

[permies.com](#)[pie forums](#)[private forums](#)[all forums](#)

this forum made possible by our volunteer staff, including ...

master stewards:

Nicole Alderman
Anne Miller
Pearl Sutton
r ranson

stewards:

Mike Haasl
paul wheaton
Dave Burton

master gardeners:

John F Dean
jordan barton
Carla Burke
Leigh Tate

gardeners:

Steve Thorn
Greg Martin
Jay Angler



I've alternated where I have the air inlet, either at the base of the feed tube, or from the opening of the feed tube as pictured.

[reply](#)

Reply to this post

scott dimelow

Posts: 17

posted 4 years ago



1

Hey all, I wondered why my recent post about a steel heater didn't get any replies. Well I've been reading more on the subject, and I've read it's not good to use steel for a riser!!

Well this has put a spanner in the works, I've been welding and cutting, and re-welding and re-cutting! All trying to make an efficient stove.

I really want to make a mini rocket stove for my live in van.

My plan was to use 3" box section for the J tube, and insulate the riser with perlite.

Now this stove doesn't have to be mega hot, I'd be happy with 3-400 degrees C.

Is it still a bad idea to use steel? I'd look for an alternative for the riser, but I'm not sure how anything of a cast nature would handle movement of being in a van.

Any help appreciated.

Scott

Reply to this post

Gilbert Fritz

pollinator

Posts: 1726

Location:
Denver, CO

posted 4 years ago



How do you plan to vent the rocket stove?

85

<https://happyareyoupoor.com>

Reply to this post

Ralf Siepmann

Posts: 26

Location:
Northern
Germany

posted 4 years ago



Hi Scott,

there are several reasons why your current heater configuration doesn't work properly:

1) the recommended ratio of the lengths of feed tube, burn tunnel and heat riser are 1:2:4, So your heat riser is way on the sort side.

2) the area around the heat riser where the gases must come down again seems very narrow, normally the minmum gap should be 2 inches / 5 cms all around. Not to forget a big enough top gap between riser and ceiling for the gases to turn direction.

3) the use of metal to contain the burning fuel has serveral disadvatages:

It conducts heat away from the fire, thus cooling the burn and limiting its efficiency. Due to this the feed tube will also heat up and serve as a competing chimney causing smokeback.

With an unsinsualted heat riser the metal wil also conduct heat between the inner (upwards) and outer (downwards) exhaust gas path, so the heat riser gets less hot and produces less updraft and the surrounding chamber gets hotter and produces less downdraft.

If you manage to get hot and clean rocket combustion by insulating the burn area form the outside, metal will spall and disintegrate over time.

However metal is fine as a casing around an insulated burn tunnel and heat riser made of refractory materials,

reply

8

I like...



exhaust you'd have to redesign your stove quite a bit.

First thing would be that you construct your feed, burn tunnel and riser of firebrick splits. There's a mock up for a small fire brick core and heat riser that I found very nice in the first few minutes of this video

#323 Rocket Stove J-tube construction wood burning



This fire brick core should be wrapped either in ceramic insulative fiber board or put into a bigger metal tube that is backfilled with a mixture of 1 part fireclay and 3 parts Perlite, both serving as insulation to keep the combustion super hot and clean. Also such a "soft insulation" will protect the firebrick core from shocks while driving with your van. And the radiating casing around all this should be big enough to not restrict the downflow of the burn gases.

I hope this is helpful.

All the best,
Ralf

+ highest truth is highest joy +

Reply to this post

Glenn Herbert
gardener
 staff

Posts: 3404
Location:
Upstate NY,
zone 5

199

2

posted 4 years ago



J-tube systems of 4"/100mm or less seldom work well, as you run into issues of scale. The cross section and the power of the stove vary as the square of the diameter, so a 4" stove has not 2/3 but less than half the potential power of a 6" system; and the radiating surface pulling heat out only varies linearly, so is proportionately worse in a small system.

If you really want a very small system, try a batch box, which does scale down directly while still working well. Read all about them at batchrocket.eu. I built a working mockup of a [4" batch box firebox and riser](#) which was only 9" wide x 21" long x 29" high outside firebrick dimensions, without cutting any bricks. (22cm x 53cm x 72cm) It burned strongly and was so clean that I comfortably breathed the exhaust (from 4' above) for several full deep breaths. If you have a tile or masonry saw to cut bricks, you could make a smaller one.

Reply to this post

reply

1

Thanks for the replies guys.

Gilbert, do you mean vent the exhaust? It would have a flue up through the ceiling.

I've actually moved on from the one pictured, as like you say it's out of proportion. My new design would've been 3" box section from feed to flue. With an insulated riser, and sufficient gap around the riser.

Until you lovely people ruined my plans 😊.

The main issue I have is space, I can't afford a wide stove.

I'll do some more research on the batch rockets, they look interesting. However, I think even those would be too bulky.

Does anyone know of a 3" csa rocket heater that's worked? I could start from scratch with my design, and use refractory cement for burn tunnel and riser. But if it's useless on a small scale, there's no point.

Thanks again everyone, you've saved me a lot of time a money. I was going to go out and buy new steel today!

Regards,
Scott

Reply to this post

Peter van den Berg

gardener

 **staff**

Posts: 747

Location: +52°
1' 47.40", +4°
22' 57.80"

134

I like...



posted 4 years ago



Scott,

Your dimensions are off, 1:2:4 should be measured along the centerline of each part, the feed tube should be vertical, no low air inlet, preferably the same cross section area throughout the system, the whole thing should be insulated around bar the top part of the feed, don't shove fuel in the burn tunnel at all. Please, build a straightforward J-tube, insulate the hell out of it and try again. The steel wouldn't survive this long, but it's just to demonstrate what's possible.

And I am really puzzled by the placement of the chimney pipe, it looks like it is connected to the base of the heat riser? That's completely the wrong spot, no wonder why it smokes. The exhaust shouldn't be connected to the core itself but low in a heat extracting drum or something and the same diameter as system size. Please read at least the first and second page [of this thread](#), that'll explain a lot.

regards, Peter

Reply to this post

Peter van den Berg

gardener

 **staff**

Posts: 747

Location: +52°
1' 47.40", +4°
22' 57.80"

134

I like...



posted 4 years ago



scott dimelow wrote:

Does anyone know of a 3" csa rocket heater that's worked? I could start from scratch with my design, and use refractory cement for burn tunnel and riser. But if it's useless on a small scale, there's no point.

I would say it's pretty useless, even a 4" system wouldn't play ball every the time without the bells and whistles mentioned on Donkey's forum. That one is probably the smallest footprint that can be realised although it isn't a mass heater.

regards, Peter

reply

scott dimelow

Posts: 17

posted 4 years ago



1

Thanks Peter, I'd actually move on from this design so it wasn't related to these pics. And the flue doesn't come out of the riser, the riser is within the outer box section.

I'm gutted to hear a small rocket stove won't work, I just love them.

I'll have to look at designs for a normal wood stove, although I hate the inefficiency of a steel box jammed with wood.

[Reply to this post](#)

r ransonmaster steward
& author

Posts: 22525

Location: Left
Coast Canada

6546

posted 4 years ago



If a rocket stove isn't practical on such a small scale, what is? What kind of system would be efficient for cooking and occasionally heating with wood?

By the way, I think it's marvelous that you can not only build your own stove, but you are also willing to build a second one. Some people might get frustrated when faced with so many challenges. Keep up the good work.

3
I like...



"be kind, be calm, be safe"

homegrown yarn and fibre

homegrown linen ~ crowing hen farm ~ how permies works



[Reply to this post](#)

scott dimelow

Posts: 17

posted 4 years ago



1

Thank you for the encouragement 😊

I'm finding it really hard to fight the urge to just try a smaller design. I'm going to make a sketchup plan, using the correct ratios, and vermiculite bricks.

Even if I have to spend a bit more money on another build, I'll enjoy doing it, and maybe find a design that works?

Scott

[Reply to this post](#)

