2016

End-of-life recycling options for glass fibre reinforced polymers

Hall, S.

Hall. S. (2016) 'End-of-life recycling options for glass fibre reinforced polymers', The Plymouth Student Scientist, 9(2), p. 68-94.
http://hdl.handle.net/10026.1/14129

The Plymouth Student Scientist
University of Plymouth

Appendices

Appendix A: Stacking Sequence Determination

Polishing Procedure

1. In order to apply pressure to the specimen when polishing it is first necessary to polish the top surface to create a flat surface.
2. Once a flat surface has been created, it is necessary to mark the top ‘T’.
3. Apply appropriate paper to the platen.
4. Run polishing cycle with the relevant parameters.
5. Check polished surface, if happy, dry and place in the ultrasonic bath for 5 minute to remove any residual dust particles which may scratch the surface.
6. Rinse ultrasonic bath cup and repeat steps 3-5 until desired surface finish has been achieved.

Polishing Sequence

Table 1 - Polishing Sequence

Paper/ Surface	***Duration (min)***	***Force (N)***	***Platen Speed (RPM)***	***Head Speed (RPM)***	***Direction***
P320 Grit (46µm)	2	20	200	50	Complimentary
P500 Grit (30µm)	2	20	200	50	Complimentary
P800 Grit (22µm)	2	20	200	50	Complimentary
P1200 Grit (15µm)	2	25	200	50	Complimentary
P2500 Grit (8µm)	5	25	200	50	Complimentary
6µm Spray	5	35	250	50	Contradictory
1µm Spray	5	35	250	50	Contradictory
Colloidal Spray	2	35	250	50	Contradictory

Appendix B: Fibre Recovery

Experimental Procedure

1. Set furnace to desired test temperature.
2. Record time it takes to reach desired temperature.
3. Place specimens within furnace and note their configuration.
4. Remove specimens after specified burn-off time and allow to cool.
5. Record room conditions (temperature, humidity and pressure).
6. ≈ 5 minutes after removal, weigh specimens using the Avery-Berkel WA205 Analytical Balance scales and record.
7. Place the specimen back into the furnace, repeating steps 3-7 until constant mass is achieved.
8. Turn off furnace.
9. Record total burn-off time.
10. Record all energy consumption recordings:
    a. Furnace run time
    b. Minimum energy usage (W)
    c. Maximum energy usage (W)
    d. $KgCO_2$
    e. kWh
    f. Tariff (£/hour)
    g. Cost (£)

Appendix C: Experimental Specimen Sizes

Table 2 - Experimental Specimen Sizes

Specimen	*Length (m)*	*Width (m)*	*Weight (kg)*	*Area (m^2)*	*Thickness (m)*	*Vf*
EXP 1	0.02768	0.01916	0.00899	0.000530	0.00861	0.63
EXP 3	0.02800	0.01936	0.00918	0.000542	0.00862	0.63

Appendix D: Recovered Fibres

Figure 1 - Specimen 1H Recovered Fibres

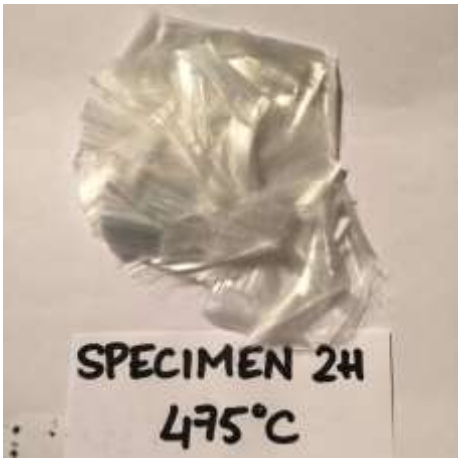


Figure 2 - Specimen 2H Recovered Fibres

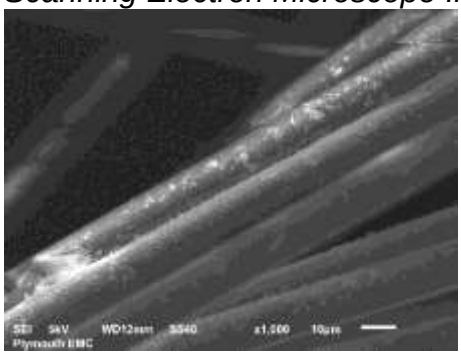
Figure 3 - Specimen 3H Recovered Fibres

Figure 4 - Specimen 4H Recovered Fibres

Figure 5 - Specimen 5H Recovered Fibres

Figure 6 - Specimen 6H Recovered Fibres

Scanning Electron Microscope Images



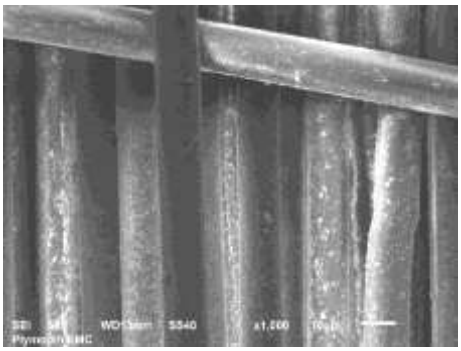
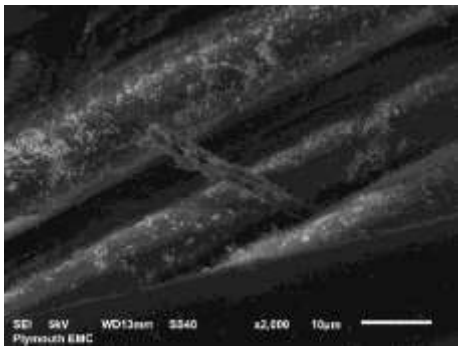


Figure 7 - Recovered Fibres (400°C) (1) **Figure 8** - Recovered Fibres (400°C) (2)



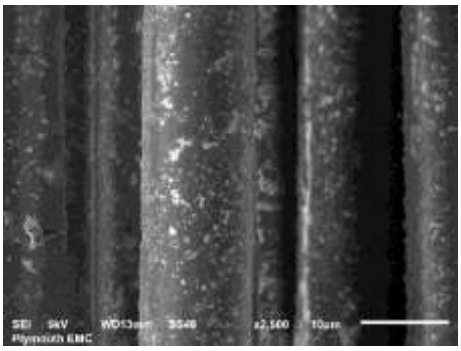
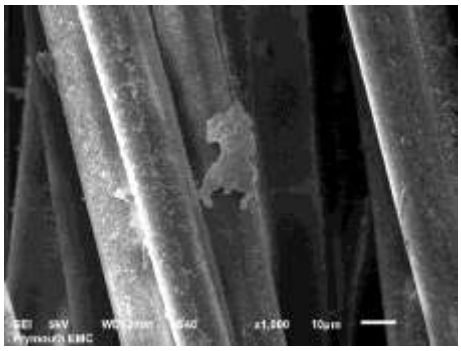


Figure 9 - Recovered Fibres (400°C) (3) **Figure 10** - Recovered Fibres (400°C) (4)



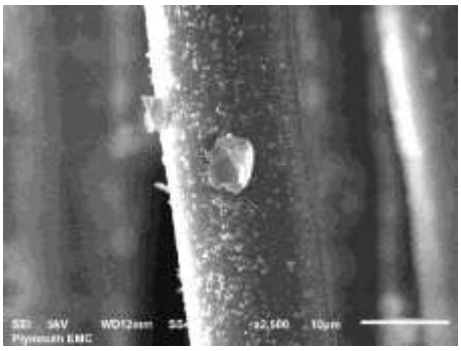
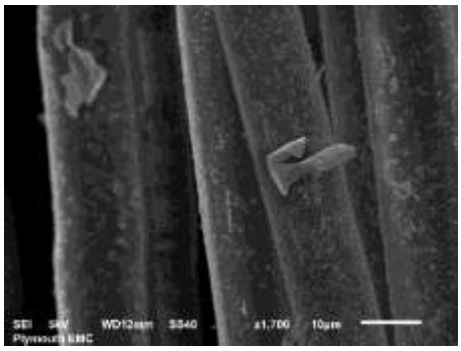


