



Advances in Bituminous Geomembrane Welding Methodology

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GEOANZ #1

ADVANCES IN GEOSYNTHETICS
7-9 JUNE 2022 | BRISBANE CONVENTION & EXHIBITION CENTRE



S U M M A R Y

Bituminous Geomembrane Components

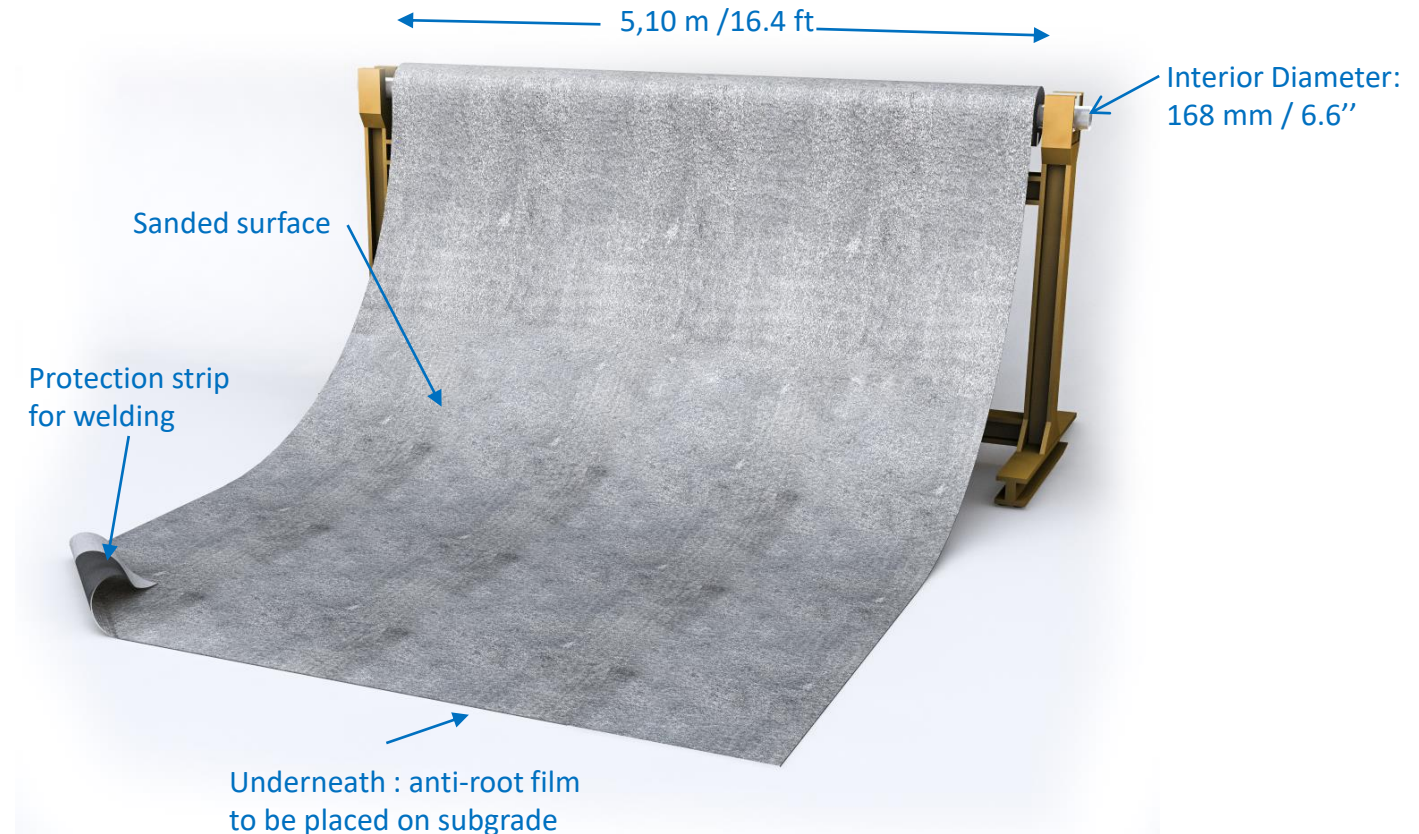
Material Properties

Torch Welding

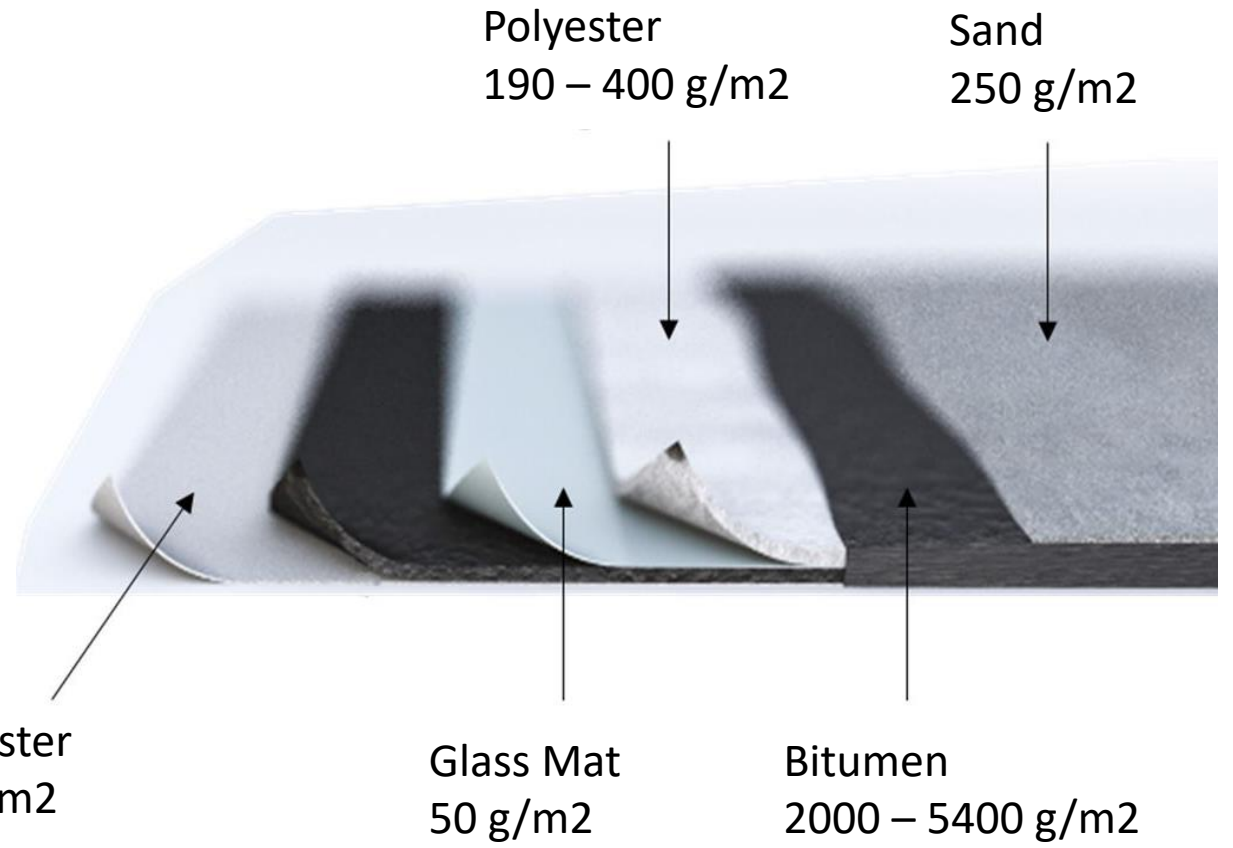
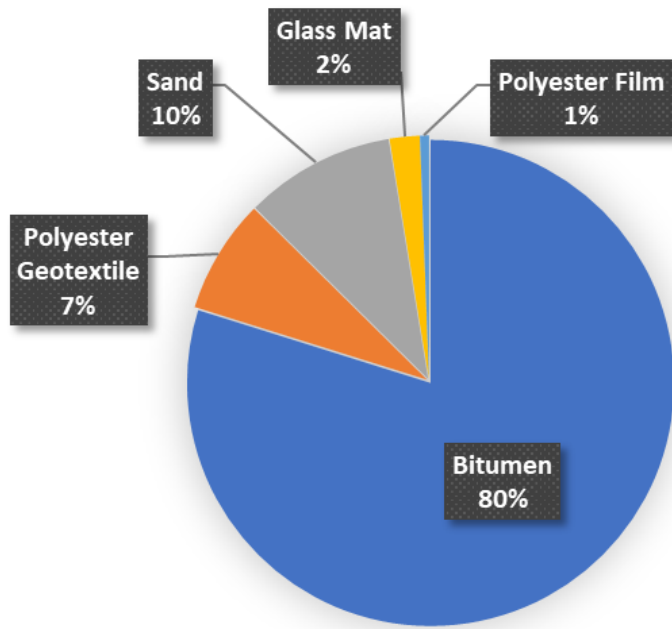
Hot Air Welding

Thermodynamics of Hot Air Welding

Bituminous Geomembrane



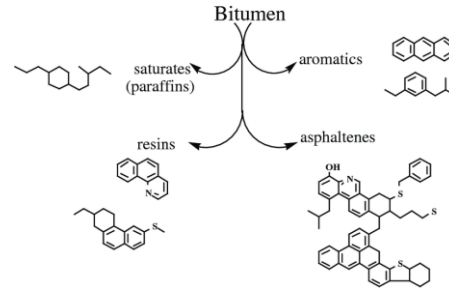
Materials By Mass



Material Properties

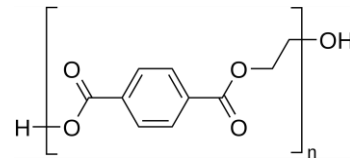
