Research Article

INDONESIAN SCHOLAR SOCIETY

Indones. J. Chem. Stud.
2025, 4(2), 101–107
Available online at journal.solusiriset.com
e-ISSN: 2830-7658; p-ISSN: 2830-778X

Indonesian Journal of Chemical Studies

Comparative Analysis of the Performance of Magnesium-Teflon-Viton (MTV) and Aluminum-Teflon-Viton (ATV) Flares

Satria Aqilla Widyatama[1], Elda Pratita[1], Gunaryo[1]*, Minandre Wiratama[1], Anggaria Maharani[2]

[1]*Department of Chemistry, The Republic of Indonesia Defense University, IPSC Sentul, Bogor 16810, Indonesia*

[2]*Department of Product Development, PT. Dahana, Subang 41285, Indonesia*

Received: 23 May 2025; Revised: 27 Aug 2025; Accepted: 23 Sep 2025;
Published online: 25 Dec 2025; Published regularly: 31 Dec 2025

***Abstract*—** The development of effective pyrotechnic flare compositions is critical for advancing indigenous defense capabilities. This study presents a comparative analysis of two formulations, Magnesium-Teflon-Viton (MTV) and Aluminum-Teflon-Viton (ATV) to evaluate their suitability for application in decoy systems within Indonesia's defense sector. Key performance factors, including luminosity, combustion temperature, burn rate, and spectral color distribution, were assessed through controlled laboratory experiments. The MTV composition demonstrated superior luminous intensity, reaching up to 3572.5 lux, alongside broader spectral color output, indicating enhanced visibility and potential effectiveness in visual signaling applications. Conversely, the ATV composition exhibited higher average burn rates, peaking at 5.55 g/s, which suggests greater combustion efficiency and faster energy release, advantageous for time-sensitive deployments. Both systems maintained comparable combustion temperatures, with variations attributed to compositional differences in fuel-metal interactions and binder behavior. This study emphasizes the trade-offs between brightness and combustion kinetics inherent in flare formulations and provides valuable insights for optimizing material selection according to mission-specific applications. The results obtained in this study are expected to contribute to the creation of independence in defense material development by utilizing locally available resources and promoting domestic innovation in pyrotechnic technology.

***Keywords*—** *ATV-MTV; Burn rate; Luminosity; Pyrotecnics; Temperature measurement*

1. INTRODUCTION

Pyrotechnics can be defined as a type of component in weapon systems that contains high-energy materials capable of supporting operational functions and the effectiveness of weapon systems. In addition, pyrotechnics can be applied in rocket propulsion systems, signaling devices, and integrated defense systems. One type is light pyrotechnics, commonly known as flares. Light pyrotechnics ignite and produce emissions in the visible light spectrum (380 to 780 nm) [1].

Flares, which are a type of light pyrotechnics, can be categorized into illumination flares and decoy flares. In the formulation of flares, the materials commonly used include fuel, oxidizers, and other additives. Each material used can enhance the performance of the resulting flare product. In its application, flares have various formulas that are linear with their functions, one of which is a flare using a magnesium-teflon-viton (MTV) formulation and an aluminium-teflon-viton (ATV) formulation. The MTV composition has been developed since the 1950s and is used in various types of flares, including tracking flares, signaling flares, illuminating flares, and decoy flares [2]. MTV has several advantages, such as high energy output, low hygroscopicity, burn rate that is slightly affected by pressure and temperature, and relatively high safety levels [3].

Although much research has been conducted on the dynamic performance of pyrotechnic compositions, there is still much to understand about the thermochemistry and kinetics of the MTV composition. There is also the ATV composition that has superior potential and physical and chemical properties almost identical to MTV. The raw materials for MTV and ATV flare compositions are readily available in Indonesia. Raw materials such as aluminium are abundant in Indonesia, considering that Indonesia has very large bauxite reserves, which are the primary raw material for aluminium production [4]. The availability of these potential materials presents a significant opportunity for Indonesia to develop an independent domestic

***Corresponding author**.
Email address: gunaryo92000@gmail.com
DOI: 10.55749/ijcs.v4i2.95

defense industry. With optimal utilization, we can produce modern and sophisticated weapon systems in large quantities. The fuels consist of various compositions, including magnesium (Mg), aluminium (Al), along with additives such as Teflon and Viton. Furthermore, different compositions also affect performance parameters, including the emitted color spectrum, emission intensity [5]. and burn rate upon ignition [6].