Figure 11 - Recovered Fibres (425°C) (1) **Figure 12** - Recovered Fibres (425°C) (2)



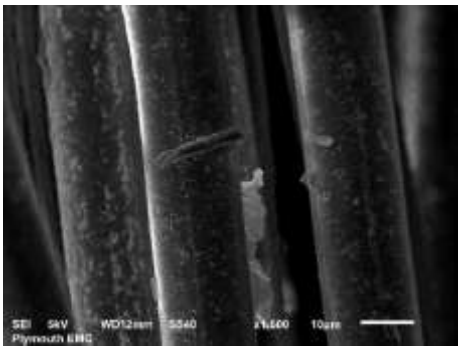
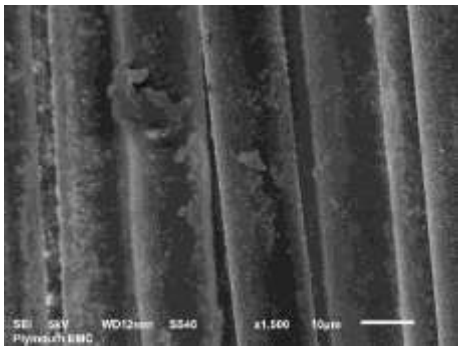


Figure 13 - Recovered Fibres (425°C) (3) **Figure 14** - Recovered Fibres (425°C) (4)



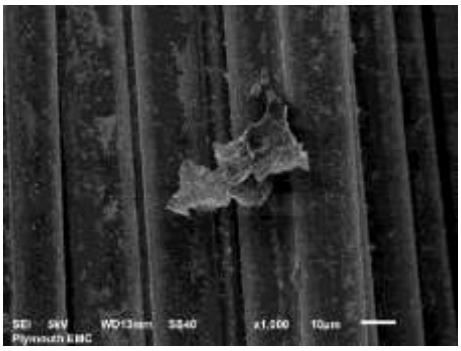
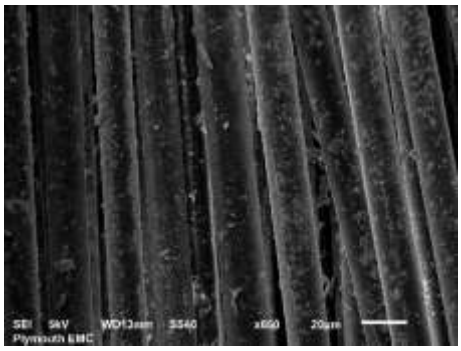


Figure 15 - Recovered Fibres (450°C) (1) **Figure 16** - Recovered Fibres (450°C) (2)



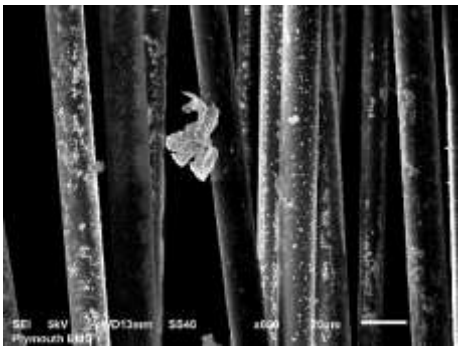
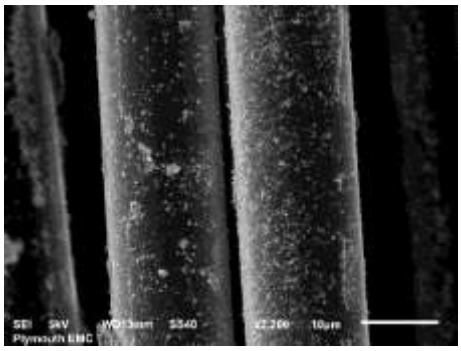


Figure 17 - Recovered Fibres (450°C) (3) **Figure 18** - Recovered Fibres (450°C) (4)



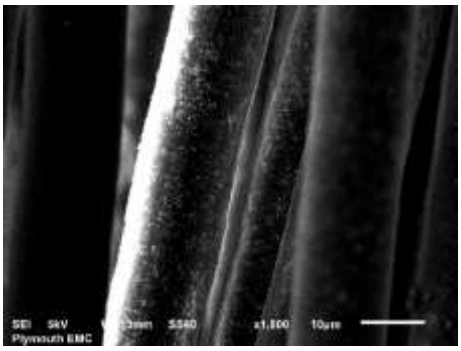
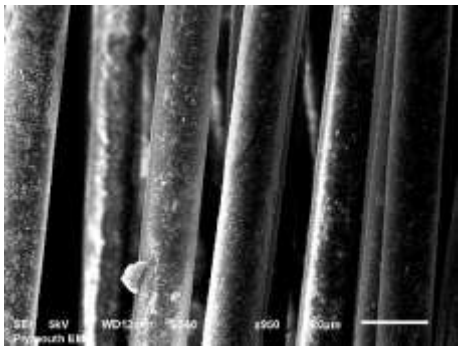


Figure 19 - Recovered Fibres (475°C) (1) **Figure 20** - Recovered Fibres (475°C) (2)



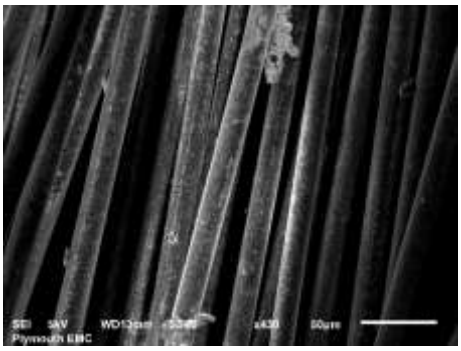
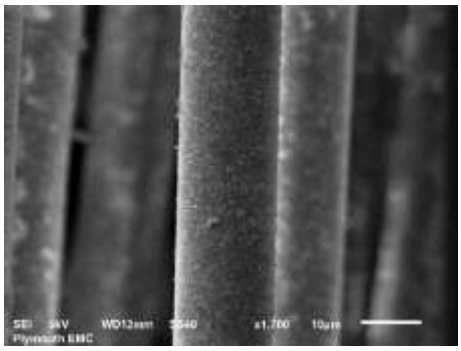


Figure 21 - Recovered Fibres (475°C) (3) **Figure 22** - Recovered Fibres (475°C) (4)



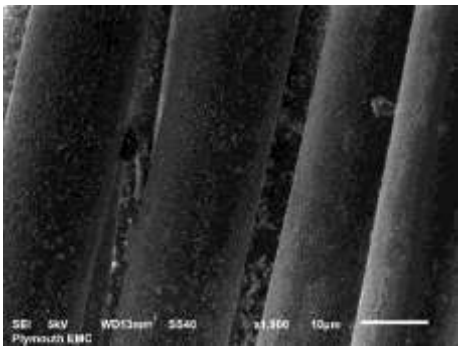


Figure 23 - Recovered Fibres (500°C) (1) **Figure 24** - Recovered Fibres (500°C) (2)