- **Bitumen (simplified)**

- Melting Temp $\sim 160^{\circ}\text{C}$
- Boiling Temp $\sim 525^{\circ}\text{C}$
- Solid Specific Heat $\sim 2.1\text{kJ/kg C}$
- Liquid Specific Heat $\sim 2.9\text{kJ/kg C}$



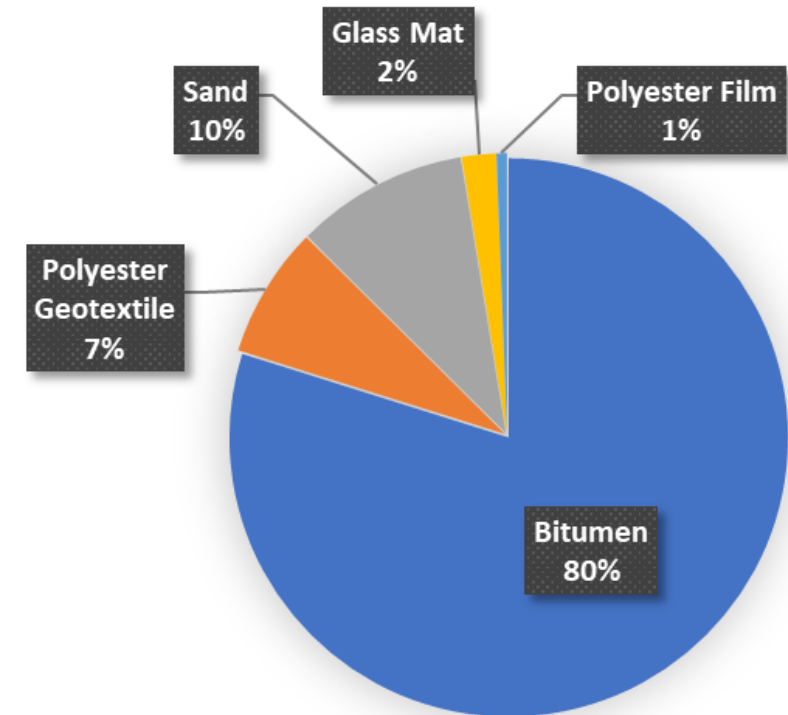
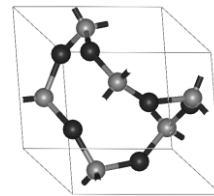
- **Polyester**

- Melting Temp $\sim 260^{\circ}\text{C}$
- Boiling / Decomposition temp $\sim 350^{\circ}\text{C}$



- **Silica Sand / Glass Mat (SiO_2)**

- Melting Temp $\sim 1,710^{\circ}\text{C}$
- Boiling Point $\sim 2,230^{\circ}\text{C}$



Torch Welding



Propane (LNG) + Oxygen → Carbon Dioxide + Water + Heat

Heat Output: (~ 49 MJ/kg)

