Luxfer Magtech Inc.

PRODUCT EVALUATION AND RATING SCORECARD

Issues & Criteria		Performance Evaluation Criteria	Magnesium-based Heater			Aluminum-based Heater		
			Rating	Comment	Symbol	Rating	Comment	Symbol
	1	PERFORMANCE	●	100% of samples reach 100°F (56°C) change in temperature in 12 minutes (Figure 1)		⊘	15% of samples reach 100°F (56°C) change in temperature in 12 minutes (Figure 1)	
	2	MAXIMUM TEMPERATURE	●	Average maximum change in temperature of 140°F (78°C) after 8 minutes (Figure 1)		⊘	Average maximum change in temperature of 120°F (67°C) after 20+ minutes (Figure 1)	
	3	VARIABILITY	●	Limited variability in temperature performance. Standard temperature heating profile variance of less than 1%		⊘	Variability in temperature performance. Standard temperature heating profile variance of 36%	
	4	CORROSIVE MATERIAL	●	Does not contain corrosive material		⊘	Contains sodium hydroxide	
	5	WEIGHT	●	Net active heater weight of 12g.		⊘	Net active heater heater weights of 19.5g and 25g.	
	6	EFFICIENCY	●	330% more efficient on a per gram basis, as determined by change in temperature per gram (Figure 2)		⊘	Not as efficient (Figure 2)	
	7	SHELF-LIFE (Ambient)	●	Exceeds 3-year minimum.		⊘	Does not meet stated 2-year shelf life.	
	8	SHELF-LIFE (Accelerated)	●	100% of samples pass performance test after 6 days in 75% Humidity, 45°C accelerated conditions (Figure 3)		⊘	0% of samples pass performance test after 1 day in 75% Humidity, 45°C accelerated conditions (Figure 3)	
	9	HYGROSCOPIC TENDENCY (Water Absorption)	●	Minimal hygroscopic tendency of 0.005g/day in accelerated environmental conditions (Figure 4)		⊘	Extreme hygroscopic tendency of 0.16g/day in accelerated environmental conditions (32 times more hygroscopic) (Figure 4)	
	10	ENVIRONMENTAL	●	Biodegradable active ingredients, non-toxic byproducts. Byproduct Health Hazard of 1.		⊘	Byproducts are harmful to aquatic life. Byproduct Health Hazard of 3	
	11	SAFETY & HEALTH ISSUES	●	Magnesium hydroxide byproduct is slightly irritating in case of contact with skin or eyes. Safe in small quantities for ingestion and incidental contact with food		⊘	Sodium aluminate byproduct is extremely hazardous in case of skin/eye contact, ingestion or inhalation Sodium hydroxide is very hazardous in case of skin/eye contact, ingestion or inhalation	
	12	WARNING LABELS	●	Necessary warning labels/icons, cautionary statements		⊘	Warning labels/icons, and cautionary statements absent	
	13	HYDROGEN PRODUCTION	●	12g heater, produces theoretically 10L of hydrogen gas.		⊘	25g heater produces theoretically 12.4L hydrogen gas	
	14	HYDROGEN PRODUCTION RATE	●	Produces greater than 20L hydrogen gas per kilo/hr and less than 10L any one minute.		●	Produces greater than 20L hydrogen gas per kilo/hr and less than 10L any one minute.	
	15	TRANSPORTATION	●	Classified as Class 4.3, PG II		●	Classified as Class 4.3, PG II	
				MEETS/EXCEEDS	●		DOES NOT MEET	⊘

Technical Overview of Safety, Performance, and Long-Term Stability of Magnesium-based Heaters and Aluminum-based Heaters