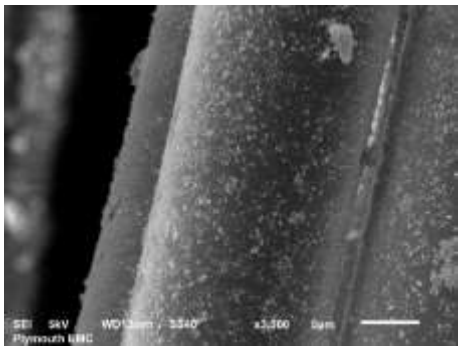


Figure 25 - Recovered Fibres (500°C) (3)

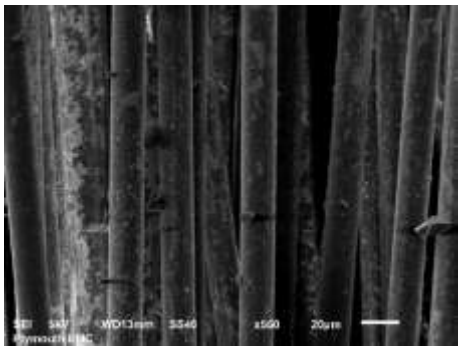


Figure 26 - Recovered Fibres (600°C) (1)

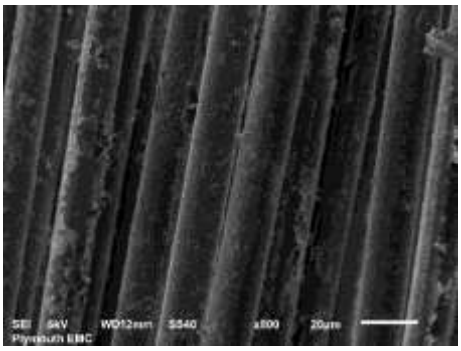


Figure 27 - Recovered Fibres (600°C) (2)

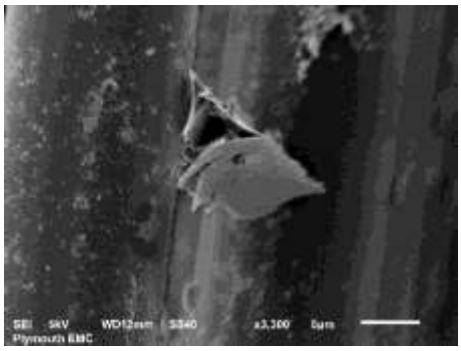


Figure 28 - Recovered Fibres (600°C) (3)

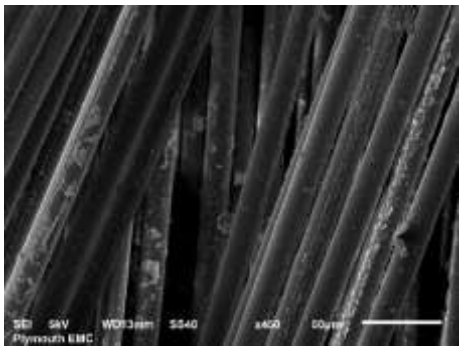


Figure 29 - Recovered Fibres (600°C) (4)

Appendix E: Test Specimen Details

Table 3 - Specimen Group C Details

Specimen	*Length (m)*	*Width (m)*	*Weight (kg)*	*Area (m^2)*	*Thickness (m)*	*Vf*
1C	0.0294	0.0292	0.0145	0.000861	0.00853	0.610
2C	0.0294	0.0293	0.0147	0.000862	0.00859	0.606
3C	0.0294	0.0293	0.0147	0.000862	0.00864	0.602
4C	0.0294	0.0295	0.0146	0.000864	0.00857	0.607
5C	0.0294	0.0293	0.0145	0.000861	0.00864	0.602

Mean	0.0294	0.0293	0.0146	0.000862	0.0086	0.605
St Dev	3.6E-05	7.22E-05	7.97E-05	1.27E-06	4.22E-05	0.003

Table 4 - Specimen Group D Details

Specimen	***Length (m)***	***Width (m)***	***Weight (kg)***	***Area (m^2)***	***Thickness (m)***	***Vf***
1D	0.0293	0.0295	0.0147	0.000864	0.00864	0.602
2D	0.0293	0.0293	0.0146	0.000858	0.00861	0.604
3D	0.0292	0.0294	0.0146	0.000856	0.00867	0.600
4D	0.0291	0.0294	0.0146	0.000856	0.00877	0.593
5D	0.0293	0.0294	0.0145	0.000861	0.00856	0.608
Mean	0.0292	0.0294	0.0146	0.000859	0.0087	0.602
St Dev	6.88E-05	5.19E-05	5.23E-05	2.94E-06	7.01E-05	0.005

Table 5 - Specimen Group E Details

Specimen	***Length (m)***	***Width (m)***	***Weight (kg)***	***Area (m^2)***	***Thickness (m)***	***Vf***
1E	0.0294	0.0293	0.0146	0.000860	0.00862	0.604
2E	0.0293	0.0294	0.0147	0.000861	0.00861	0.604
3E	0.0294	0.0291	0.0146	0.000856	0.00866	0.601
4E	0.0292	0.0294	0.0144	0.000858	0.00859	0.606
5E	0.0293	0.0294	0.0146	0.000861	0.00855	0.609
Mean	0.0293	0.0293	0.0146	0.000859	0.00861	0.605
St Dev	8.43E-05	1.03E-04	9.85E-05	1.96E-06	3.61E-05	0.00254

Table 6 - Specimen Group F Details

Specimen	***Length (m)***	***Width (m)***	***Weight (kg)***	***Area (m^2)***	***Thickness (m)***	***Vf***
1F	0.0294	0.0293	0.0145	0.000862	0.00854	0.609
2F	0.0292	0.0294	0.0146	0.000857	0.00862	0.604
3F	0.0293	0.0293	0.0146	0.000859	0.00866	0.601
4F	0.0292	0.0293	0.0146	0.000858	0.00863	0.603
5F	0.0294	0.0291	0.0146	0.000855	0.00867	0.600

Mean	0.0293	0.0293	0.0146	0.000858	0.00862	0.603
St Dev	8.42E-05	8.27E-05	3.54E-05	2.42E-06	4.59E-05	0.00323

Table 7 - Specimen Group G Details

Specimen	*Length (m)*	*Width (m)*	*Weight (kg)*	*Area (m^2)*	*Thickness (m)*	*Vf*
1G	0.0294	0.0294	0.0147	0.000863	0.00865	0.602
2G	0.0293	0.0294	0.0146	0.000859	0.00859	0.606
3G	0.0294	0.0293	0.0147	0.000863	0.00865	0.602
4G	0.0294	0.0293	0.0146	0.000860	0.00863	0.603
5G	0.0293	0.0294	0.0147	0.000861	0.00863	0.603
Mean	0.0294	0.0293	0.0147	0.000861	0.00863	0.603
St Dev	5.51E-05	3.07E-05	6.22E-05	1.35E-06	2.19E-05	0.002

Table 8 - Specimen Group H Details

Specimen	*Length (m)*	*Width (m)*	*Weight (kg)*	*Area (m^2)*	*Thickness (m)*	*Vf*
1H	0.0293	0.0293	0.0147	0.000860	0.00865	0.602
2H	0.0293	0.0294	0.0145	0.000862	0.00855	0.609
3H	0.0294	0.0294	0.0146	0.000862	0.00860	0.605
4H	0.0293	0.0293	0.0146	0.000859	0.00865	0.602
5H	0.0293	0.0294	0.0146	0.000860	0.00866	0.601
Mean	0.0293	0.0294	0.0146	0.000861	0.008622	0.603
St Dev	2.71E-05	2.99E-05	6.34E-05	1.19E-06	4.17E-05	0.003