2.15% to 9.6% LPG/air mixture required for combustion

Optimal mixture is 4% LPG/air

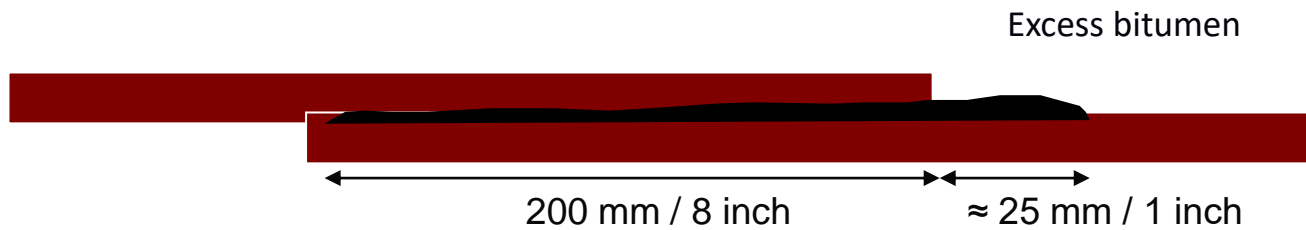
Blue flame indicates complete combustion at ~1,980C



Blue Flame - ~1,980C

Torch Welding

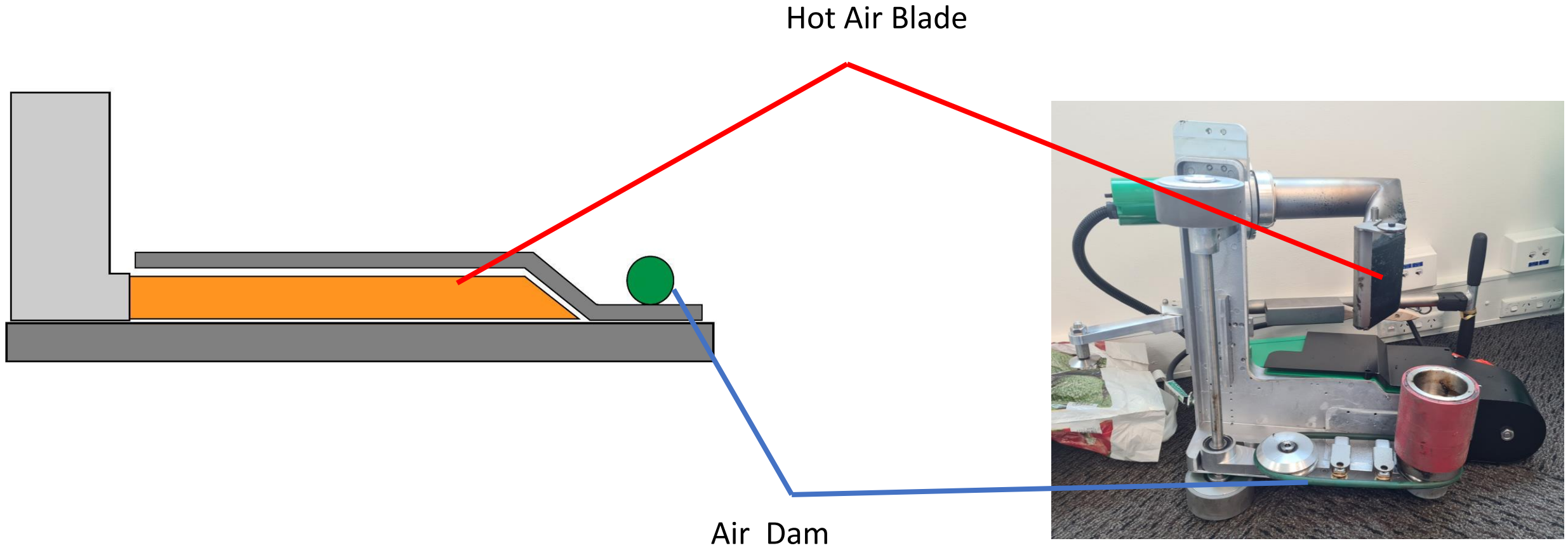
- Fast and Efficient
- Versatile
- Can be Mechanized
- Usage rate : $\sim 80\text{g/Lm}$
- Heat Output: ($\sim 49 \text{ MJ/kg}$)
- = 3.9MJ/Lm



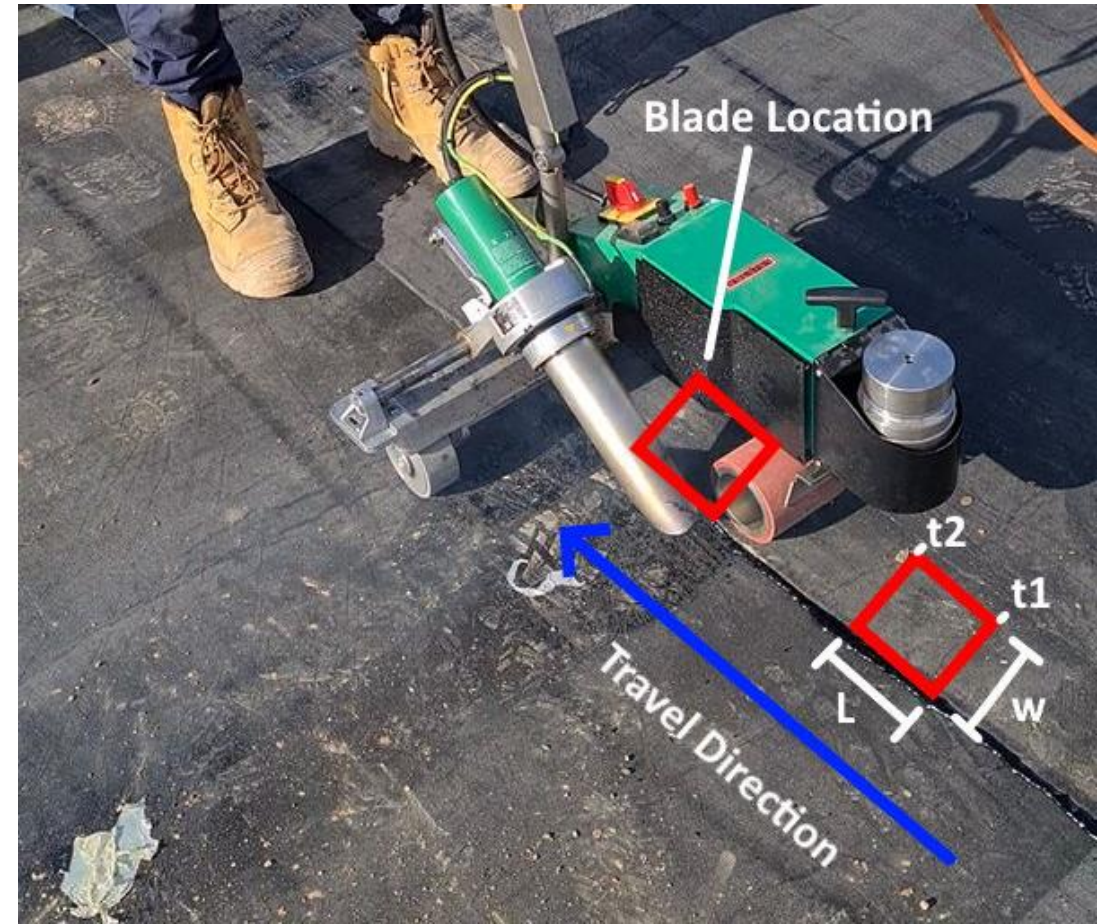
Torch Welding Innovation



Hot Air Welding



Hot Air Welding



Conservation of Energy

T1, E1(joules)