scott dimelow

Posts: 17

posted 4 years ago



1

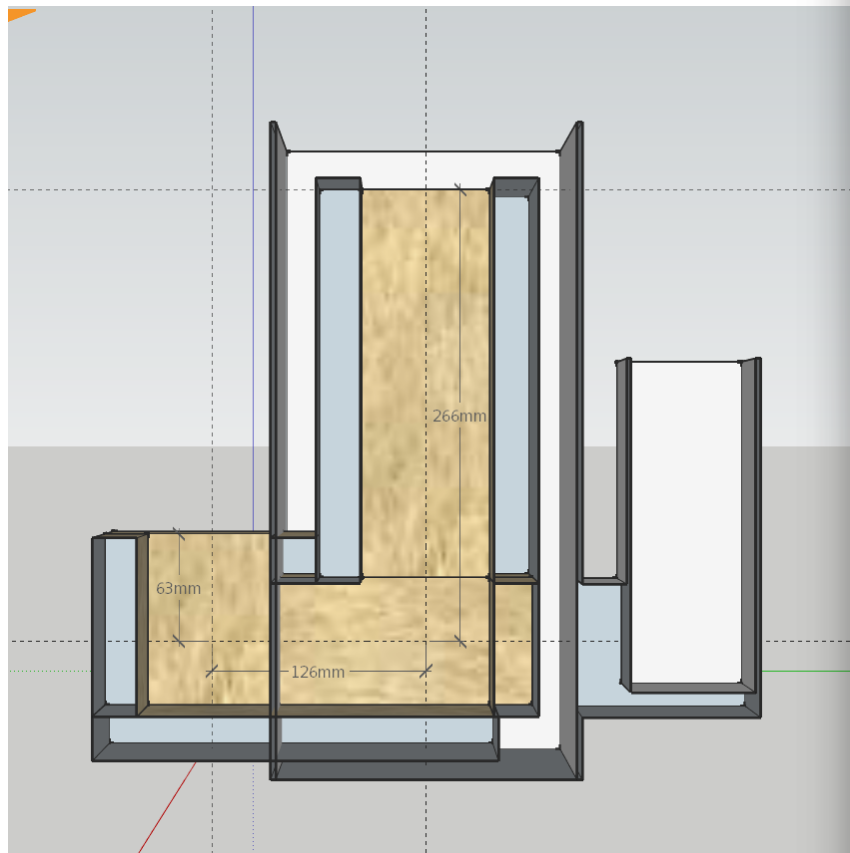
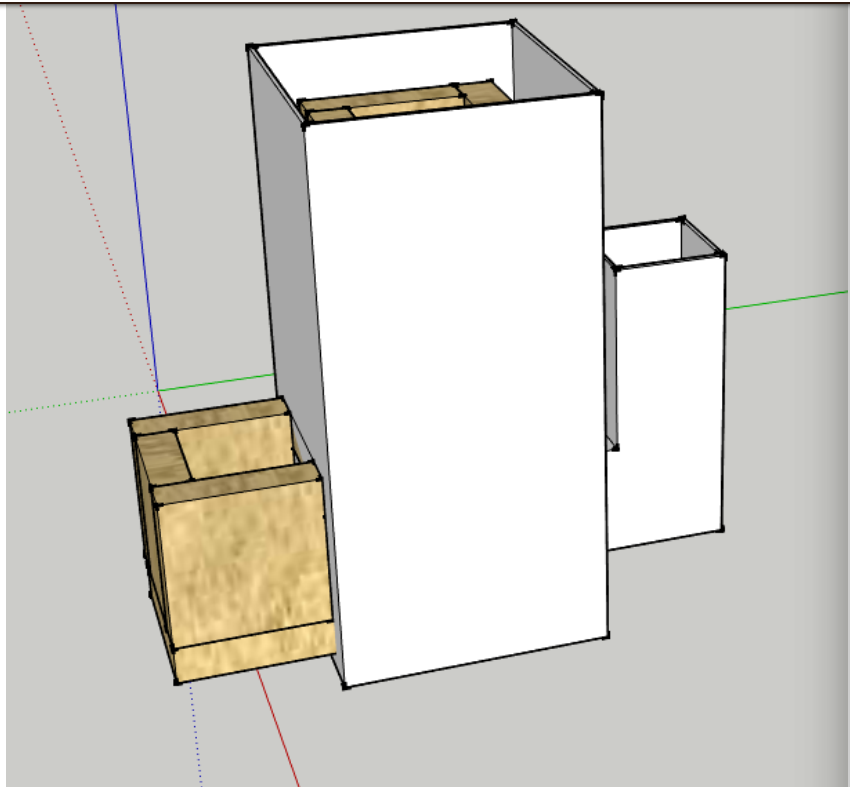
So guys, I've been busy in sketchup!

I hear what you're saying about smaller rocket stoves not working, but I think I'll have to try it anyway. Even if it's not 100% efficient I can still use it, and it has to be better than a micro wood stove.

This time I'll use vermiculite blocks for the hot stuff, and construct a steel 'barrel' around it all. The feed tube will also be cased externally in sheet steel.

So if you wouldn't mind, would you look over my ratios to see if I've worked them out correctly?

[reply](#)



I measured everything from the centre line this time, so the feed tube is 63mm the burn tube is 126mm and the riser is more than 4x the feed tube. That's just where a full length block ended up.

The cross section throughout will be $75 \times 75 \text{ mm} = 5625 \text{ mm}^2$

Gap between top of riser and hot plate - 30mm which gives a csa of 10500 mm^2

The area around the riser is 12936 mm^2

The gap between riser and 'barrel' is 25mm all around

[reply](#)

Scott

Reply to this post

Ralf Siepmann

Posts: 26
Location:
Northern
Germany

8



posted 4 years ago



This thread got my head spinning 😊

Scott, if you have room for a footprint of approx. 30 x 50 cms I have got an idea:
Your heat extraction bell can be a capped standing steel tube (with removable top lid /cooking plate in case of inspection) of 30 cms diameter, about 1 meter high or more.
Cut an opening low on the side to fit in a rectangular box-like tube of steel plates which protrudes towards the inside of the big tube as well as towards the outside.

The box should be just big enough to contain a small (4 inch /10 cm) batch box (maybe cast of refractory concrete with thin walls) wrapped or embedded in refractory (and shock absorbing) insulation.

Heat riser could be made of 5 cms /2 inch refractory fiber blanket fitted inside a 20 cms / 8 inch diameter steel tube which is fixed near the rear inner wall of the big tube (viewed from the opening of the fire box).

This way you will further shorten the required length you need for the batch box by "shoving" it deeper into the big tube.

Then you only need a door at the front of your batch box "insert" and that's it.

You'd only have to watch out that there's enough space to the left and right of your inserted box so that the gases can pass it unhindered on their way down to the exhaust opening.

This would be basically a shrunk version of Peter van den Berg's workshop heater made of three full-sized barrels stacked on top of each other.

It can be found [here](#).

Ralf

+ highest truth is highest joy +

Reply to this post

scott dimelow

Posts: 17

1

posted 4 years ago



Hi Ralf, thanks for your reply. Unfortunately I just don't have the space for anything that big.

The design I've come up with is basically the size I have to play with, I have quite a narrow gap to play with.

Reply to this post

Ralf Siepmann

Posts: 26
Location:
Northern
Germany

8



posted 4 years ago



Hi Scott,

I will leave the evaluation if your new design will work to someone with more practical experience under his/her belt.

My feeling is that the top gap would work better with 50 mms /2 inch (it's not only the cross-section needed but also room for the direction change of the gases).
And if you could somehow construct a round or at least octagon heat riser in that square tube it would leave a little more room for the gases to stream down on all four corners.
It would not harm the upward draft through the riser as long as it's got 75 mms inner diameter

Just my 5 cents.

reply

+ highest truth is highest joy +

Reply to this post

scott dimelow

Posts: 17

1

posted 4 years ago

+1 Quote Report

Thanks Ralf, from what I've gleaned from various sources, the area above the riser should be 1.5-2x the csa of the riser. That's how I came up with the 30mm gap.

Zero told me that if the gap is too big, then not enough turbulence is created.

Good idea with the octagonal shape, I'd have to figure out how to do that without a sheet metal bender.

Reply to this post

Gilbert Fritz

pollinator

Posts: 1726

Location:
Denver, CO

85

posted 4 years ago

+1 Quote Report

If space is so tight around the stove, so that you can't make anything bigger, will the hot stove set anything on fire?

Interesting thread, thanks for posting your experiments!

<https://happyareyoupoor.com>

Reply to this post

scott dimelow

Posts: 17

1

posted 4 years ago

2 +1 Quote Report

That's the reason I can't go too big Gilbert, I've allowed a sensible gap around it. I will then line the surrounding area with aluminium, with an air gap.

Reply to this post

Peter van den Berg

gardener

staff

Posts: 747

Location: +52°
1' 47.40", +4°
22' 57.80"

134

I like...



posted 4 years ago

1 +1 Quote Report

Dimensions looking correct now, although I would like to make the riser a bit higher. The smaller the system size the more unfavorable the aerodynamics are. The recommended top gap is a minimum value, not an absolute one. I built 4" systems with a top gap of 600 mm without adverse effects according to my Testo analyser so in practise there isn't a maximum. Don't forget you need a proper vertical chimney stack, venting horizontally through the wall won't work in most cases. Beware for your knuckles when adding fuel, don't touch the metal bell housing. And, I fully expect the thing to heat up like... a rocket?

regards, Peter

Reply to this post

scott dimelow

Posts: 17

1

posted 4 years ago

+1 Quote Report

Thanks Peter, that's good to hear.

I did think about making the riser taller, which I probably will do actually.

I'll get some fire bricks and get building 😊

Reply to this post

Glenn Herbert

gardener

staff

posted 4 years ago

+1 Quote Report

reply

zone 5

and cooking without taking too much space.

199

2

Reply to this post

scott dimelow

posted 4 years ago

 +1   Quote  Report

Posts: 17

1

Thanks Glenn, that's the reason the new design uses vermiculite bricks for the feed, tunnel and riser.

What are peoples thoughts on the thickness of the barrel? I was thinking either 2 or 3mm. The hotplate will be 6mm.

Reply to this post

Glenn Herbert

gardener

 **staff**

Posts: 3404

Location:
Upstate NY,
zone 5

posted 4 years ago

 1  +1   Quote  Report

The barrel only needs to be thick enough to stand up to any knocks it will get. After the combustion zone, there is not enough oxygen for scaling or corrosion to be a problem. A 6mm hotplate sounds like a good idea, as buckling or bowing there is not helpful.

Reply to this post

199

2

scott dimelow

posted 4 years ago

 +1   Quote  Report

Posts: 17

1

Thanks again Glenn, I think I'll go with 2mm to keep the weight down.