Part 1: Magnesium-based heaters are optimized for superior performance

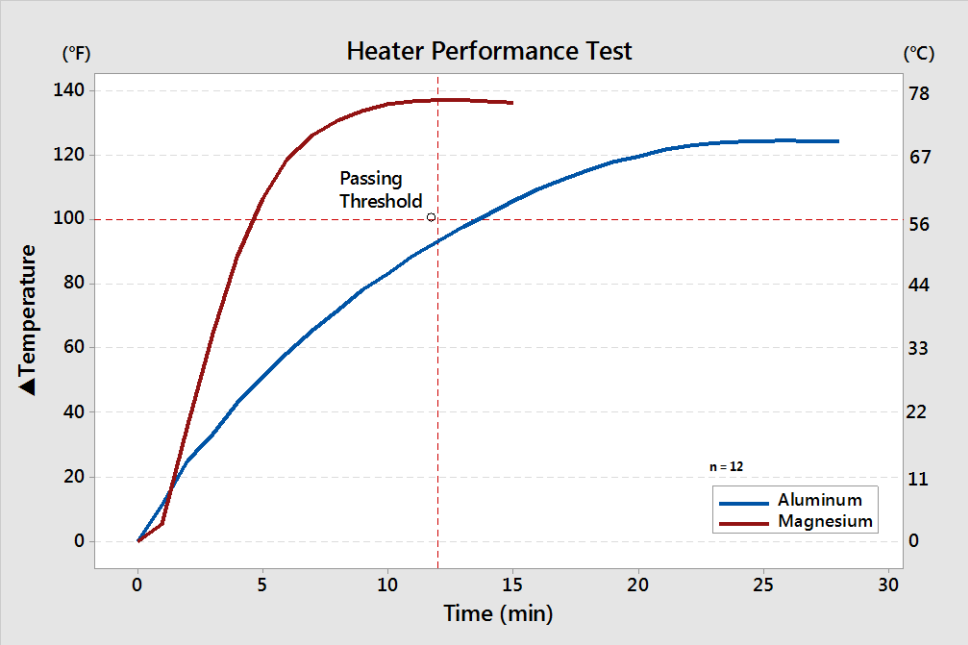

Figure 1: Standard heater performance test using a 25g aluminum-based heater (blue) and a 12g Magnesium-based heater. Test measures the change in temperature of a 300g water filled retort pouch (n=12). The passing threshold is reached when a change in temperature of 100°F (56°C) in 12 minutes is obtained. On average, the Magnesium-based heaters passed the required 100°F (56°C) threshold in 5 minutes, whereas Aluminum-based heater failed to meet the minimum 100°F (56°F) temperature rise in 12 minutes. Notably, the average maximum rise in temperature is approximately 140°F (78°C) after 8 minutes for the Magnesium-based heater, and 120°F (67°C) in 20 minutes for the Aluminum-based heater.

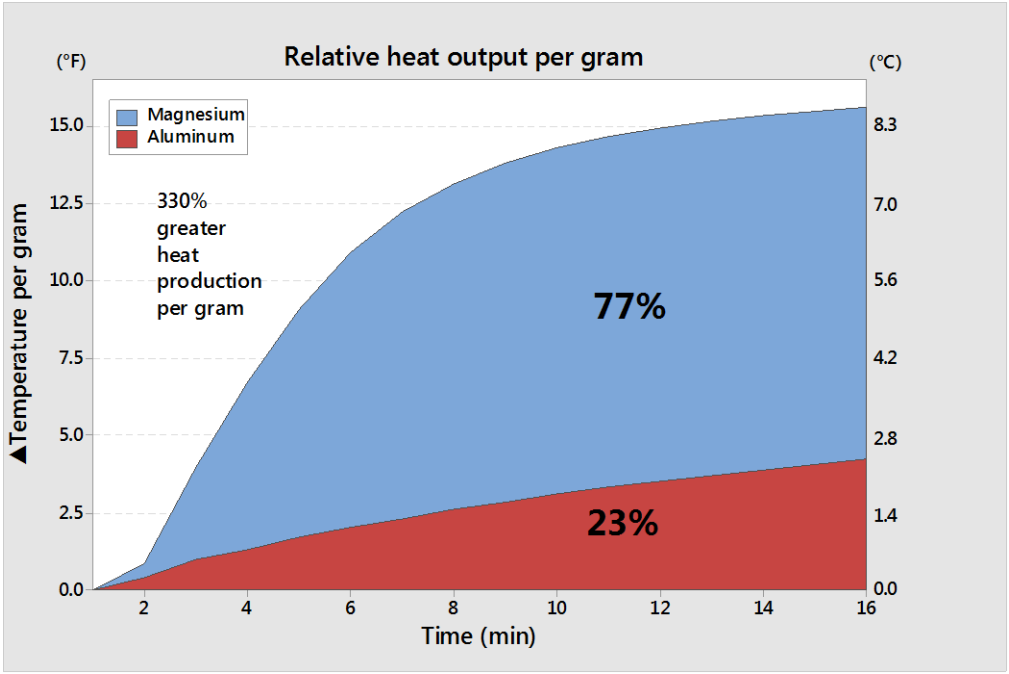

Figure 2: Relative heater output per gram comparison of Magnesium-based heater (blue) and Aluminum-based heater (red). Magnesium-based heater yields 330% greater heat production per gram than the Aluminum-based heater.