T1, E1(joules)

Heat Energy Applied

T2, E2 (joules)

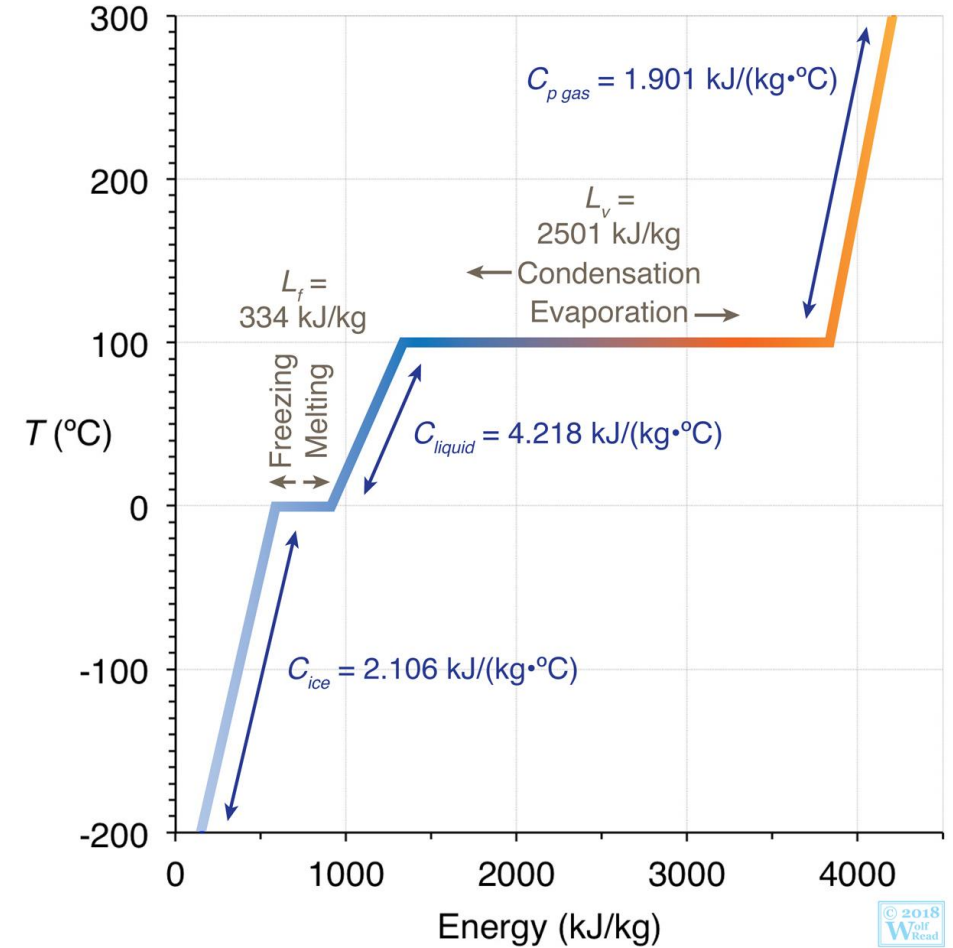
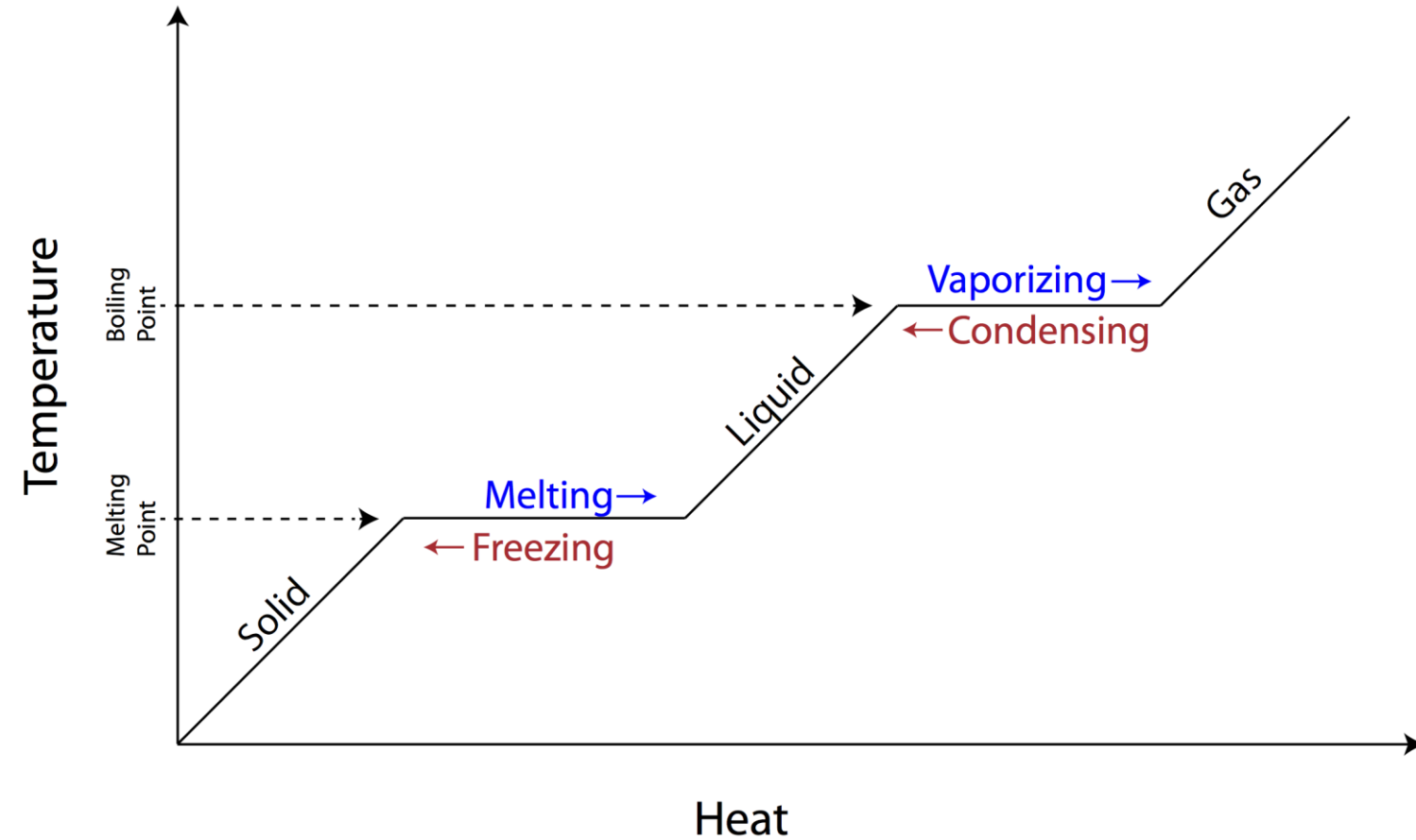
$$E1 + \text{Heat Energy Applied} = E2$$