Reply to this post

scott dimelow

posted 4 years ago

 3  +1   Quote  Report

Posts: 17

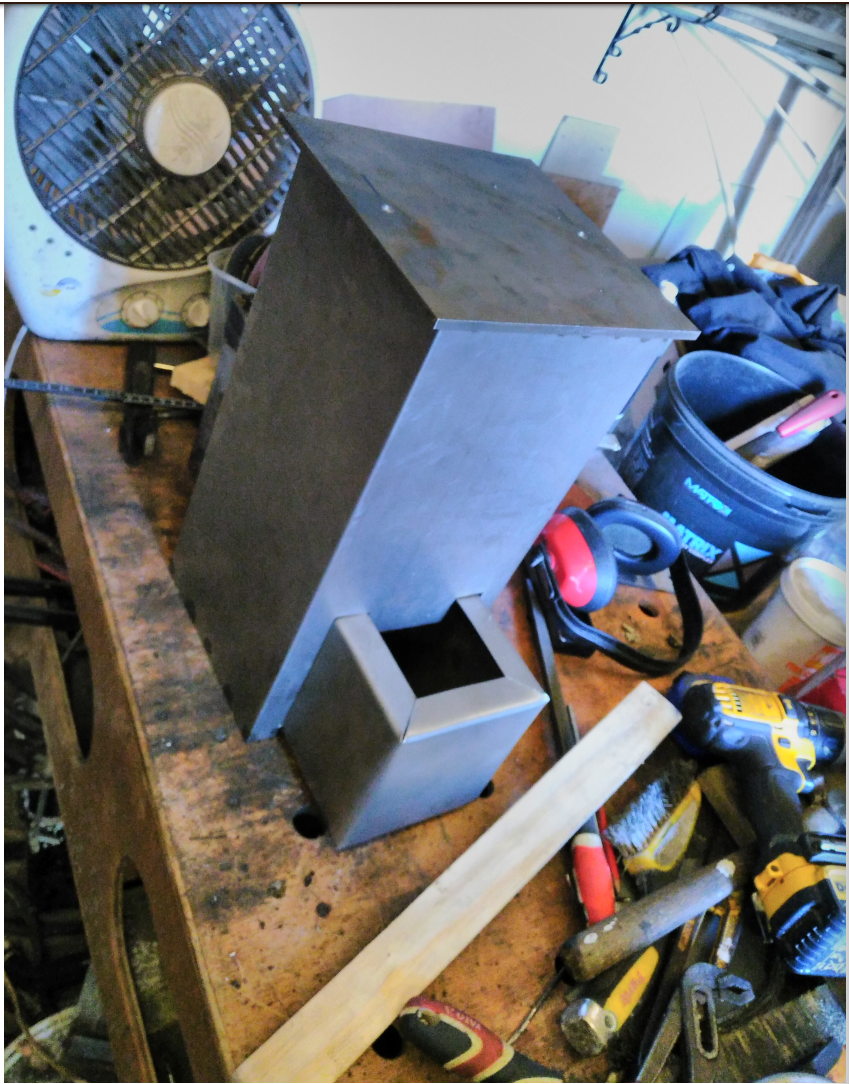
1

Hi guys and gals, I just thought I'd share my progress thus far.

I got the bulk of the work done yesterday, I'm now just waiting around for the vermiculite bricks to arrive.

It looks big in the pic, but it's quite a compact unit. I had to keep checking my measurements because it seemed too small lol.

reply



Reply to this post

scott dimelow

Posts: 17

posted 4 years ago

👍 4 +1 +👍 Quote Report

1

Hello folks. Well I'm really excited tonight! I've had my stove burning, the bricks arrived so I got it all assembled.

I lit a small fire lighter in the feed tube, and within a couple of seconds it was burning horizontally. So I loaded it up with wood, and away it chooched! Burt clean from the start which amazed me, even with a petroleum based fire lighter.

I got it loaded up properly and it was rocketing nicely, it was at around 340 centigrade on the hot plate. Which is more than enough for my needs. I reduced the wood down to a couple of sticks, and it held a temp around 150. Which is most likely what I'll keep it at in most cases.

Here's a video, you can just about hear the rocket sound over the crackling.

reply



I'll do a longer test burn over the weekend.

As this is for my live in van, the only concern I have is the bricks moving around. I'm tempted to make the core a single, or 2 piece unit. What do you think? Any recommendations on a good castable mix?

Regs,
Scott

Reply to this post

scott dimelow
Posts: 17

posted 4 years ago

2

1

Here's the finished stove, with new shoes and a couple of coats of paint 😊

Can't wait to install it.

reply



Thanks for all your input folks.

Reply to this post

Kyrt Ryder

Posts: 947
Location:
Graham,
Washington
[Zone 7b,
47.041
Latitude]
41inches
average annual
rainfall, cool
summer
drought

53

posted 4 years ago

+1 + Love Quote Report

Do you think you could possibly expand UP to compensate for the lack of total space? I don't know the clearance you're working with inside the van, but two thirty gallon drums stacked ontop of eachother might provide enough power to drive a 3 inch batch box.

[All armchair theory here, I've yet to construct my own Rocket Heater.]

EDIT: that's what I get for running my metaphorical mouth [aka fingers] before finishing reading the thread. Glad to see you got your stove running the way you want it.

Reply to this post

John McDoodle

Posts: 614
Location:
ontario,
canada

12

posted 4 years ago

+1 + Love Quote Report

I think it's much better now And it's a cool little unit. However I agree with Kurt. It could be taller. Especially the feed tube, I noticed a tiny bit of smoke-back on your video. Good work though in your revised design.

Are "vermiculite bricks" the same as firebricks? Good job on the van window. Is the black cat yours?

reply

I like...



Reply to this post

scott dimelow

Posts: 17

1

posted 4 years ago



It can't be taller as I'm short on space, it'd be too imposing in the van.

It's not actually smoking back in the clip, it draws down nicely ☺

Reply to this post

Glenn Herbert

gardener

staff

Posts: 3404

Location:
Upstate NY,
zone 5

199

2

posted 4 years ago



Vermiculite bricks would be insulating firebricks, not the hard common variety.

Reply to this post

**John
McDoodle**

Posts: 614

Location:
ontario,
canada

12

posted 4 years ago



Thanks for the clarification Glenn, those are what I used in my riser and Venturi.

I saw a bus conversion once and the guy used a 5" transport truck exhaust stack for his rocket stove chimney. I gotta admit it looks more natural and awesome on a vehicle. Do you have a final exhaust stack plan?

I like...



image.png

reply

Bus conversion stove chimney stack



Permies.com

Rocket stove in a bus/RV (rocket stoves forum at permies)

since you have a bus, its made to be tough and can handle a small mass bench near the rocket stove without breaking apart. a good suggestion would be to use ...

Images may be subject to copyright.

positively optimistic
SUBSCRIBE for free videos <https://www.youtube.com/MrJohn613>

Reply to this post

Robert Fairchild

Posts: 25
Location:
Kentucky, USA

posted 4 years ago

+1 + Like Quote Report

Riser needs to be same or smaller cross sectional area as feed tube. It'll work better if the bottom of the feed tube is the front of the riser.

See: http://www.instove.org/sites/default/files/20Lstove_tech_bulletin_v1.3.pdf

Reply to this post

Douglas Pohl

Posts: 12

1

posted 4 years ago

+1 + Like Quote Report

Scott, take a look online at what is working small in Japan - might be to your needs - See:

<http://rocketstove.tokyo/lineup/rockeko/> and

<http://rocketstove.tokyo/lineup/wanco/>

Reply to this post

Glenn Herbert

gardener
staff

posted 4 years ago

2 +1 + Like reply

zone 5

199

2

completeness of an angled feed straight to the base of the riser versus the standard J-tube, but part of the design of the J-tube is to have sharp changes in direction of the flames for turbulent mixing. You would not get this with the "V" configuration, nor would you probably get as much dwell time of gases in the hot zone for combustion to finish.

Also, the angled feed will let any stick that is not perfectly smooth snag on feed edges and hang up; the vertical feed is less prone to this, and allows the fuel to be positioned so air is drawn between sticks for maximum oxygen access rather than above the sticks which may allow coals to be buried out of the airstream.

[Reply to this post](#)**Robert Fairchild**

Posts: 25
Location:
Kentucky, USA

posted 4 years ago

[+1](#) [+2](#) [Quote](#) [Report](#)

Rocket stove combustion is rocket stove combustion, after that it's heat transfer.

[Reply to this post](#)**Glenn Herbert**

gardener
 **staff**

Posts: 3404
Location:
Upstate NY,
zone 5

posted 4 years ago

[5](#) [+1](#) [+2](#) [Quote](#) [Report](#)

Combustion efficiency depends on the details of the core. A typical rocket stove (outdoor type) is going to be distinctly less efficient than a well-designed RMH core.

[Reply to this post](#)

199

2



Rocket Mass Heater podcast gob

will be released to subscribers in: **11 : 41 : 15**

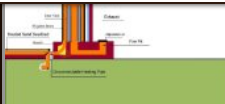
[click here for details](#)[reply](#)[1](#) [2](#) [▶](#)[Bookmark Topic](#)[Watch Topic](#)[New Topic](#)[Boost this thread!](#)

Similar Threads



Rocket Stove progressing.

[reply](#)



Building a RMH/Rocket stove



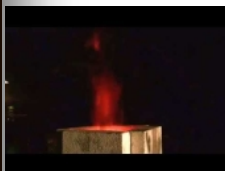
FWIW: Rocket stove heater concept (no mass) for shop.....



Richard C. Hill Rocket?



why the rocket mass heater works so efficiently



Results of the 8" batch box thingy at the Innovators Gathering



Peter van den Berg



Peter van den Berg 4 inch Minnie Mouse rocket mass heater



rocket mass heater myths - youtube video series

[More...](#)

Increasing fuel efficiency and reducing harmful emissions in traditional cooking stoves

by Dean Still and Larry Winiarski, Aprovecho Research Center, 80574 Hazelton Road, Cottage Grove, Oregon 97424, USA. Email: Apro@efn.org. Website: <http://www.efn.org/~apro>

Introduction

In 1976 consultants from the Aprovecho Research Center helped to design the Lorena stove in Guatemala. The massive, earthen Lorena stove has been built in many countries since then. The design has some attractive features: the stove is made from rammed earth so material costs are low, its chimney removes smoke from the kitchen and it can be attractive. However, further studies at Aprovecho have shown how to improve the stove. More modern designs can achieve better fuel efficiency while producing fewer emissions and less smoke.

Dr. Larry Winiarski, Technical Director at Aprovecho, has devised a set of design principles which can be adapted to many types of cooking stoves so that while the outside of a particular stove may look the same, the stove becomes more efficient. These principles are described below; the design principles can be applied to many stove designs including bread ovens, heating stoves, water heaters, incinerators, kilns and dryers.

The latter part of this article describes a set of cooking stoves which are based on these principles, and are now proving very successful in Nicaragua, Honduras, El Salvador and Guatemala. Another version of the stove is described in this edition in the article by Rogério C. de Miranda and Frances G. Tilney entitled *The modernization of small business through the Ecostove in Nicaragua*.