Appendix F: Fibre Recovery 1 Data

Table 9 - Specimen Group C Weights

Specimen Group C

	Specimen						
	1C	**2C**	**3C**	**4C**	**5C**	**Average**	**Total**
Burn-off Time (hours)	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**
0	39.77	38.61	39.65	40.38	37.47	39.18	195.88
0.25	37.63	36.39	37.21	37.98	37.30	37.30	186.51
0.5	36.80	35.60	36.58	37.33	36.51	36.56	182.82
0.75	36.77	35.59	36.56	37.31	36.48	36.54	182.71
1	36.75	35.57	36.54	37.28	36.47	36.52	182.61
1.25	36.73	35.55	36.51	37.26	36.45	36.50	182.51
1.75	36.68	35.49	36.45	37.20	36.41	36.44	182.21
2.25	36.61	35.41	36.36	37.12	36.34	36.37	181.84
3	36.52	35.33	36.27	37.03	36.28	36.29	181.43
3.75	36.20	36.94	36.19	35.26	36.46	36.21	181.04
4.5	36.18	36.93	36.16	35.25	36.44	36.19	180.95
5.25	36.08	36.87	36.11	35.17	36.39	36.12	180.62
6	36.03	36.84	36.09	35.14	36.35	36.09	180.46
6.75	35.98	36.82	36.07	35.10	36.31	36.06	180.29
7.5	35.97	36.81	36.06	35.09	36.30	36.05	180.23
8.25	35.97	36.81	36.06	35.09	36.29	36.04	180.21
9	35.98	36.82	36.08	35.11	36.30	36.06	180.28
9.75	35.97	36.81	36.06	35.09	36.28	36.04	180.21
10.75	35.96	36.81	36.06	35.09	36.28	36.04	180.21

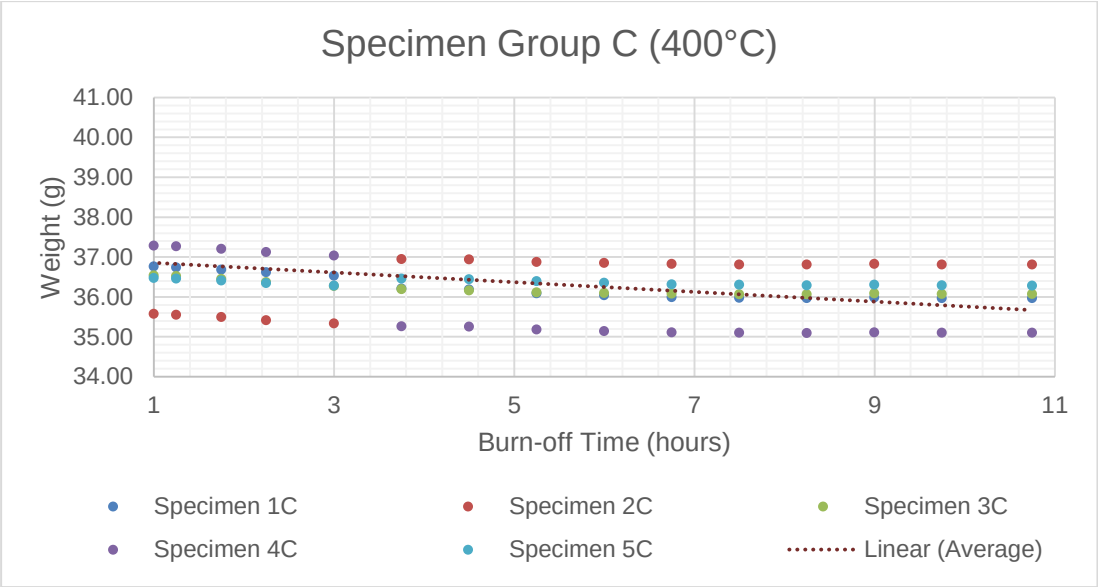


Figure 30 - Specimen Group C (Weight vs. Burn-off Time)

Table 10 - Specimen Group D Weights

Specimen Group D

	Specimen						
	1D	**2D**	**3D**	**4D**	**5D**	**Average**	**Total**
Burn-off Time (hours)	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**
0	39.99	38.53	39.58	40.37	39.47	39.59	237.52
0.5	36.81	35.47	36.36	37.21	36.28	36.43	218.55
1	36.68	35.32	36.22	37.07	36.14	36.29	217.72
1.75	36.52	35.13	36.08	36.97	36.04	36.15	216.89
2.75	36.42	35.04	36.01	36.87	35.98	36.06	216.37
3.75	36.41	35.03	35.99	36.86	35.95	36.05	216.29
4	36.39	35.01	35.98	36.85	35.94	36.03	216.21
4.5	36.38	35.00	35.98	36.84	35.94	36.03	216.18
5	36.37	34.99	35.98	36.84	35.93	36.02	216.13
5.5	36.37	34.99	35.98	36.84	35.93	36.02	216.13

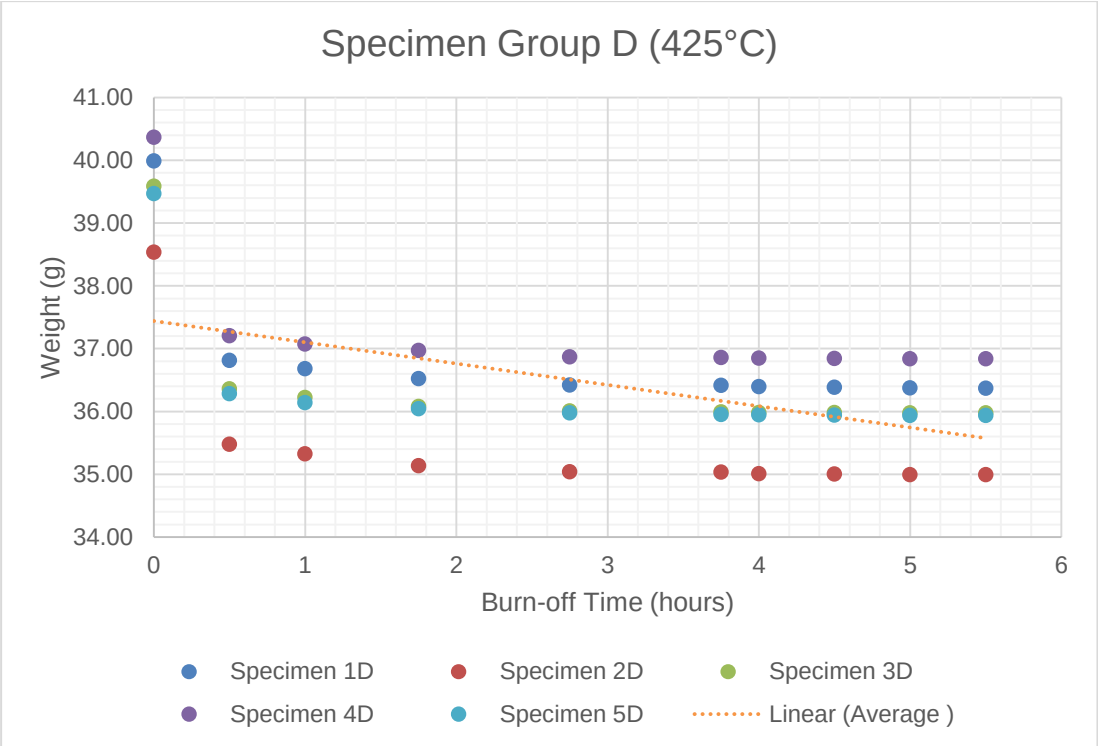


Figure 31 - Specimen Group D (Weight vs. Burn-off Time)