$$\text{Heat Energy Applied} = \text{Welder Power} - \text{Losses}$$

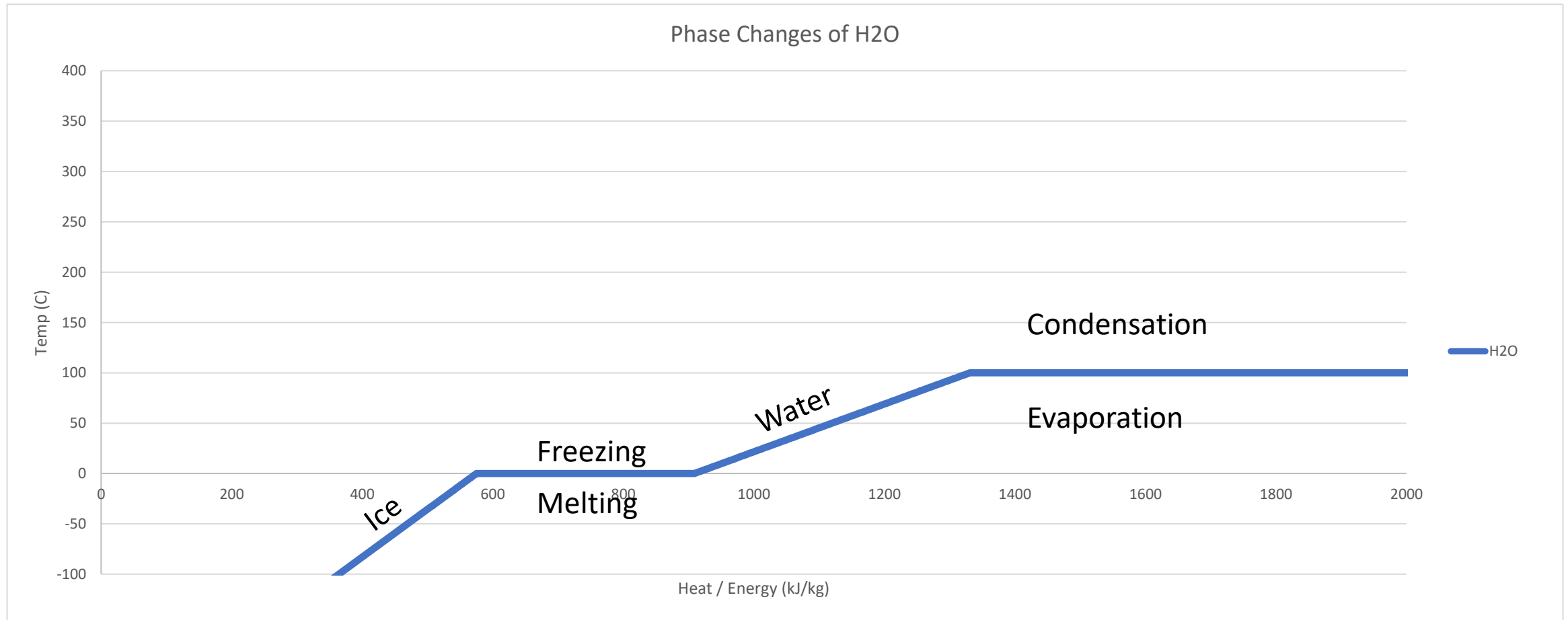
$$\text{Heat Energy Applied} = \text{Welder Power} * \text{Efficiency Factor}$$

?