Design principles resulting in improved fuel efficiency

- Insulate everywhere around the fire and hearth except where it touches the pot(s) – the next section describes

what materials make good insulators.

- Force the hot gases to rub against the outside of the pot(s) by creating small channels with narrow gaps that follow the shape of the pot(s) – otherwise the flames will just warm the escaping air.
- Get the pot near to the hot flames. Intense heat is much better at heating food than moderate heat.
- Use pot materials which allow heat to pass through quickly and easily to the food, so if possible, use metal pots rather than ceramic.
- Increase the speed of the hot gases as they hit the pots. Faster hot flue gases punch through the still air that surrounds the pot(s).

Earth is not insulation

Good insulation is made up of little pockets of air separated from other tiny pockets of air by a lightweight relatively non-conductive material. Air is very, very light and cannot absorb and hold a lot of thermal units of heat. Heat passes much more slowly through separated pockets of air than through packed earth. Wood ash, pumice rock, perlite, vermiculite, dead air spaces, etc. are good insulators. Good insulation slows down the passage of heat.

Earth is heavy and dense, and does not contain pockets of air, so it is not a good insulator – it does the opposite and absorbs heat, robbing the heat from the pot. Before experiments proved that we were wrong, Aprovecho stove designers thought that earth was good insulation. We did not understand the difference between a heavy dense material that absorbs heat, and insulation – which does not.

In mud stoves, the flames, and all the heat they contain, are in direct contact with the heavy earthen walls, which rob heat from the pot. Also, the heavy walls around the fire itself cool the fire, causing smoke. Instead of placing sand and clay near the fire now, Aprovecho designers use natural insulation, like wood ash or pumice rock or homemade insulative fire bricks.

Getting more heat into the pot

Replacing mass with insulation and forcing hot gases to rub against the pot dramatically improves fuel efficiency. Increasing combustion efficiency helps to reduce smoke. Making sure that hot gases scrape against as much of the pot(s) surface area as possible determines, to a large degree, the fuel efficiency of the stove. In many older stoves, the hot gases are not forced to rub against the pots. Instead, hot flue gases flow past the pots in big spaces and most of the heat escapes without cooking food.

These principles can be applied to most stoves. The following sections show how these ideas have been put into practice.

The Winiarski 'Rocket' stove design

Basic rocket stove

Rocket stoves are based on a combination of simple principles:

- The combustion chamber is insulated in order to keep the fire hot (above 650°C) to burn the wood more completely, thereby reducing smoke (which is fuel that has not burnt completely).
- The combustion chamber and interior stove parts are as insulative and lightweight as possible. Heavy materials in contact

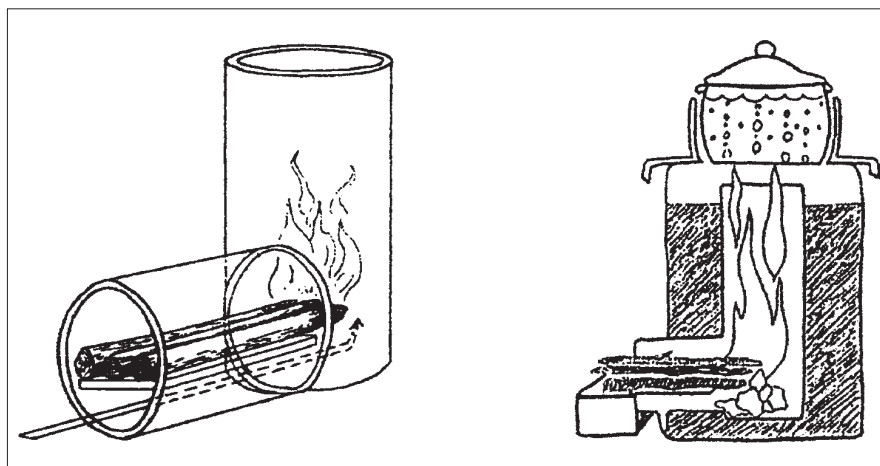


Figure 1: Diagram of Rocket stove

with hot flue gases absorb heat that could have been used for cooking.

- The 'elbow' is an important part of the Rocket family of stoves. Made in the shape of the letter L for horizontal feed, or the letter J for vertical feed, fuel is fed into a combustion chamber, placed at the bottom of a short internal chimney.
- Wood is burned at the tips and is pushed in towards the fire as it burns. This limits the amount of wood being heated and the amount of volatile wood oils being driven off at any given time, so that they all get burnt completely. Pushing the sticks of fuel into the combustion chamber as it is burnt ensures that the fuel is fed into the stove at the correct rate, creating cleaner combustion, reducing smoke. The feed opening is sized to prevent too much fuel in the combustion chamber, and arranged to force much of the incoming air to pass through the burning fuel rather than over it. Too much air just cools the fire. As the air moves through the burning fuel, it is heated, which helps to keep the fire above 650°C assisting more complete combustion.
- A 'skirt' surrounds the pot on all sides. A small gap (about 7mm) between the skirt and the pot forces hot flue gases to scrape against the sides of the pot, which greatly increases heat transfer. The hot gases

contacts the sides of the pot as well as the bottom. Putting insulation around the skirt decreases heat loss even more.

Rocket stove with internal chimney and combustion chamber

- A shelf supports the sticks of wood so that air can enter from underneath the sticks. Creating a grate from sticks entering the fire helps to diminish smoke and burn up the charcoal. The feed magazine (horizontal pipe through which the fuel is fed) protects the fire from wind and creates some preheating of air which rushes in under the sticks as the air is pulled up the internal chimney.
- The short insulated interior chimney, placed above the fire, creates a strong draft that helps the wood to burn fiercely and cleanly. It also makes the stove easier to light and to use. To get the fire going, it is best to have several thin sticks burning at the same time so that the draught will fan the flame rather than extinguish it. Once the combustion chamber is very hot, it is good to have two or three medium sized sticks filling the combustion chamber as they give heat to each other and the fire between the sticks will be much hotter. However, it is possible to burn just one thick stick at a time.
- Adding an external chimney to a simple Rocket stove (as shown in Figure 2) is accom-

plished by partially submerging the pot into the body of the stove. The top of the stove is formed to allow the pot to be placed snugly inside, usually down to the level of the handles on the pot. The gap between the pot and the stove body is about 6mm. The external chimney exits from the side of the stove body which also surrounds the Rocket elbow. The Rocket elbow is surrounded with insulation, usually wood ash. Using insulation, like wood ash, pumice rock, vermiculite, or perlite also seals cracks in the combustion areas.

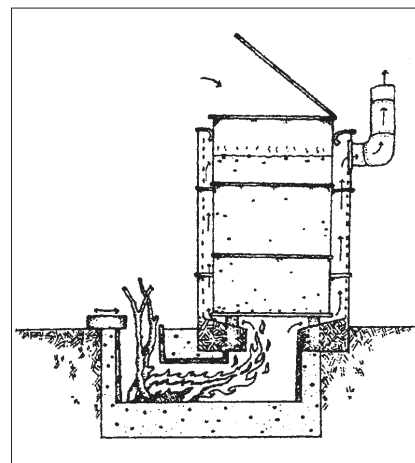


Figure 2: Adding an external chimney

The pot is located 20mm above the short internal chimney above the combustion chamber. The intense heat, in contact with the pot, increases efficient heat transfer.

- Removing smoke from a room is only a partial solution if the smoke then pollutes the village. Hot, rapid fires reduce escaping smoke before it enters into shared spaces. Where possible, Rocket stoves use external chimneys to remove the smoke from the interior of the house. However, where chimneys are not used, the stove itself can reduce harmful smoke.

Refractory Materials

The Rocket stove principles encourage high temperatures in the combustion chamber. Most

materials are degraded by high temperatures, even stainless steel will be damaged over time. Ceramic parts can be made, however, that will last for years in Rocket elbows. Ken Goyer, an Aprovecho researcher, has developed a mixture that makes durable stove parts: it is kiln-fired, refractory, and highly insulative. This mixture comprises:

- 2 parts ordinary clay, like earthenware, that melts at a low temperature
- 1 part clay that melts at a higher temperature to add strength.
- 1 part cement. This holds everything together until it is fired in the kiln and adds more strength.
- 4 parts fine sifted organic matter, like sawdust. This burns out making the ceramic light weight and provides air pockets for insulation.

A women's co-operative in Honduras called Nueva Esperanza makes long lasting refractory ceramic stove parts from a mixture of clay, sand, horse manure and tree gum.

Using the Rocket stove principles

The new Lorena stove

For three years now, Aprovecho has been working with local groups in Nicaragua, Honduras, El Salvador and Guatemala to develop and build various types of Plancha (griddle) stoves. Plancha stoves allow the user to fry tortillas, keep pots clean, and to cook

using multiple pots. Flue gases are removed from the kitchen through a chimney. This work has been largely sponsored by Trees, Water and People. Organizations in Central America working on griddle stove projects include Ahdesa, Prolena Nicaragua, CLUSA, Fundacion Vida, HELPS International, the Peace Corps and the Godchild Project.