Table 11 - Specimen Group E Weights

Specimen Group E

	Specimen						
	1E	**2E**	**3E**	**4E**	**5E**	**Average**	**Total**
Burn-off Time (hours)	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**
0	39.59	40.47	39.55	38.39	39.88	39.58	197.88
0.25	36.30	37.17	36.27	35.19	36.63	36.31	181.57
0.5	36.16	37.05	36.16	35.09	36.51	36.19	180.96
1	36.03	36.90	36.01	34.94	36.39	36.05	180.26
1.75	36.00	36.88	35.98	34.91	36.34	36.02	180.12
2.25	35.99	36.87	35.98	34.90	36.34	36.01	180.07
2.75	35.99	36.87	35.98	34.90	36.34	36.01	180.07

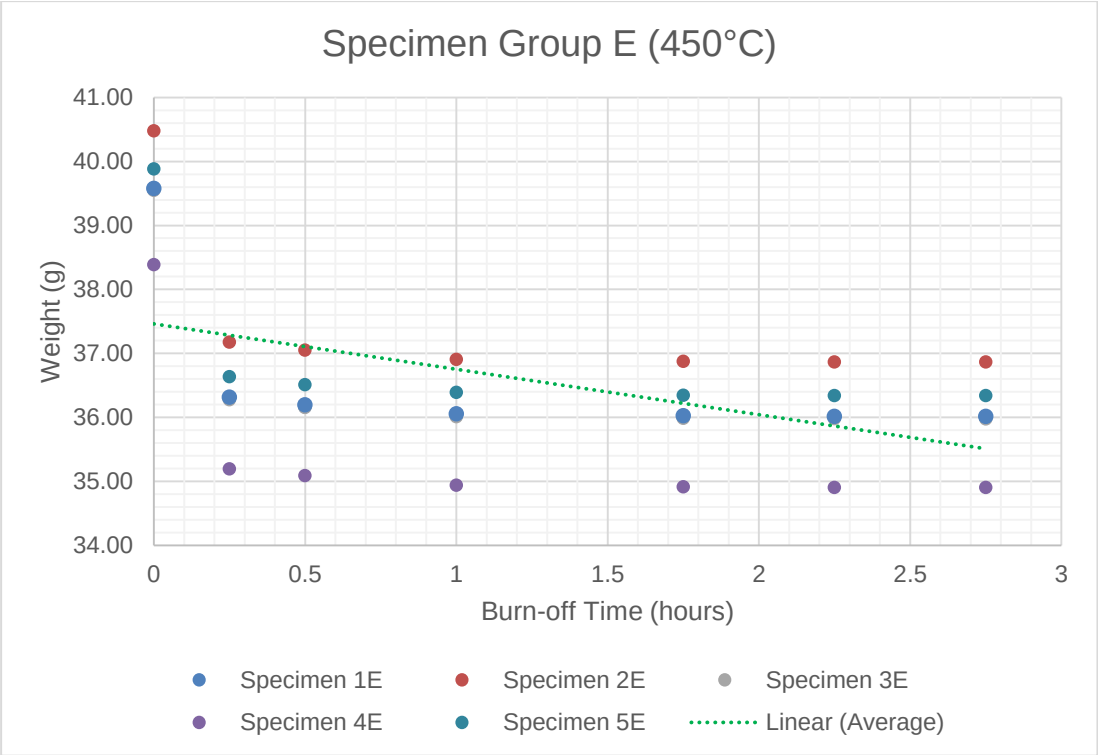


Figure 32 - Specimen Group E (Weight vs. Burn-off Time)

Table 12 - Specimen Group F Weights

Specimen Group F

	Specimen						
	1F	**2F**	**3F**	**4F**	**5F**	**Average**	**Total**
Burn-off Time (hours)	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**
0	39.83	38.57	39.60	40.32	39.54	39.57	197.87
0.25	36.42	35.14	36.03	36.87	35.99	36.09	180.44
0.5	36.36	35.06	36.00	36.81	35.98	36.04	180.21
0.75	36.34	35.03	35.99	36.77	35.98	36.02	180.10
1	36.33	35.02	35.99	36.76	35.98	36.01	180.07
1.25	36.32	35.01	35.98	36.75	35.98	36.01	180.03
1.5	36.32	35.01	35.98	36.75	35.98	36.01	180.03

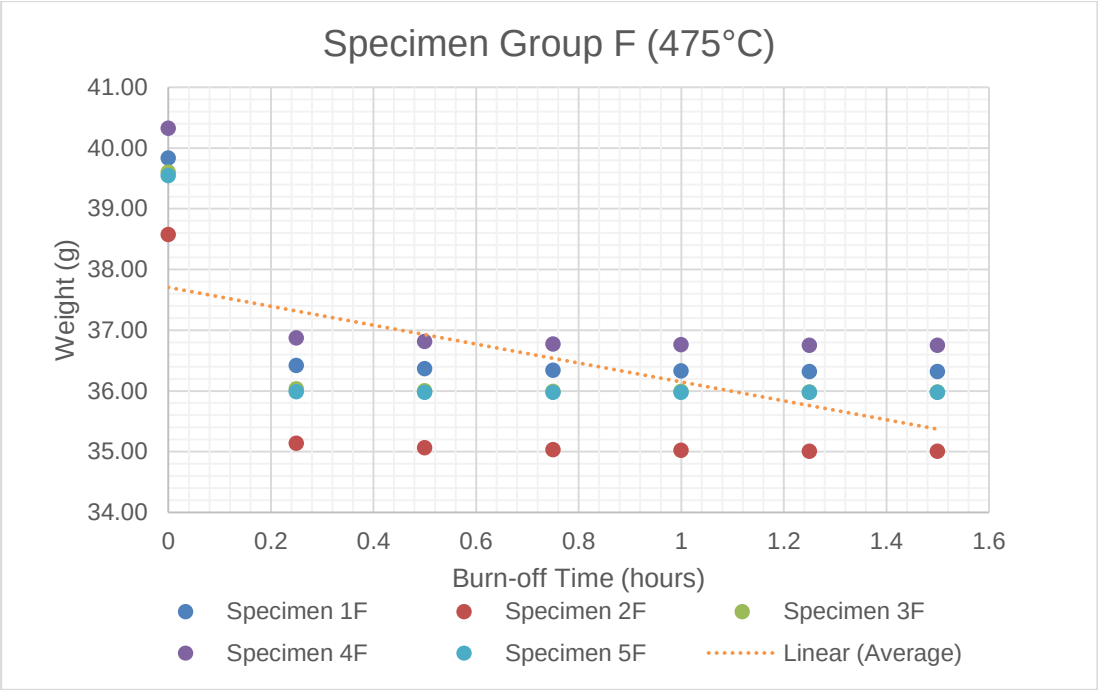


Figure 33 - Specimen Group F (Weight vs. Burn-off Time)

Table 13 - Specimen Group G Weights

Specimen Group G

	Specimen						
	1G	**2G**	**3G**	**4G**	**5G**	**Average**	**Total**
Burn-off Time (hours)	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**	**weight (g)**
0	40.04	38.55	39.72	40.37	39.61	39.66	198.29
0.25	36.18	36.81	36.15	35.03	36.38	36.11	180.55
0.5	36.11	36.76	36.12	35.02	36.39	36.08	180.40
0.75	36.09	36.75	36.11	35.00	36.38	36.07	180.34
1	36.09	36.75	36.11	35.00	36.39	36.07	180.34