Phase Diagram Water

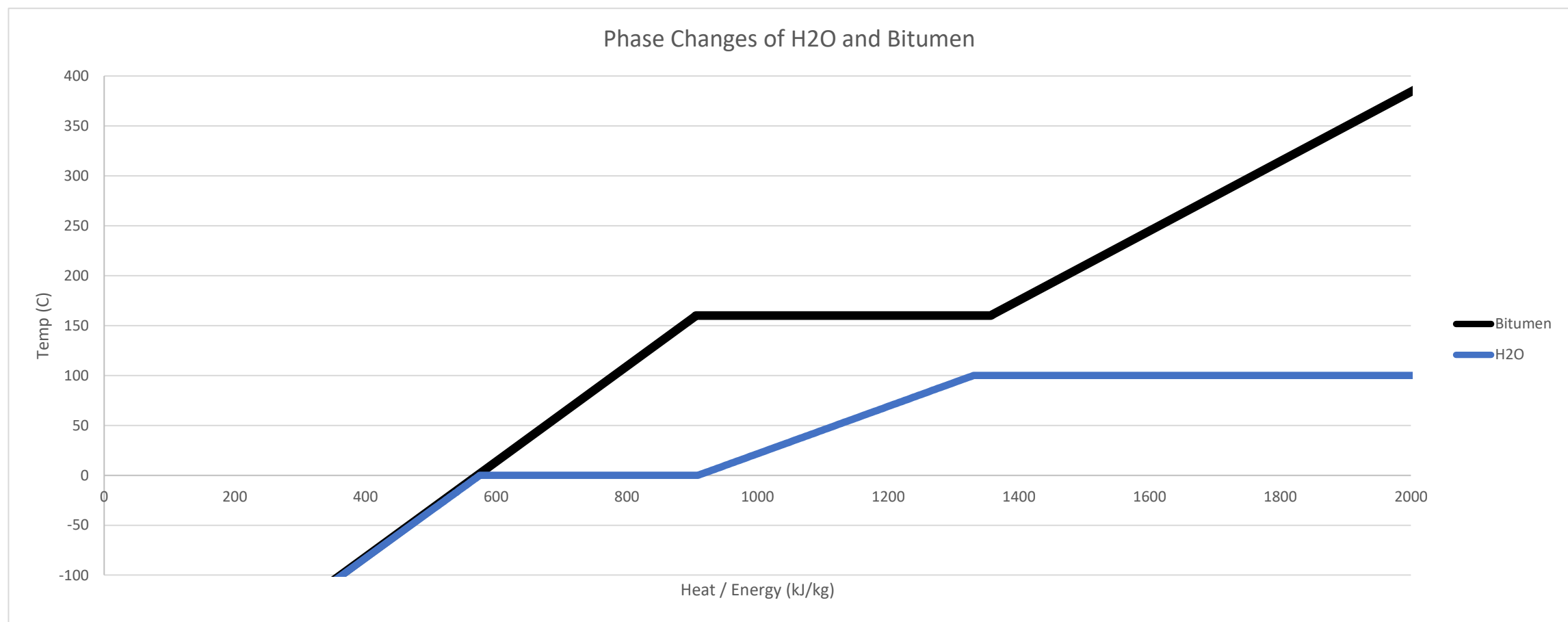


Phase Changes of H₂O

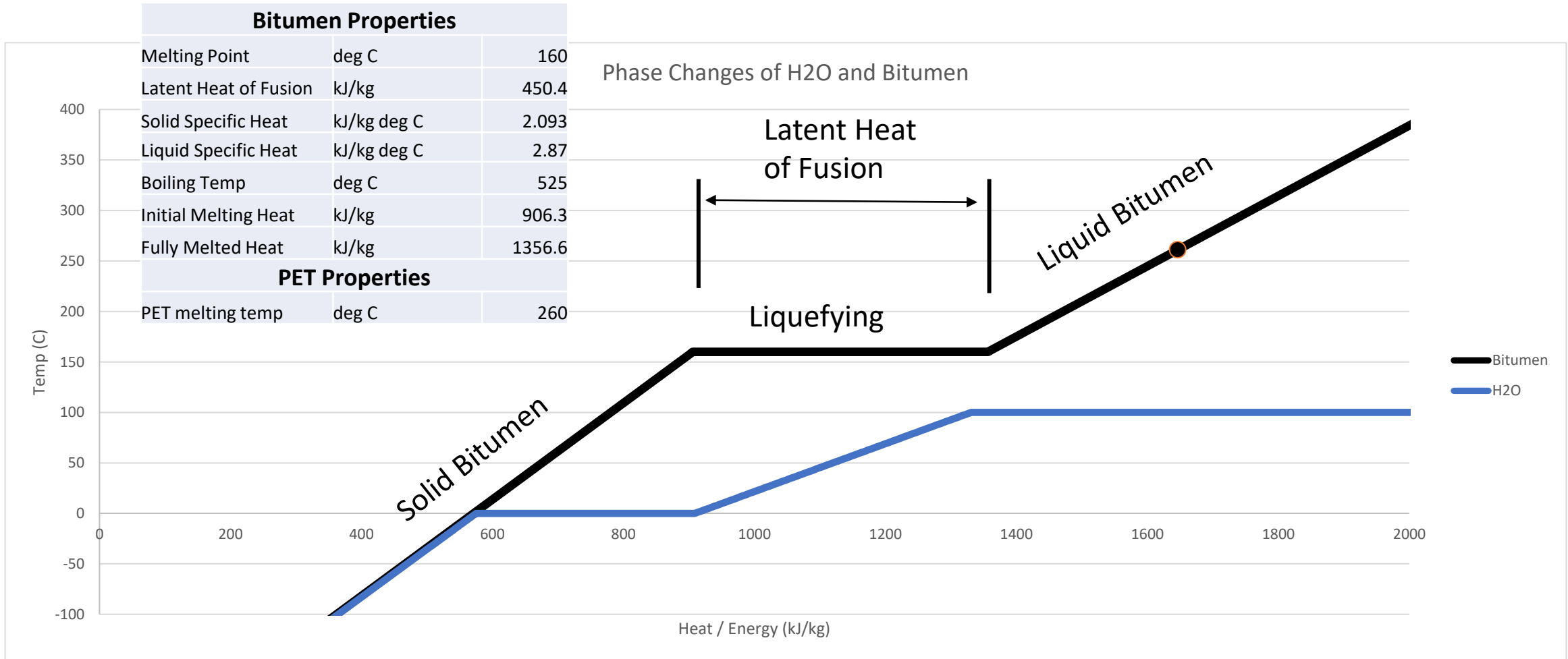




Phase Changes of H2O and Bitumen

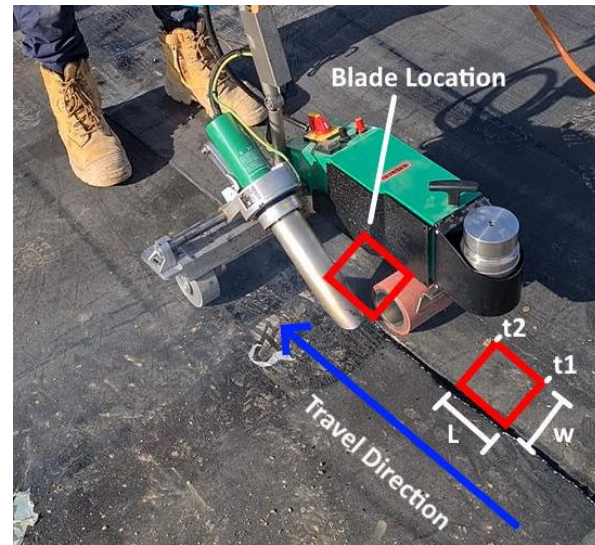


Phase Changes of H2O



Hot Air Welding Thermodynamic Model

Bitumen Properties		
Melting Point	deg C	160
Latent Heat of Fusion	kJ/kg	450.4
Solid Specific Heat	kJ/kg deg C	2.093
Liquid Specific Heat	kJ/kg deg C	2.87
Boiling Temp	deg C	525
Initial Melting Heat	kJ/kg	906.3
Fully Melted Heat	kJ/kg	1356.6
PET Properties		
PET melting temp	deg C	260
Welder Properties		
Welder Power	kW	6.7
Welder Efficiency	%	75
Blade Length	m	0.12