The Doña Justa stove

The 'Rocket stove' version of the Plancha stove includes a Rocket type insulated firebox and chimney. Hot flue gases are forced to pass directly underneath the metal griddle (Figure 4). The diagram points out the design features of

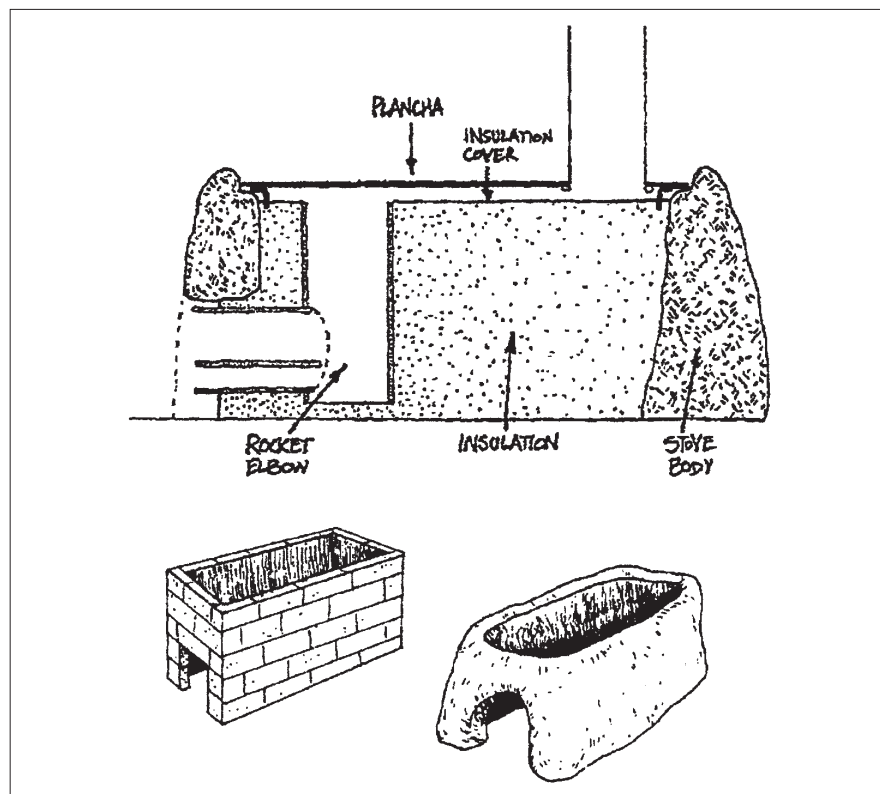


Figure 4: The Doña Justa stove

this type of improved Plancha stove named after Doña Justa. (She continues to improve, build, and test this stove in Honduras.)

The pots can either sit on top of the griddle, be placed over holes cut in the griddle, or be partially submerged into the griddle. When more of the pot is directly exposed to heat, efficiencies rise. The griddle is supported on top of a box built from ordinary brick, lorena mix, sheet metal, or any inexpensive material like adobe, etc. An insulative material like wood ash isolates the heat from the high mass stove body. If the chimney is cement, it can be a part of the box, supported by four walls. The heavy chimney is placed behind a wall of brick that allows hot flue gases to flow freely into the bottom of the chimney. If the chimney is made from lightweight sheet metal it can rise directly out of a hole cut in the griddle.

Griddle stoves with submerged pots

Partially submerging the pots under the griddle can double the efficiency of heat transfer. The efficiency of this type of stove is highest because the design allows

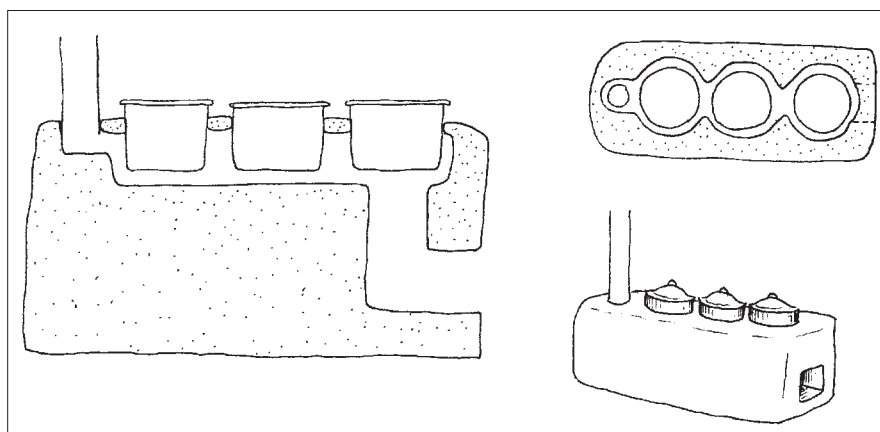


Figure 3: The new Lorena stove

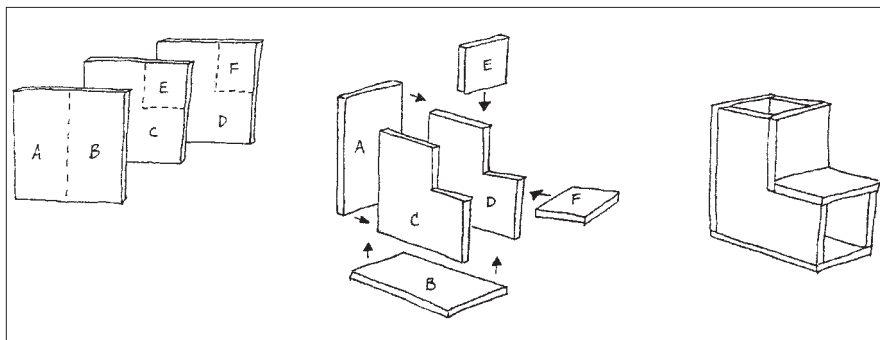


Figure 5: Baldosa tile combustion chamber

the greatest amount of heat to strike the increased surface area of the pots. The most efficient griddle stove with multiple pots can achieve efficiencies of more than 40%. Sheet metal or insulative ceramic material form walls near the pots to create a 6mm gap so that the hot gases are forced to rub against the pots. Like the other stoves, both the combustion chamber and fire flow path are insulated.

The HELPS stove

In Guatemala, an inexpensive soft brick tile called a baldosa (Figures 5 and 6) is used to make the combustion chambers in the beautiful and inexpensive HELPS molded cement Plancha stove. These insulative ceramic combustion chambers make the stoves easier to start and faster to heat up compared with dense materials like cast iron or normal brick.



Figure 7: The HELPS stove

Women in the village of Santa Avelina, Guatemala who tested both versions of the HELPS stoves, much preferred the lower mass ceramic parts, which boiled water more quickly (Figure 7)

Who are using the stoves?

Up to the present time:

- PROLENA has built 1,750 EcoStoves and plans to build 3,000 by the end of 2002 in Nicaragua;
- AHDESA has built more than 500 Justa stoves in Honduras;
- TWP/Guatemala has built 160 Justa stoves; and FUEMCO has built 40 Justa stoves in El Salvador.
- TWP is funded to build 1,300 Justa stoves next year in Honduras and 500 stoves in Guatemala. TWP will finance the construction of 500 Justa stoves in El Coco, El Salvador over the next two years, as well.

It is reckoned that the number of women using their Justa and EcoStoves is well over 90%.

Summary

There is always a need for variations in stove design. One village may insist that pots stay clean. A village fifty miles away may need greater fuel efficiency. Rocket stoves can change to meet local needs but the essential design principles remain the same. Working with local people, it is important to be flexible in designing stoves to meet local needs. Not changing the outward appearance of the traditional stove can be helpful in gaining acceptance of the new technology inside the stove.

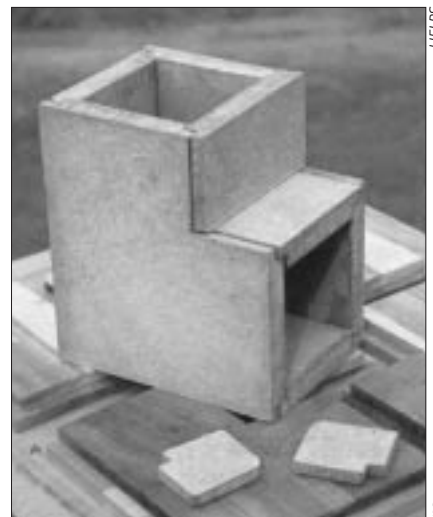


Figure 6: Baldosa tile combustion chamber

All of these Rocket stoves demonstrate various efficient ways to cook while creating a reduced or smoke free kitchen. The simple Rocket stove can be a useful option if, for economic or other reasons, a chimney is not going to be used. The added chimney removes all of the smoke and for that reason is always preferable. The Plancha stoves and the New Lorena stove also contain design features that are novel and important:

- The Rocket elbow assists cleaner, more complete combustion.
- The heat flow path is directed through narrow channels that force hot gases to scrape against pots increasing heat transfer efficiency.
- The entire heat flow path is low mass and insulated, lessening heat absorption into the stove body.
- The small, well insulated combustion chamber under an internal insulated chimney allows the use of fewer sticks since the fire does not tend to die out as easily.

For further information, please contact: Dr. Larry Winiarski, Technical Director, Aprovecho Research Center, 80574 Hazelton Road, Cottage Grove, Oregon 97424, USA. Apro@efn.org <http://www.efn.org/~apro>. For further information on Rocket, Down-draught and wood-burning stoves see: 'Building and using an efficient cookstove' by Dr Winiarski – Boiling Point no 23, 1990

Vindt u dit forum ook zo waardevol, overweeg dan eens te doneren en kom zo van deze vervelende reclame af! Klik op deze regel en lees hier hoe u kunt doneren

Ecologieforum

[Snelle links](#) [V&A](#)[Registreer](#) [Aanmelden](#)[Home](#) < [Forumoverzicht](#) < [Discussie](#) < [Verwarming, isolatie, huiselijk energieverbruik](#)

Rocket stove van stalen koker

Moderator: [Moderators](#)

[Plaats reactie](#)10 berichten • Pagina **1** van **1**[sjoerdb](#)

Rocket stove van stalen koker

10 dec 2019, 22:25

Ik wil experimenteel rocket stove in elkaar lassen van stalen koker, via het werk kan ik aan koker komen waar we niks mee doen. Het zijn korte, dunwandige kokers van ongeveer 45x45mm.

Als volgt te bouwen:

Horizontaal voor de luchtinlaat, verticaal voor de verbranding en diagonaal voor de hout toevoer.

is er een handleiding voor de lengte van de kokers?

Heb je ervaring dan hoor ik graag bevindingen en tips.



Laatst gewijzigd door [sjoerdb](#) op 10 dec 2019, 22:33, 1 keer totaal gewijzigd.