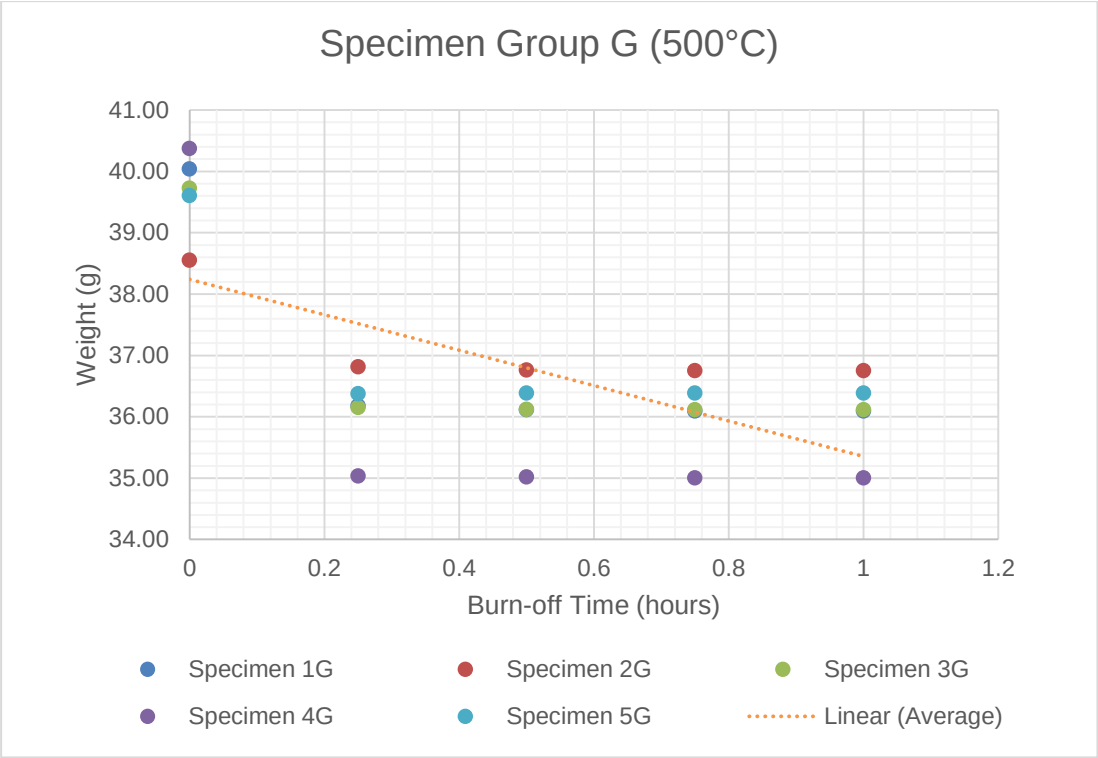


Figure 34 - Specimen Group G (Weight vs. Burn-off Time)

Appendix G: Bomb Calorimetry

Experimental Procedure

1. Weight sample to get specified weight (±0.02g)
2. Fill water jacket with 2000g of distilled water (±0.5g)
3. Cut fuse wire to 100mm
4. Clip fuse wire across electrodes to close the circuit
5. Place crucible, with sample, into the bomb head
6. Place fuse wire into crucible ensuring it is in contact with the sample
7. Check that electrical connections are intact using the digital multimeter (readings should be at least 6 using 200Ω setting)
8. Fill bomb with 1g of distilled water
9. Gently lower bomb head into the bomb cylinder taking care not to disturb sample and fuse wire
10. Screw down cylinder head cap until tight (N.B. do not force the screw down, check it is not cross threaded)
11. Endure pressure relief valve is screwed shut

Filling the bomb with oxygen

12. Connect the oxygen pipe onto oxygen inlet valve
13. Select 'O_2' key on keypad
14. Disconnect the oxygen pipe when complete

Setup procedure

15. Place the water jacket into the calorimeter – ensuring dimples are aligned
16. Attach lifting handle to the bomb
17. Partially lower the bomb into the water

18. Push the two ignition lead wires into the terminal sockets on the bomb head
19. Lower the bomb completely into the water – ensuring the bomb base spans the circular boss in the bottom of the bucket
20. Remove lifting handle, shaking off any water droplets back into the bucket
21. Check for air bubbles escaping from bomb (if so do not commence)
22. Close the firing cover – ensuring electrode wires do not get pinched or either of the probes get caught on the bomb

To fire the bomb

23. 'Start' – 'Enter' – 'Enter' – Input sample weight – 'Enter'

Appendix H: TRL Figure

	Technology Readiness Level:	1	2	3	4	5	6	7	8	9	Limited to:
Re-use	Second-hand market								*		
Primary recycle	*(no current technology retains full duty)*										
Secondary recycle	Remelting thermoplastic composites								*		
Tertiary recycle	Pyrolysis									*	CFRP to CF
	Fluidised bed combustion					*					CFRP to CF
	Chemical digestion				*						
	Solvothermal processes		*								
	Ionic liquids	*									
Quaternary recycle	Incineration/energy recovery									*	
	Composting						*				biomaterials
Dump	Landfill/scuttle									*	

Figure 35 - TRL EOL Composites (What shall we do with the End-of-Life vessel, 2015)

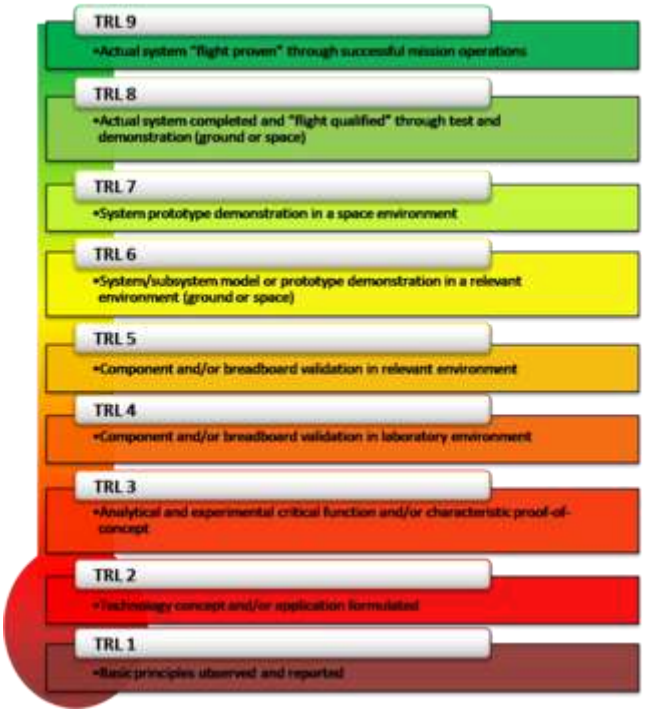


Figure 36 - Technology Readiness Levels (Mai, 2015)

Appendix I: Calculations

Table 14 - Cost Percentage Difference between Fibre Recovery 1 and Fibre Recovery 2

Test Temperature Cost (£)

Fibre Recovery	**400**	**425**	**450**	**475**	**500**	**600**	
1	0.664	0.181	0.262	0.197	0.154	/	
2	0.408	0.305	0.200	0.128	0.111	0.100	**Mean**
% Difference	47.76	51.03	26.84	42.46	32.45	/	**40.1**

$$V_f = \frac{n * A_W}{\rho_f * t}$$

Equation 1 - Laminate Thickness

Where;

n = Number of plies

A_W = Areal weight of GFRP (g/m^2)