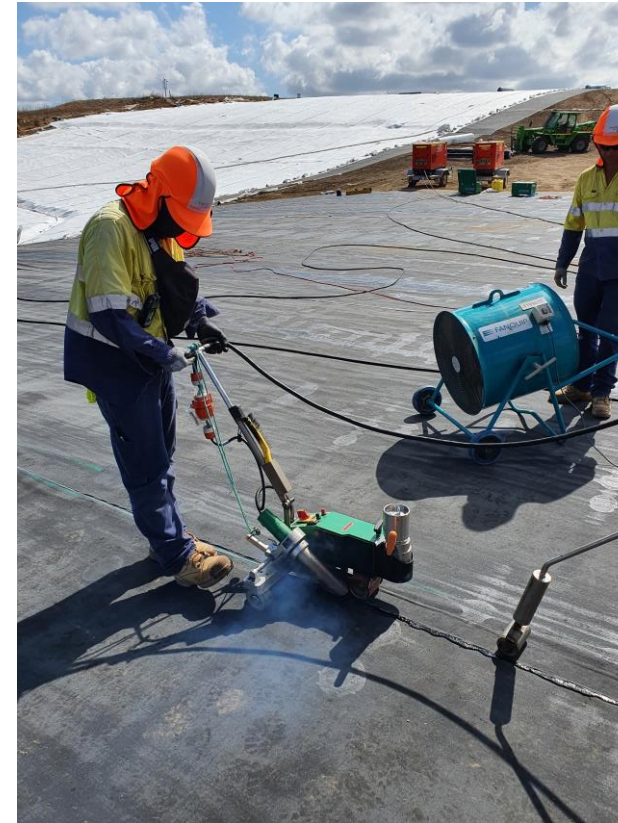


Variable Inputs		
Speed	m/min	1.48
time of contact	s	4.864865
Blade Width	m	0.12
Heat Applied	kJ	24.4
Heat Applied	kJ/m ²	1697.6
Heat Applied	MJ/Lm	0.20
Welded Bitumen Mass	kg	2
Heat Delivered	kJ/kg	848.8
Initial Liner Temp	deg C	10
Initial Liner Heat	kJ/kg	592.3
Total Heat	kJ/kg	1441.1
Outputs		
Target Heat	kJ/kg	1356.6
Heat to PET softening	kJ/kg	1529.7
Target Delivered Heat	kJ/kg	764.3
Min Delivered Heat	kJ/kg	314.0
Target Speed	m/min	1.64
Max Speed	m/min	4.00
Min Speed (PET risk)	m/min	0.84