Part 2: Magnesium-based Heater has exceptional long-term stability and minimal water absorption

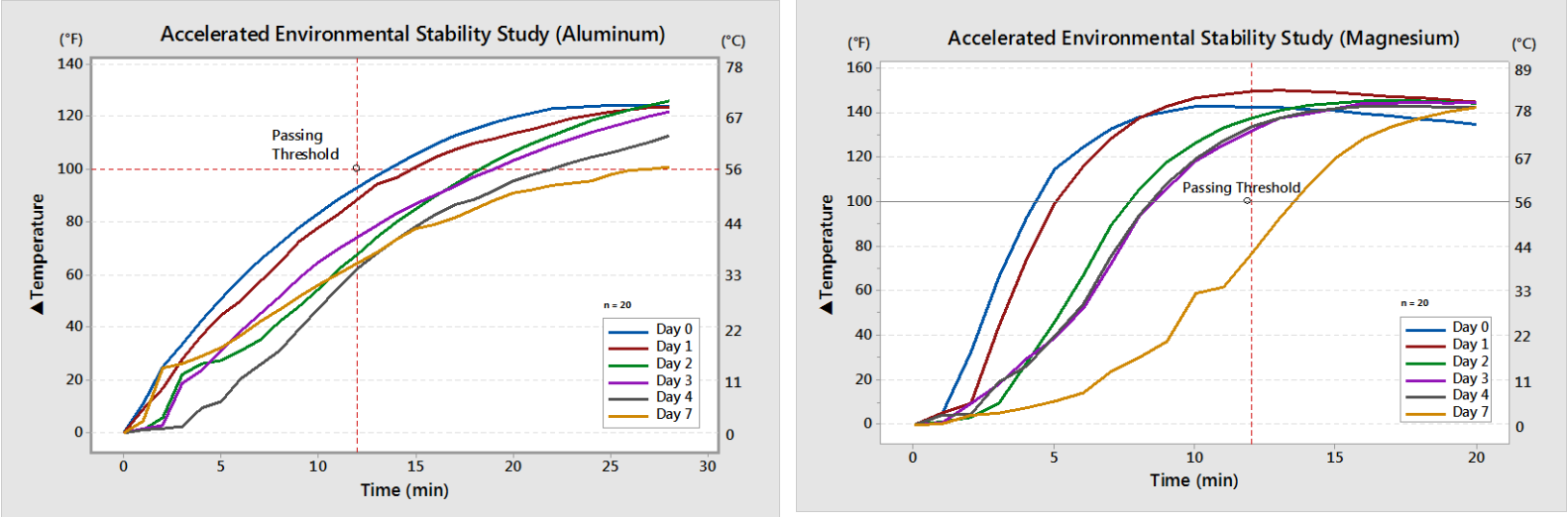

Figure 3: Heater performance tests of accelerated environmental stability study for Aluminum-based heater (left), and Magnesium-based heater (right); (n=20). Heaters were stored in an environmental chamber (75% Humidity, 45°C) for 1 week. Heater performance tests demonstrate long-term stability performance and shelf-life correlations. Passing threshold is a rise in temperature of 100°F (56°C) in 12 minutes. Only 15% of the Aluminum-based heaters tested met the passing threshold for Day 0. None of the samples met the passing threshold on Day 1. Magnesium-based heaters met passing threshold for 6 days, and failed on Day 7. One day of these accelerated environmental conditions is equivalent to 6-8 months real-time storage. Therefore, the Aluminum-based heaters do not meet their stated two-year shelf-life.