Vindt u dit forum ook zo waardevol, overweeg dan eens te doneren en kom zo van deze vervelende reclame af! Klik op deze regel en lees hier hoe u kunt doneren

[maarten martens](#)

Re: Rocket stove van stalen koker

10 dec 2019, 22:32

fijn project, staan al veel voorbeelden op youtube

belangrijke nuance : **dunwandig** ... hoeveel mm ?
doorbranden is zeer goed mogelijk

succes en post hier maar relaas, liefst met fotos 😊

"earth does not belong to us, we only borrow it from our children"

onafhankelijk holistisch bouwexpert
www.huisadvies.be



sjoerdb



Re: Rocket stove van stalen koker

10 dec 2019, 22:36

2mm dik dacht ik, het zijn kokers die als afstand dienen voor een motorblok vervoer frame.

Wanddikte en levensduur horen bij elkaar, het is rest afval en ik dacht er wat leuks mee te willen doen



bertocello



Re: Rocket stove van stalen koker

11 dec 2019, 08:46

Als experiment, ja! Maar in gebruik is de binnenmaat van 41 mm veel te klein.



peterberg
Moderator



Re: Rocket stove van stalen koker

11 dec 2019, 11:51

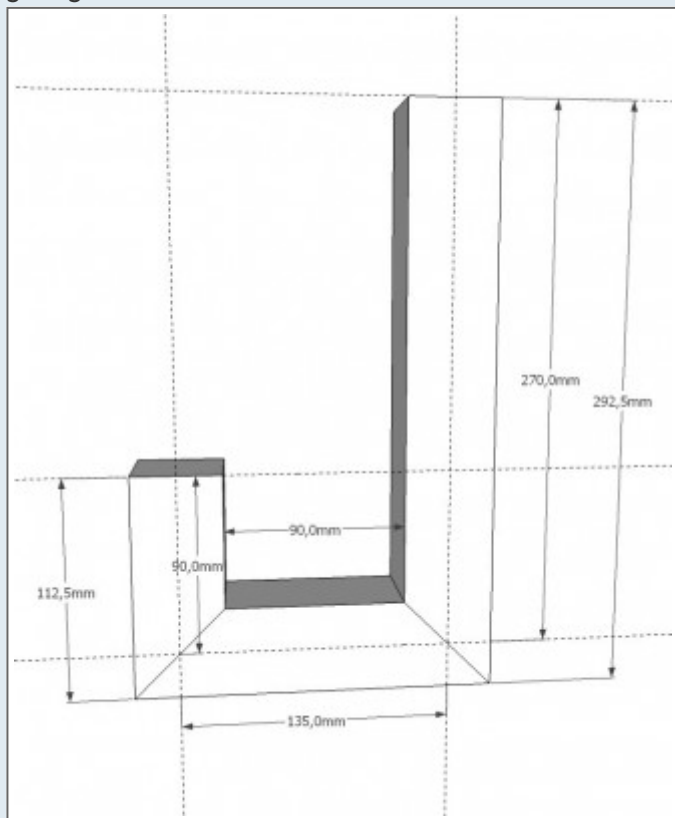
Er zijn een paar echte ontwerpen die samen onder de noemer rocket stove vallen. Je hebt de oer-rocket (als kooktoestel) van Larry Winiarski en de J-tube (ruimte verwarming) van Ianto Evans. Daar tussenin zit de batch box rocket geklemd waar ik zelf een flink aandeel in heb gehad. Verder heb je sinds enige tijd ook de K-rocket, het model dat je hier bedoelt. Dit ding heeft geen van de eigenschappen van de andere drie omdat er nauwelijks of geen secundaire verbranding plaatsvindt, het is enkel een klein vuurtje onderin een lange schoorsteen. Schoon branden doet-ie dus eigenlijk helemaal niet, warm worden natuurlijk wel maar dat is bij een rokend vuur in een oliedrum ook zo.

Het K-model appelleert aan het idee dat er lucht van onder de brandstof moet komen. Dat is een diep gewortelde misvatting, op deze manier heb je wel snel een vuur maar van goed verbranden is geen sprake. In mijn ogen is het dan ook een kl*te ding, het wekt ten onrechte de indruk van een serieuze variant.

Als je echt een goed werkend dingetje wilt maken van de buizen die je hebt, bak een J-tube in elkaar. Gebruik de verhoudingen 1:2:4:6, 1 is de maat van de buis, 2 de lengte van de korte J-poot, 4 de lengte van de horizontale buis en 6 de lengte van de lange verticale buis. De maten 2, 4 en 6 zijn gemeten in het hart van de buis. De maten zijn niet exact, als je maar zorgt dat de tunnel niet langer is dan pakweg 1,5 keer de staande poot (feed) en de lange poot (riser) 3 keer de feed.

Maak een klein vuurtje in de korte staande buis, blaas er even in en hij gaat. Het hout dat er rechtop in staat blijft vrijwel nooit hangen, wat onder de 45 graden hoek regelmatig voorkomt. Met als gevolg dat de onderkant van de brandstof er af brandt en de rest er brandend en wel uitvalt. Het vuur blijft onderin omdat de lucht exclusief van boven af komt. Om aan te steken zet ik wat houtjes in de feed en laat er een brandend aanmaakblokje in zakken, tussen twee houtjes geklemd zoals met chinese eetstokjes.

Ik heb even een tekeningetje gemaakt hoe het ding in elkaar zit, met de hartmaten er bij voor de buis die je wilt gebruiken. Als je er een echte van wilt maken moet er isolatie omheen, de temperatuur gaat dan flink oplopen en de verbranding wordt beter. Dan wordt met name de horizontale buis roodgloeiend en vallen de gaten er al vrij snel in als gevolg van snelle corrosie. Vandaar dat alle echte rocket heaters van vuurvaste materialen zijn gemaakt.



groeten, Peter
+52° 1' 47.40", +4° 22' 57.80"

sjoerdb



Re: Rocket stove van stalen koker

11 dec 2019, 20:42

Bedankt voor deze zeer uitgebreide en duidelijke uitleg, ik ga er van allebei bouwen. Door de koker maat zullen ze best schattig blijven en is het vooral leuk om van te leren.

Mijn idee is ook om ze dan mee te kunnen nemen naar weekendje weg met de vrienden, zo kan ik de kinderen leuk vermaken

sjoerdb



Re: Rocket stove van stalen koker

17 dec 2019, 21:11

Ik zat nog even na te lezen en tekening vergelijken,

@peterberg, je schrijft 1,2,4,6 maar in je tekening zie ik 1,2,3,6..... zie ik wat verkeerd of mag de 135 mm dus 180mm zijn?

pelletpower

Re: Rocket stove van stalen koker

18 dec 2019, 08:13

En de korte j in vuurvast beton storten. Dan kan staal wegrotten, J blijft.



peterberg
Moderator

Re: Rocket stove van stalen koker

18 dec 2019, 12:41

“ sjoerdb schreef: ↑

@peterberg, je schrijft 1,2,4,6 maar in je tekening zie ik 1,2,3,6..... zie ik wat verkeerd of mag de 135 mm dus 180mm zijn?

Goed gezien, de verhoudingen zijn in de tekening anders dan wat ik in cijfers heb opgegeven. Allebei zijn correct, indien mogelijk dan heeft de kortere tunnel van de tekening de voorkeur. Komt doordat er continue (internationaal) onenigheid is over de verhoudingen, de maat van de buis wordt doorgaans niet meegenomen in de berekening. De lengte van de tunnel heeft wat meer speling, hoewel er ook mensen zijn die de zo'n ding willen bouwen door de wand van een huis heen. De feed buiten, de riser binnen lijkt heel leuk maar de tunnel wordt als gevolg daarvan te lang wat weer beperkt gecompenseerd kan worden met de lengte van de riser. De meeste mensen belanden dan weer in andere problemen.

In jouw geval: maak er gewoon eentje met de maten van de tekening en probeer hoe het werkt. Aangezien er een ruime bron van deze afval stukken is kun je een paar verschillende maken als je de smaak te pakken krijgt. En je hebt gelijk: het is een heerlijk ding om aan kinderen te laten zien. Volwassenen trouwens ook.

groeten, Peter
+52° 1' 47.40", +4° 22' 57.80"

sjoerdb

Re: Rocket stove van stalen koker

18 dec 2019, 22:47

De 1,2,4,6 versie is vandaag gelast, nog even 3 pootje eronder maken voor goeie stabiele stand. De 1,2,3,6 versie komt na de kerst vakantie wel, mooi even de tijd om deze te proberen.

Plaats reactie



10 berichten • Pagina 1 van 1

< Terug naar "Verwarming, isolatie, huiselijk energieverbruik"

Ga naar

Vindt u dit forum ook zo waardevol, overweeg dan eens te doneren en kom zo van deze vervelende reclame af! Klik op deze regel en lees hier hoe u kunt doneren

[Home](#) < [Forumoverzicht](#)

[Het team](#) [Verwijder alle forumcookies](#) Alle tijden zijn UTC+02:00

Rocket stoves

A **rocket stove** is an efficient and hot burning stove using small-diameter wood fuel. Fuel is burned in a simple combustion chamber containing an insulated vertical chimney, which ensures almost complete combustion prior to the flames reaching the cooking surface. Rocket stove designs are most often used for portable stoves for cooking but the design is also used for large fixed stoves in institutions, and to make rocket mass heaters for heating.

In field tests in India, rocket stoves used 18 to 35 percent less fuel compared to the traditional stoves and reduced fuel used 39-47 percent compared to the simple traditional open three-stone fire, as well as a large reduction in emissions.