50C temperature ranges are typical



NSW, Winter, No Sun
0-10C

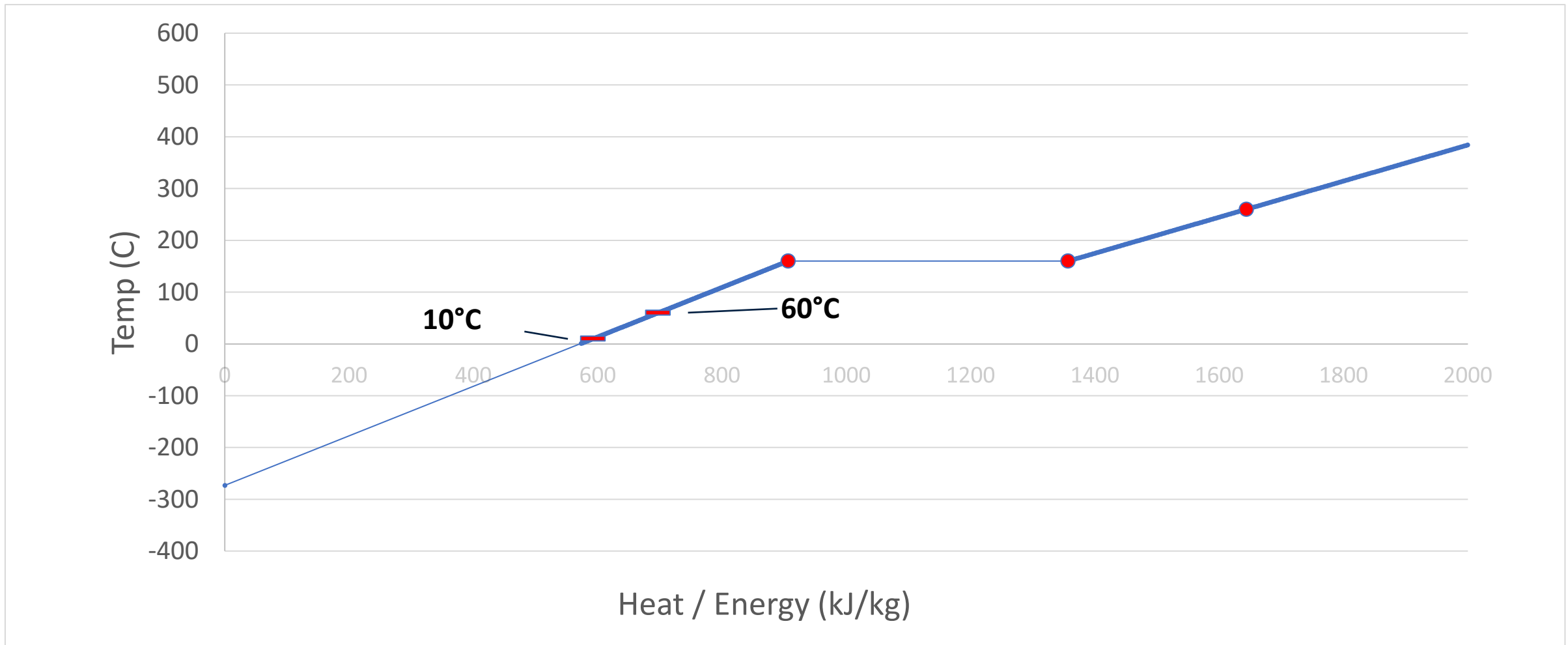


QLD, Summer, Full Sun
60C+

10 deg C versus 60 deg C

Variable Inputs				Variable Inputs		
Speed	m/min	1.48		Speed	m/min	1.48
time of contact	s	4.86		time of contact	s	4.86
Blade Width	m	0.12		Blade Width	m	0.12
Heat Applied	kJ	24.4		Heat Applied	kJ	24.4
Heat Applied	kJ/m ²	1697.6		Heat Applied	kJ/m ²	1697.6
Heat Applied	MJ/Lm	0.20		Heat Applied	MJ/Lm	0.20
Welded Bitumen Mass	kg	2		Welded Bitumen Mass	kg	2
Heat Delivered	kJ/kg	848.8		Heat Delivered	kJ/kg	848.8
Initial Liner Temp	deg C	10	➔	Initial Liner Temp	deg C	60
Initial Liner Heat	kJ/kg	592.3		Initial Liner Heat	kJ/kg	697.0
Total Heat	kJ/kg	1441.1		Total Heat	kJ/kg	1545.8
Outputs				Outputs		
Target Heat	kJ/kg	1356.6		Target Heat	kJ/kg	1356.6
Heat to PET softening	kJ/kg	1529.7		Heat to PET softening	kJ/kg	1529.7
Target Delivered Heat	kJ/kg	764.3		Target Delivered Heat	kJ/kg	659.7
Min Delivered Heat	kJ/kg	314.0		Min Delivered Heat	kJ/kg	209.3
Target Speed	m/min	1.64		Target Speed	m/min	1.90
Max Speed	m/min	4.00		Max Speed	m/min	6.00
Min Speed (PET risk)	m/min	0.84		Min Speed (PET risk)	m/min	0.93

10 deg C versus 60 deg C



Size Isn't Everything

Variable Inputs			Variable Inputs		
Speed	m/min	1.48	Speed	m/min	1.48
time of contact	s	4.864864865	time of contact	s	4.864864865
Blade Width	m	0.12	Blade Width	m	0.2
Heat Applied	kJ	24.4	Heat Applied	kJ	24.4
Heat Applied	kJ/m ²	1697.6	Heat Applied	kJ/m ²	1018.6
Heat Applied	MJ/Lm	0.20	Heat Applied	MJ/Lm	0.20
Welded Bitumen Mass	kg	2	Welded Bitumen Mass	kg	2
Heat Delivered	kJ/kg	848.8	Heat Delivered	kJ/kg	509.3
Initial Liner Temp	deg C	50	Initial Liner Temp	deg C	50
Initial Liner Heat	kJ/kg	676.0	Initial Liner Heat	kJ/kg	676.0
Total Heat	kJ/kg	1524.9	Total Heat	kJ/kg	1185.3
Outputs			Outputs		
Target Heat	kJ/kg	1356.6	Target Heat	kJ/kg	1356.6
Heat to PET softening	kJ/kg	1529.7	Heat to PET softening	kJ/kg	1529.7
Target Delivered Heat	kJ/kg	680.6	Target Delivered Heat	kJ/kg	680.6
Min Delivered Heat	kJ/kg	230.2	Min Delivered Heat	kJ/kg	230.2
Target Speed	m/min	1.85	Target Speed	m/min	1.11
Max Speed	m/min	5.46	Max Speed	m/min	3.27
Min Speed (PET risk)	m/min	0.91	Min Speed (PET risk)	m/min	0.54



Finding the Goldilocks Scenario

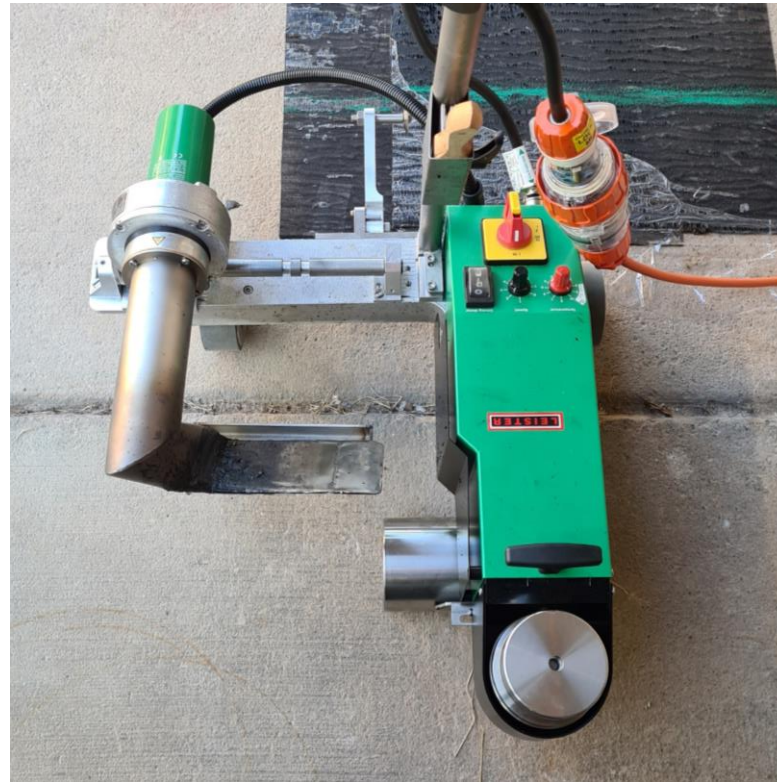
Variable Inputs			Variable Inputs		
Speed	m/min	1.48	Speed	m/min	1.48
time of contact	s	4.864864865	time of contact	s	4.864864865
Blade Width	m	0.12	Blade Width	m	0.15
Heat Applied	kJ	24.4	Heat Applied	kJ	24.4
Heat Applied	kJ/m ²	1697.6	Heat Applied	kJ/m ²	1358.1
Heat Applied	MJ/Lm	0.20	Heat Applied	MJ/Lm	0.20
Welded Bitumen Mass	kg	2	Welded Bitumen Mass	kg	2
Heat Delivered	kJ/kg	848.8	Heat Delivered	kJ/kg	679.1
Initial Liner Temp	deg C	50	Initial Liner Temp	deg C	50
Initial Liner Heat	kJ/kg	676.0	Initial Liner Heat	kJ/kg	676.0
Total Heat	kJ/kg	1524.9	Total Heat	kJ/kg	1355.1
Outputs			Outputs		
Target Heat	kJ/kg	1356.6	Target Heat	kJ/kg	1356.6
Heat to PET softening	kJ/kg	1529.7	Heat to PET softening	kJ/kg	1529.7
Target Delivered Heat	kJ/kg	680.6	Target Delivered Heat	kJ/kg	680.6
Min Delivered Heat	kJ/kg	230.2	Min Delivered Heat	kJ/kg	230.2
Target Speed	m/min	1.85	Target Speed	m/min	1.48
Max Speed	m/min	5.46	Max Speed	m/min	4.37
Min Speed (PET risk)	m/min	0.84	Min Speed (PET risk)	m/min	0.72



Testing Continues



120mm



150mm





Thank You

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