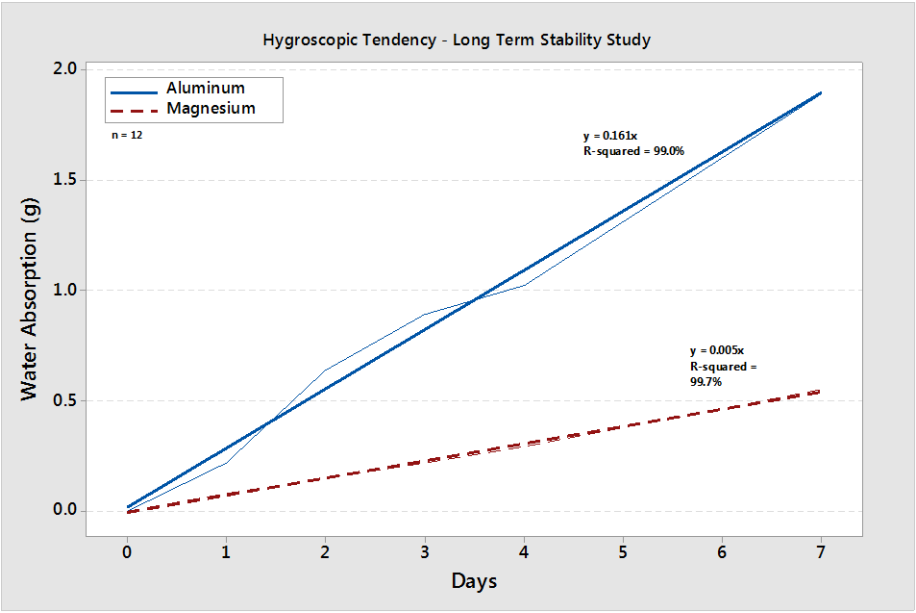

Figure 4: Long-term hygroscopic (water absorbing) tendency of Aluminum & Magnesium-based heaters, determined by loss on drying from accelerated environmental stability study. As seen, in accelerated conditions Aluminum-based heaters absorb 0.16g/day water compared to 0.005g/day water for the Magnesium-based heater. This demonstrates that the Aluminum-based heaters are 32 times more hygroscopic, influencing long-term stability by accelerating degradation, reducing shelf life and performance. This also has a profound impact on shipping considerations, and transportation safety.

Part 3: Environmental impacts, ease of disposability and food grade qualities

Magnesium-based heaters contain non-toxic, non-harmful, readily biodegradable active ingredients, FDA food additive reactants and byproducts with very low environmental and health impacts. Both the reactants and byproducts are non-toxic and in small quantities are not harmful in the event of ingestion or incidental contact with food. Magnesium hydroxide byproduct is listed as an FDA food additive; elemental iron is a food grade FDA food additive and sodium chloride is a common FDA food additive. All byproducts are able to be disposed in household garbage. The HMIS Classification identify magnesium hydroxide with a health grade of 1, slightly irritating in case of skin/eye contact, ingestion or inhalation.

Aluminum-based heaters contain sodium hydroxide, which is classified as a corrosive substance and the sodium aluminate byproduct are both dangerous if incidentally consumed. The HMIS Classification identify sodium aluminate with a health grade of 3, extremely hazardous in case of skin/eye contact ingestion or inhalation and sodium hydroxide with a health grade of 3 and reactivity grade of 1. In addition, sodium aluminate cannot be disposed of in household trash or drains due to its acute aquatic toxicity which indicates that it may be harmful to aquatic life.

Part 4: Hydrogen Emissions

Misinformation Claim #1: Aluminum-based heaters produce no to little amount of hydrogen gas

Aluminum-based heaters are advertised as being magnesium-free, with the implication that they do not produce hydrogen gas. However, according to both theory as well as empirical evidence, these implications are false.

In theory, the reaction of the Aluminum-based heater follows the reaction below:

$$2\,Al + 2\,NaOH + 6H_2O \longrightarrow 3\,H_2 + 2\,AlNa(OH)_4$$

Approximately 12.4L of H2 gas per 25 gram heater is produced

In theory, the reaction of the Magnesium-based heater follows the reaction below:

$$Mg + 2\,H_2O \longrightarrow Mg(OH)_2 + H_2$$

Approximately 10.0L of H2 gas per 12 gram heater is produced

Misinformation Claim #2: Aluminum-based heaters have a lower rate of hydrogen gas evolution

When tested in accordance with the UN Manual of Tests; Test N.5: Both the Magnesium & Aluminum based heaters are classified as Class 4.3: PG II. This specifies that a substance reacts readily with water at ambient temperatures, such that the maximum rate of hydrogen gas is greater than or equal to 20 liters of hydrogen gas per kilogram of per hour and produces less than 10 liters of hydrogen gas per kilogram over any one minute.

Part 5: Corrosivity and cautionary packaging statements

One of the primary reactants in Aluminum-based heaters is sodium hydroxide. Sodium hydroxide is considered an extremely corrosive substance which can cause severe skin burns and eye damage. Sodium hydroxide is also extremely hygroscopic, which leads to an increase in water absorption and decreased shelf-life. Due to the nature of this substance, proper shipping considerations must be met.
Due to the corrosive nature of the heater formulation, Aluminum-based heaters require additional hazard warning labels. Most notably “Do not eat” and cautionary statements. Magnesium-based heaters contain all necessary warning icons and cautionary statements required for proper shipping.