— From [Wikipedia:Rocket stove](#)

Inhoud

Overview

Construction

On Appropedia

Featured projects

Original research

Literature review

Uses and benefits

International aid

Social enterprises

Video tutorials

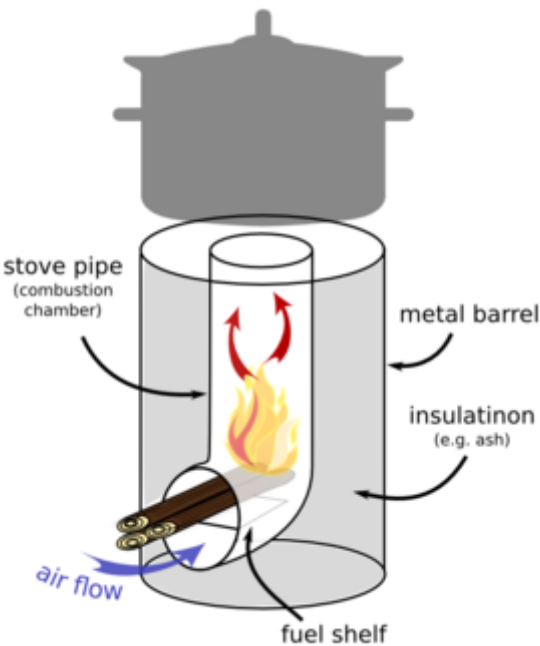
External links

References

The rocket stove is a variety of wood-burning cooking stove with a higher efficiency than other types of traditional ovens due to a better insulation and a better combustion process. They function under a similar principle as rocket stove mass heaters. Most rocket stoves are easy to build, and can be made with low-cost materials.

Overview

A rocket stove addresses air quality problems arising from the use of an open pit fire for cooking and home heating. Biomass fuels release large amounts of air pollutants when burned on traditional open pit fire, and these pollutants become concentrated in inadequately ventilated



Barrel rocket stove for outdoor cooking

homes and dwellings, generating respiratory problems to families, especially in rural areas.

Another concern with traditional wood fires is the environmental cost due to inefficiency of fuel consumption. Traditional open pit wood fires are very efficient at turning wood into energy, but inefficient at transferring the released energy into the cooking vessel. Most of the released energy in the wood is wasted heating the surrounding air rather than heating the cooking vessel. The inefficient transfer of energy requires the use of more wood, which has to be harvested from the surrounding environment, causing environmental stress.

The third drawback of traditional wood fires is the danger to children. Because open fires are located on the floor of the dwelling, children can easily fall into the fire.

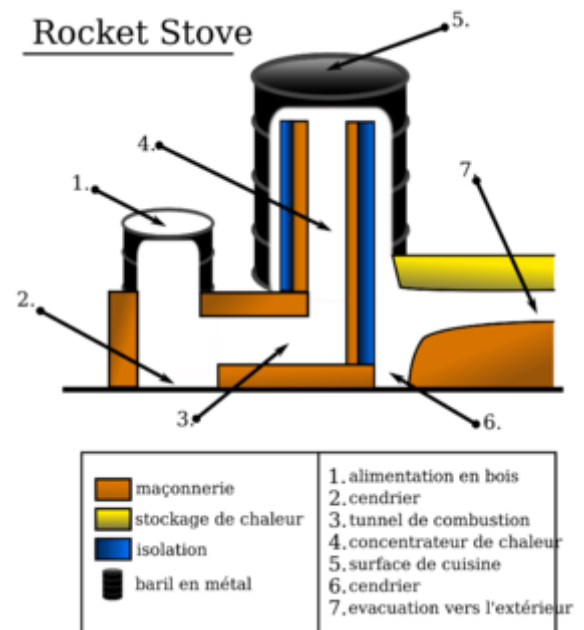
The rocket stove operates roughly twice as efficiently, and substantially more cleanly, than the open fire cooking methods still used in many areas of the world. Furthermore, the design of the stove requires small diameter lengths of wood, which can generally be satisfied with small branches. As such, sufficient fuel for cooking tasks can be gathered in less time, without the benefit of tools, and ideally without the destruction of forested areas.

Because these qualities improve local air quality, and discourage deforestation, the rocket stove has attracted the attention of a number of appropriate technology concerns, which have deployed it in numerous third-world locales (notably, the Rwandan refugee camps). This attention has resulted in a number of adaptations intended to improve convenience and safety, and thus the size of the target audience. The Justa Stove, for example, is a cousin of the rocket stove adapted for indoor use and family cooking needs.

Construction

A rocket stove is a simple mechanism mostly made of the following elements:

- Chimney: this can be made out of a metal box -- such as a 5-gallon tin can-- or pipe standing vertically to support the cooking vessel.
- Fuel magazine: a short length of steel or ceramic pipe fitted horizontally into the base of a chimney.
- Fuel shelf: a flat plate to hold the fuel clear of the bottom of the magazine to allow air to flow underneath.
- Heat exchanger: a tubular metal shield that forces hot gases from the chimney to pass over the sides of the cooking vessel.



Some of the principles for building a rocket stove are:^[1]

- Insulating every element in contact with the fire and hearth.
- Drive the flow of combustion gasses around the edge of the cooking pot.
- A good air draft into the fire to increase the air flow speed.
- Design the stove so that the pot comes as close to the fire as possible.
- Consider the use of metal pots for cooking.
- Insulation around the fire

Metering the fuel The most important factor, metering the fuel, requires only the burning portion of the wood to be heated. Fully burned biomass fuel produces less smoke and emissions. The main way to improve the fuel efficiency of rocket stoves is to improve the heat transfer from the fire to the cooking vessel.

Most importantly, the hot air and gas released from the fire must contact the cooking vessel over the largest possible surface area. This is accomplished through the use of a pot skirt that creates a narrow channel forcing hot air and gas to flow along the bottom and sides of the cooking vessel. Heat transfer can also be increased by using wide pots. Increasing the speed of the hot gases that flow around the pot can also improve heat transfer.

On Appropedia

Featured projects



The Rancho Mastatal earthen rocket oven is a regular earthen oven using principles from the rocket stove.



The Forest biochar rocket stove was designed to provide a source of biochar for small scale growers.



The CCAT rocket stove is a demonstrative rocket stove prototype built at Humboldt State University.

Original research

- CCAT Rocket Stove operations manual

Literature review

Uses and benefits

Wood, charcoal, coal and other biomass are used by about 2.4 billion people worldwide as their primary cooking fuel. In 'developing' countries, these fuels are often burned in open fires or poorly functioning stoves^[2]. Several factors from these cooking processes have been shown to be damaging to human health, especially attributing to respiratory related illness. Indoor smoke given off by these fuels contains constituents including small soot or dust particles that are able to penetrate deep into the lungs. Every year, indoor air pollution is responsible for the death of 1.6 million people -one death every 20 seconds ^[3].

Women and children being the ones most involved or exposed to this environment are worst affected. Charcoal production has been associated with environmental issues such as deforestation which further increases other environmental and social vulnerabilities. The trees that grow most slowly; hardwood trees make the highest quality charcoal, furthering the impact. Wood or wood charcoal is the primary cooking fuel in Haiti, and this dependence has contributed to only 2% of Haiti's forests remaining. In places like Haiti, the limited availability of wood means that finding gathering fuel consumes time and energy, causes more severe weather, increases vulnerability, reducing capacity, costs money and further stresses an already depleted resource. In some places such as in Mali, due to changes in the energy and economic sectors a pronounced shift from fuel wood to charcoal is happening which is raising concerns for the local resources.

The main justifications for rocket stoves are economical, social, and environmental. Stove programs can produce economic benefits, saving time and money for the users. In urban areas where people purchase biomass fuel, the payback time for the cost of a rocket stove is short, thus saving on the cost of fuel.

Rocket stoves can help reduce the over-harvesting of trees. Improved indoor air quality and fuel efficiency have social and health benefits, especially for women and children. In order to reduce indoor air pollution, rocket stoves must improve combustion of the wood fuel, which means reducing the amount of smoke and harmful emissions produced during the burning process. The key to efficient combustion is to burn wood at a high temperature, and there are several ways to achieve this:

Rocket stoves are insulated and lifted off of the floor. This reduces the danger of children burning themselves, which is an important improvement over traditional open pit fires.

International aid

- Kenya: Rocket stoves by PSDA with support from GIZ.^[4]
- Guatemala: Guatemala Stove Project by Aprovecho Research Center ^[3] (<https://guatemalastoveproject.org/aprovecho-research-centre-newsletter/>)

Social enterprises

- The Paradigm Project ^[4] (<https://guatemalastoveproject.org/>).
- Justa stoves ^[5] (<https://www.stovesonline.co.uk/>).

Video tutorials

- How to make a Rocket Box Stove (<https://www.youtube.com/watch?v=hkFqpkV3fF4>) - AIDG
- How does a Rocket Oven Work? (<https://www.youtube.com/watch?v=DhMeg3VUFWs>) - By Paul Wheaton from permies.com (<http://permies.com>)

External links

- Category:Rocket stoves
- Wikipedia:Rocket stove
- Poster on how to make a Rocket Stove (<https://web.archive.org/web/20190916094429/http://www.fourthway.co.uk:80/posters/pages/fuelsavingstove.html>)
- Videos, pictures, and diagrams (<http://www.richsoil.com/rocket-stove-mass-heater.jsp>) on how to make a *rocket stove mass heater*
- Clean Cooking Catalog^[6] (<http://catalog.cleancookstoves.org/pages/about>)

References

1. Still, Dean, and Larry Winiarski. "Increasing fuel efficiency and reducing harmful emissions in traditional cooking stoves." Boiling Point 47 (2001): 36-39. ^[1] (<http://www.stoves.bioenergylists.org/stovesdoc/Still/BoilingPoint47/BP47Still.pdf>)
2. Smith, K.R. "Health impacts of household fuelwood use in developing countries" (<http://www.fao.org/docrep/009/a0789e/a0789e09.htm>) *Food and Agriculture Organization of the United Nations*
3. World Health Organization. "Indoor air pollution and health" (<http://www.who.int/mediacentre/factsheets/fs292/en/>)
4. PSDA-GIZ Rocket Stove Manual ^[2] (https://energypedia.info/images/8/8d/En-GIZ_Kenya_brick-rocket-stove-builder%27s-manual-2011.pdf)

Overgenomen van "https://www.appropedia.org/w/index.php?title=Rocket_stoves&oldid=469021"

Deze pagina is voor het laatst bewerkt op 5 feb 2021 om 13:00 door [Felipe Schenone](#). Gebaseerd op werk van [Ethan](#), [Appropedia-gebruikers](#) [Dead links script](#), [Emilio](#) en [NF](#) en [anderen](#).