ρ_f = Fibre density (kg/m^3)

t = Laminate thickness (mm)

V_f = Fibre Volume Fraction

$$C_{p_c} = (V_f * C_{p_f}) + ((1 - V_f) * C_{p_m}$$

Equation 2 - Specific Heat

Where;

C_{pc} = Composite specific heat

V_f = Fibre Volume Fraction

C_{pf} = Fibre specific heat

C_{pm} = Matrix specific heat

$$Wet\ saw\ cutting\ surface\ length = \mu d$$

$$= 0.393m$$

Where;

d = diameter = 125mm

$$Cut\ length\ Ratio = \frac{Wet\ saw}{Jigsaw}$$

Equation 3 - Cut Length Ratio

$$= \frac{0.393}{0.05}$$

$$= 7.86$$

Appendix J: Risk Assessments/ COSHH Sheets

Diamond Slitting Saw

Date:	13/11/2015	Assessed by:	Richard Cullen	Activity/Location	Test Specimen Cutting/ Brunel W7 – Diamond Slitting Saw

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	L x S	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	L x S	Responsible Person
Sharp Blade - Cut	Operator	2	3	6	Caution whilst cutting specimens (particularly small specimens), suggest use of appropriate PPE (leather gloves).	2	2	4	Operator
Composite Shards/ dust – inhalation or injury to eyes	Operator	2	3	6	Appropriate PPE to be worn (Dust mask, Safety specs, Lab Coat).	1	1	1	Operator

Approved Signature:		Print:		Date:		Review date:	

Figure 37 - Diamond Slitting Saw Risk Assessment

Jigsaw

Date:	13/11/2015	Assessed by:	Richard Cullen	Activity/Location	Preparation of Test Specimen - Jigsaw

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	L x S	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	L x S	Responsible Person
Sharp Blade - Cuts	Operator	3	4	12	Saw guard and appropriate PPE	2	2	4	Operator
Loose Particles – Eye injury	Operator	3	3	9	Saw guard and appropriate PPE (Safety Glasses)	2	2	4	Operator
Loose work-piece – Cut, Blunt trauma	Operator/ Those adjacent	2	4	8	Saw guard, work-piece clamp and emergency stop button	2	1	2	Operator
Dust – Eye injury, inhalation	Operator/ Those adjacent	3	3	9	Dust extraction and appropriate PPE (Dust mask, Safety Glasses)	2	1	2	Operator
Electricity – Electric Shock	Operator	2	4	8	Regular maintenance and PAT testing	1	3	3	Regularly PAT tested

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Figure 38 - Jigsaw Risk Assessment

Fine Powders

Date:	13/11/2015	Assessed by:	Richard Cullen	Activity/Location	Specimen Preparation for Bomb Calorimeter – Fine Powders

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	L x S	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	L x S	Responsible Person
Skin Irritation	Operator	2	3	6	Use of appropriate PPE (Gloves, Lab Coat).	1	1	1	Operator
Respiratory hazard (if < 3µm)	Operator	2	3	6	Use of appropriate PPE (Dust Mask, Lab Coat, Safety Glasses)	1	2	2	Operator
Fire – Burns	Operator/ Those adjacent	2	4	8	Avoid ignition sources.	1	3	3	Operator
Toxicity and Irritation (due to vinyl ester resin)	Operator	1	3	3	Observe precautions for vinyl ester resin in use.	1	1	1	Operator

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Figure 39 - Fine Powders Risk Assessment

Furnace

Date:	13/11/2015	Assessed by:	Richard Cullen	Activity/Location	Furnace Operation

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	LxS	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	LxS	Responsible Person
Hot Surfaces – Burns	Operator	3	3	9	Tongs to be used with appropriate PPE (Leather gloves)	1	4	4	Operator
Fume Inhalation	Operator/ Those adjacent	4	3	12	Extraction dedicated to furnace to be used during resin burn off, ensuring all other outlets are closed	1	2	2	Operator

Approved Signature:		Print:		Date:		Review date:	

Figure 40 - Furnace Risk Assessment

Bomb Calorimeter

Date:	13/11/2015	Assessed by:	Liz Preston	Activity/Location	Determination of Energy Content by Bomb Calorimetry

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	LxS	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	LxS	Responsible Person
Compressed Gas – Explosion	Operator/ Those adjacent	3	4	12	Operators are trained by Technical staff in the use of the gas supply. All sources of ignition are removed from the surrounding area. Operators must follow written procedure for the safe use of the bomb.	1	4	4	Changing of gas cylinder to be done by a **trained Technician** only.
Electricity – Electric shock	Operator/ Those adjacent	2	4	8	Equipment in isolated before cleaning, regular maintenance and PAT testing	1	4	4	PAT Tested regularly
Pressurized Bomb Calorimeter – Explosion	Operator	2	4	8	Procedures must be followed to ensure the pressure is neutralized before opening the Bomb vessel.	1	4	4	Regular maintenance and servicing of calorimeter
Moving Parts (lid, paddle) – Trapping fingers	Operator	3	1	3	Follow procedures to operate the equipment.	2	1	2	Operator
Chemical Residue in bomb vessel (acids) –Skin irritation, burns	Operator	1	3	3	Use appropriate PPE.	1	3	3	Operator
Glass Fibre Powder – Inhalation, contamination	Operator/ Those adjacent	3	3	9	Use appropriate PPE – Dust mask, and keep glass fibre powder sealed in vial	1	2	2	Operator

Approved Signature:		Print:		Date:		Review date:	

Figure 41 - Bomb Calorimeter Risk Assessment

Optical Microscope

Date:	16/11/2015	Assessed by:	Terry Richards	Activity/Location	Optical Microscope (SMB 001D)

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	LxS	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	LxS	Responsible Person
Class 2 laser – Eye damage	Operator	4	3	12	Training and controlled use	1	4	4	Operator during use and technician to provide training
Moving Parts – trapped fingers	Operator	3	1	3	Training and controlled use	1	1	1	Operator during use and technician to provide training

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Figure 42 - Optical Microscope Risk Assessment

Scanning Electron Microscope

Date:	16/11/2015	Assessed by:	Peter Bond	Activity/Location	Electron Microscope operation

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	LxS	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	LxS	Responsible Person
Moving parts – trapped fingers	Operator	3	1	3	Training and controlled use	1	1	1	Operator during use and technician to provide training
EM Operation	Operator	1	1	1	No one is to operate the microscope without appropriate training	1	1	1	Operator during use and technician to provide training

Approved Signature:		Print:		Date:		Review date:	

Figure 43 - Scanning Electron Microscope Risk Assessment

Mixing Resins

Date:	13/11/2015	Assessed by:	Richard Cullen	Activity/Location	Resin Mixing

Hazard and likely consequences	No. at Risk	Uncontrolled Risk L	S	LxS	How is the hazard controlled; (E.g. CoPs – Guidance Notes – mechanical measures – supervision – training etc.)	Residual Risk L	S	LxS	Responsible Person
Mixing Epoxy Resins - Sensitization	Operator	3	4	12	Relevant PPE, Nitrile Gloves, Safety glasses, Lab coats	2	2	4	Operator
Mixing Epoxy Resins – Hardener Toxicity	Operator	3	4	12	Relevant PPE, Nitrile Gloves, Safety glasses, Lab coats. Ensure extraction is used during decanting and mixing	2	2	4	Operator
Mixing Polyester Resins – Styrene Vapors	Operator	3	3	9	Relevant PPE, Nitrile Gloves, Safety glasses, Lab coats. Ensure extraction is used during decanting and mixing	2	2	4	Operator
Mixing Polyester Resins – peroxide Catalyst	Operator	3	3	9	Relevant PPE, Nitrile Gloves, Safety glasses, Lab coats, catalyst dispensed using pipettes	2	2	4	Operator

Approved Signature:		Print:		Date:		Review date:	

Figure 44 - Mixing Resins Risk Assessment

			Severity				
			Very Low	Low	Medium	High	Extreme
			1	2	3	4	5
Likelihood	Probable	5	5	10	15	20	25
	Very Likely	4	4	8	12	16	20
	Likely	3	3	6	9	12	15
	Possible	2	2	4	6	8	10
	Not Likely	1	1	2	3	4	5

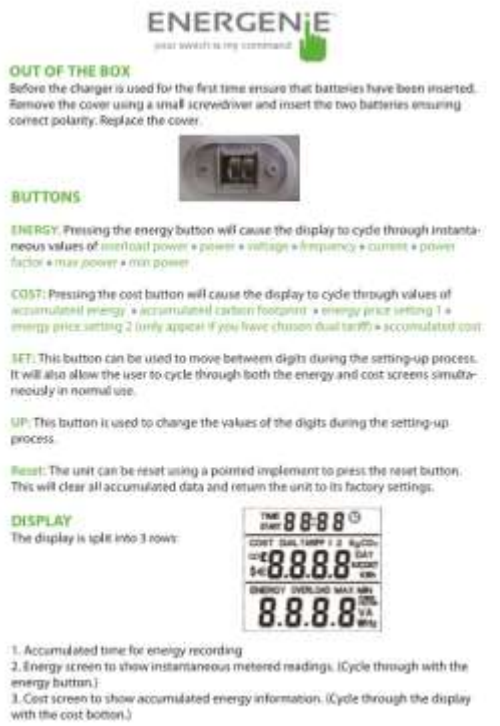
Risk Rating

Low	Medium	High

Severity		Likelihood	
5	Extreme – Multiple Fatalities	5	Probable
4	High – Single Fatality or Multiple Serious Injuries	4	Very Likely
3	Medium – RIDDOR Reportable Injury	3	Likely
2	Low – Minor Injury, no lost time	2	Possible
1	Very Low – No injury / Near miss	1	Not Likely

Figure 45 - Risk Rating, Severity and Likelihood

Appendix K: Energenie ENER007



ENERGENIE

OUT OF THE BOX

Before the charger is used for the first time ensure that batteries have been inserted. Remove the cover using a small screwdriver and insert the two batteries ensuring correct polarity. Replace the cover.

BUTTONS

ENERGY: Pressing the energy button will cause the display to cycle through instantaneous values of overload power • power • voltage • frequency • current • power factor • max power • min power

COST: Pressing the cost button will cause the display to cycle through values of accumulated energy • accumulated carbon footprint • energy price setting 1 • energy price setting 2 (only appear if you have chosen dual tariff) • accumulated cost

SET: This button can be used to move between digits during the setting-up process. It will also allow the user to cycle through both the energy and cost screens simultaneously in normal use.

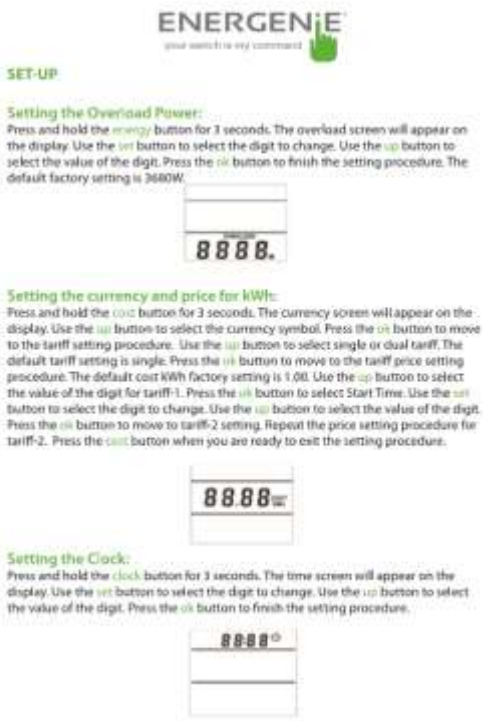
UP: This button is used to change the values of the digits during the setting-up process.

Reset: The unit can be reset using a pointed implement to press the reset button. This will clear all accumulated data and return the unit to its factory settings.

DISPLAY

The display is split into 3 rows:

1. Accumulated time for energy recording
2. Energy screen to show instantaneous metered readings. (Cycle through with the energy button.)
3. Cost screen to show accumulated energy information. (Cycle through the display with the cost button.)



ENERGENIE

SET-UP

Setting the Overload Power:

Press and hold the energy button for 3 seconds. The overload screen will appear on the display. Use the set button to select the digit to change. Use the up button to select the value of the digit. Press the ok button to finish the setting procedure. The default factory setting is 3680W.

Setting the currency and price for kWh:

Press and hold the cost button for 3 seconds. The currency screen will appear on the display. Use the up button to select the currency symbol. Press the ok button to move to the tariff setting procedure. Use the up button to select single or dual tariff. The default tariff setting is single. Press the ok button to move to the tariff price setting procedure. The default cost kWh factory setting is 1.00. Use the up button to select the value of the digit for tariff-1. Press the ok button to select Start Time. Use the set button to select the digit to change. Use the up button to select the value of the digit. Press the ok button to move to tariff-2 setting. Repeat the price setting procedure for tariff-2. Press the cost button when you are ready to exit the setting procedure.

Setting the Clock:

Press and hold the clock button for 3 seconds. The time screen will appear on the display. Use the set button to select the digit to change. Use the up button to select the value of the digit. Press the ok button to finish the setting procedure.

Figure 46 - Energenie ENER007 User Guide Part 1

ENERGENIE

Replacing the Batteries

Remove the battery cover by unscrewing the two securing screws. Remove the dead batteries and replace with the specified batteries, 2 x 1.5V AG13/LR44, ensuring correct polarity during insertion.

Specifications

Rating:	200 to 276 Volts AC 50 Hz
Load max:	13 Amps, 3120 Watts
Unit power consumption:	<0.5 Watts

Time Display

Accumulated ON time	0 seconds to 9999 days

The unit also displays the current time of day

Energy Display

Measured voltage range:	200-276 Volts AC ±1.5%
Measured current range:	0.005-13 Amps ±2%
Measured power:	0.1 to 3120 Watts ±2%
Power factor:	0.00 to 1.00
Measured frequency range:	45-65Hz
Overload threshold:	Max. 3120 Watts

Cost Display

Accumulated electricity usage:	0.00-9999 kilowatt-hour (kWh)
Accumulated carbon footprint:	0.00 to 9999 KgCO2
Selectable price/kWh:	00.00 to 99.99
Accumulated cost/kWh:	0.00 to 999
Selectable currency:	in £ / $ / €

Operating environment:	0°C to +50°C
Storage environment:	-10°C to +50°C
Weight:	200g

Regulatory Information

WEEE

This product is classed as Electrical or Electronic equipment and comes under the WEEE waste disposal and recycling requirements of Directives 2002/96/EC and 2003/108/EC within the EU. Please ensure that you dispose of this product responsibly using your local authority's recycling facilities or via your supplier for commercial customers.

ENERGENIE

User Guide for Appliance Power Meter

Model: ENER007

Energenie is a trading name of Sandal plc, Clairmont House, Deans Court, Bicester, UK, OX26 6BW
If you have questions, please visit us at
www.energenieiu.co.uk

Figure 47 - Energenie ENER007 User Guide Part 2