De inhoud is beschikbaar onder de [CC-BY-SA](#) tenzij anders aangegeven.



Science • Energy

Rocket Stoves: Tips for Designing Your Own

By Heidi Hill Updated August 02, 2017

SIMPLE SOLUTION: Rocket stoves can be made into any size to accomodate any need. (Photo: [fishermansdaughter/Flickr](#)).



They may sound high-tech, but rocket stoves (named for the way air moves through them) are anything but.

Designed to increase fuel efficiency without increasing harmful emissions, rocket stoves are helping people become more self-sufficient, slowing climate change, and saving lives in developing countries where fuelwood is scarce and traditional open fires are polluting indoor air.

They are ideal not just because of their social and environmental benefits, but also for

Treehugger uses cookies to provide you with a great user experience. By using Treehugger, you accept our [use of cookies](#).

Sustainability for All.

What Is a Rocket Stove?

The rocket stove is a wood-burning outdoor cooking stove that was developed by Dr. Larry Winiarski in the 1980s as a safe, effective, environmentally conscious alternative to open fires for impoverished people in developing countries.

Compared with traditional open fires (also called “three-stone fires”), rocket stoves can be healthier and more efficient.

They reduce smoke and harmful emissions, use less fuel wood, and increase the amount of energy from the wood that is turned into heat energy.

In countries like the Democratic Republic of the Congo, energy-efficient rocket stoves reduce air pollution, allow for more efficient cooking, provide employment opportunities, prevent widespread deforestation, and help refugees and internally displaced people cook meals when fuel is not readily available or is not safely procured.

Beyond that, rocket stoves can be an inexpensive means of slowing climate change.

According to the [Aprovecho Research Center](#), which pioneered the use of rocket stoves, “It takes only about three ARC rocket stoves to offset one average American’s driving habits for one year ... or just 13 stoves to offset an American’s entire annual footprint.”

A basic rocket stove consists of just a few components:

- An insulated rocket elbow, formed of a horizontal fuel chamber that fits into a vertical combustion chamber (also referred to as a “chimney”)
- A stove body that surrounds the elbow, made of sheet metal or some other inexpensive material, with a small opening
- A fuel grate, placed inside the fuel chamber, on which the fuel wood rests
- A pot skirt, a sheet metal shield that surrounds the cooking vessel, creating a gap, to ensure that more heat from the flue gases enters the vessel

How Does It Work?

In open fires that are not carefully maintained, only a small percentage of the heat energy released from the burning wood makes it into the cook pot.

Treehugger uses cookies to provide you with a great user experience. By using Treehugger, you accept our [use of cookies](#).

Sustainability for All.



With a rocket stove, only the tips of the fuel wood are burned, eliminating that waste (and, in an added benefit, eliminating smoke).

Rocket stoves can use most any dry plant matter, not just wood — leaves, twigs, and brush will work as well.

Fresh air enters the fuel chamber from beneath the burning wood resting on the grate, allowing the air to be preheated before it enters the combustion chamber, which in turn leads to cleaner combustion.

The small fuel entry not only demands less fuel wood, but also limits the amount of cold air that can get in.

The combustion itself is confined to a small, insulated space, so most of the energy in the wood is converted to heat for cooking.

The cook pot sits directly on top of the combustion chamber, so the hot gases contact it immediately after combustion, reducing smoke.

The pot skirt that surrounds the vessel further improves efficiency by increasing the temperature of the flame that contacts the pot, and by directing the gases to scrape the sides of the pot as well as the bottom, increasing heat transfer.

Treehugger uses cookies to provide you with a great user experience. By using Treehugger, you accept our [use of cookies](#).

Sustainability for All.

couple of hours with a few cheaply purchased or found/recycled materials: sheet metal, refractory bricks, vermiculite and cement (to secure the combustion chamber in the stove body), and steel poles for pot supports.

Want a rocket stove but aren't keen on building one yourself? Don't worry; they can be purchased.

If you do build your own, be sure to test it before using it; for instance, with a water-boiling test.

Build a rocket stove



Additional resources:

Check out [how to build a rocket stove](https://sustainablog.org/how-to-build-a-rocket-stove) on sustainablog.org

[Design Principles for Wood Burning Cook Stoves, including In Field Water Boiling Test](#) (pdf)

[CCAT Rocket Stove](#)

[Larry Winiarski's Rocket Stove Principles](#)

[StoveTec Retail Store](#)

Treehugger uses cookies to provide you with a great user experience. By using Treehugger, you accept our [use of cookies](#).

Sustainability for All.



Start the discussion...

LOG IN WITH

OR SIGN UP WITH DISQUS

Name

Be the first to comment.

Subscribe **Add Disqus to your site****Add Disqus****Add** **Do Not Sell My Data**



DIY
Build a Mini Rocket Stove From Upcycled Tin Cans

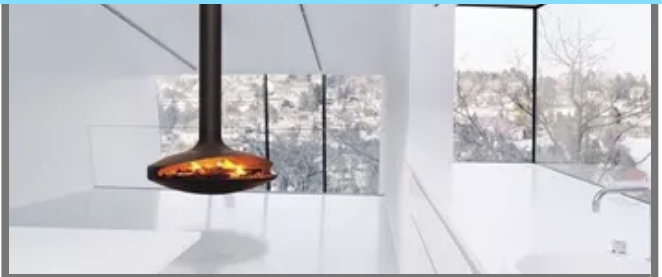


Technology
The Beautiful & Efficient Enki Biomass Stove Creates Biochar as It Cooks Your Dinner

Sustainability for All.

**Technology**

Small Rocket Stove Makes for an Efficient Offgrid or Camping Stove

**Green Design**

Which Fireplace Is Best for the Environment? Wood, Gas, Electric, Pellet or Alcohol?

**DIY**

How to Make Your Own Rocket Stove With a Few Cinder Blocks

**Renewable Energy**

Rocket Mass Stove Slashes Fuel Use, Compared to Conventional Wood Stove (Video)

Sustainability for All.

**Science**

Rocket Mass Stove Burns Tiny Amounts of Wood, Heats for Well Over 12 Hours

**DIY**

Build an Ultra-Efficient DIY Wood Stove for Backpacking

**Home**

How to Choose an Eco-Friendly Fireplace

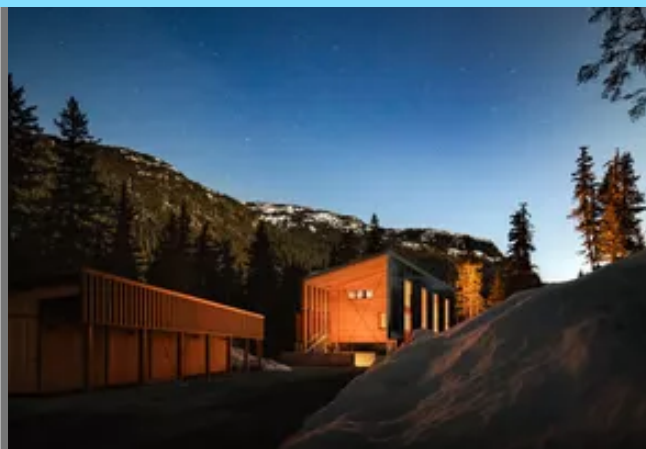
**Technology**

5 Low-Tech Innovations Making a Difference in the Developing World

Sustainability for All.

**Renewable Energy**

What Are Solar Ovens – and Why Are They Heating Up?

**Home & Design**

Wooden Prefab Cabin in the Forest is Off-Grid and Passive House

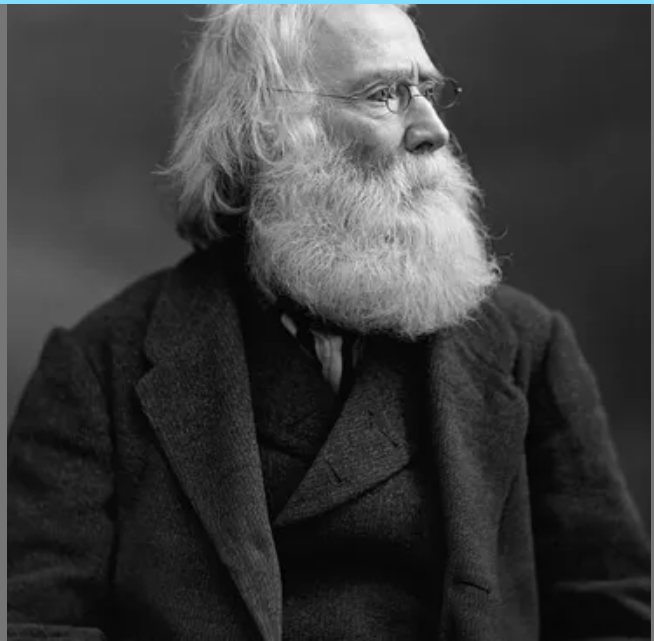
**Energy**

How to Use a Wood Stove Without Burning Down the House

**Science**

Breathe Easy: Clean-Burning Wood Stoves Are on the Way

Sustainability for All.



Architecture

Why Did People Build Houses "That Just Leak Heat Out"?



Pollution

What Is Air Pollution?

Treehugger

Sustainability for All.

Sign Up for Our Newsletter

Email Address

Follow Us



Environment

Business & Policy

Home & Garden

News

Treehugger uses cookies to provide you with a great user experience. By using Treehugger, you accept our [use of cookies](#).

Sustainability for All.



Treehugger is part of the Dotdash publishing family.

Treehugger uses cookies to provide you with a great user experience. By using Treehugger, you accept our [use of cookies](#).