The fuels in these compositions, magnesium (Mg) and aluminum (Al), combined with additives like Teflon and Viton, significantly influence performance parameters, including color distribution, intensity, and burn rate upon ignition. Understanding the precise proportions of Teflon and Viton used as oxidizers and binders is essential to optimize flare performance without adversely affecting parameters such as luminosity and temperature [7].

This research aims to compare the performance characteristics between MTV and ATV flares as potential weapon systems for Indonesia's defense industry. The findings are expected to provide valuable insights into pyrotechnic variations, offering new alternatives for flare formulation within the propellant and pyrotechnic industries. By establishing diverse alternatives, the MTV and ATV compositions could become catalysts for advancing Indonesia's pyrotechnic capabilities, ultimately strengthening the country's defense posture through indigenous technological development.

2. EXPERIMENTAL SECTION

2.1. Materials

The materials used were Magnesium (Mg, 95%) and Aluminium (Al, 95%) powder purchased from Dwilab Mandiri, Bandung, polytetrafluoroethylene (PTFE, 97,1%) from Anhui Fitech Materials, viton fluoropolymer from Sarana Luas Maju Kimia, and acetone (90%) from Chemical Indonesia Multi Sentosa.

2.2. Instrumentation

Several analytical and preparatory instruments were employed in this study. A Fluke 941 Light Meter was utilized to measure the luminous intensity (lux) of the MTV and ATV flare emissions during combustion. A Raytek 3i Plus Series High-Temperature Infrared Thermometer was used to record the surface and flame temperature profiles. A Fritsch Vibratory Sieve Shaker Analysette 3 PRO was applied to obtain uniform metal powder particle sizes before blending. A Memmert UN110 Universal Oven was used for drying and curing samples to ensure consistent moisture removal and binder setting. A Mettler Toledo MS204TS Analytical Balance was used for precise weighing of metal fuels, PTFE, and Viton components. High-resolution digital camera equipment was used to capture visual flame characteristics for subsequent spectral color analysis using ImageJ software.

General laboratory accessories (e.g., glassware, pipettes, stirring rods, spoons, and other non-analytical items) have been omitted as they did not directly contribute to measurement or analytical data collection.

2.3. Component Preparation

The initial steps taken involve preparing raw materials consisting of magnesium, aluminium, polytetrafluoroethylene (PTFE)/teflon, and viton. Magnesium and aluminium were sieved using a 60 micron sieve shaker for one hour at an amplitude of two millimeters [8]. After sieving, desired materials were weighed according to their required compositions using analytical balances. All materials were subsequently dried in an oven set at 60℃ for 2 h.

2.4. Mixing and Filling

After a drying process lasting approximately two hours, Viton was prepared for dissolution with acetone. The dissolution process took less than one hour. Once the binding component dissolved, the mixing process began. The mixing or blending of components started with the addition of PTFE followed by the fuel component (magnesium/aluminium). After finishing these processes, curing was done by placing them in an oven at 70°C for 3 h. The composition of mixing and filling can be seen in **Table 1**.

Table 1. MTV / ATV flare composition

Composition	Mg	Al	PTFE	Viton
MTV I	65	-	30	5
ATV I	-	65	30	5
MTV II	60	-	35	5
ATV II	-	60	35	5
MTV III	50	-	45	5
ATV III	-	50	45	5
MTV IV	40	-	55	5
ATV IV	-	40	55	5

3. RESULT AND DISCUSSION

3.1. Luminosity Measurements

Pyrotechnic devices require brightness assessment as they serve critical illumination functions in military operations after dark. This measurement represents the amount of light radiation or, more specifically, the level of brightness detected at the receiving end [8]. Higher lux readings during combustion indicate greater flame brightness. Brighter flames enhance the quality of illumination, making them particularly effective for night time visibility applications [9].

The luminosity ranking follows a consistent trend within both technologies, showing a decline from version I to IV. However, the rate of this decline varies significantly between them. MTV demonstrates a more gradual decrease in luminosity across its versions, dropping from 3572.5 lux (MTV I) to 2204.5 lux (MTV IV), a reduction of about 38% (**Fig. 1a**). In contrast, ATV experiences a steeper decline, decreasing from 2024 lux (ATV I) to 1194 lux (ATV IV), representing a more pronounced drop of approximately 41%. The observed decrease in luminous intensity with increasing PTFE proportion from 30 % to 55 % indicates that excessive oxidizer lowers the fuel-to-oxidizer ratio and total reaction enthalpy, thereby limiting metal vapor emission and reducing visible brightness in both MTV and ATV systems.

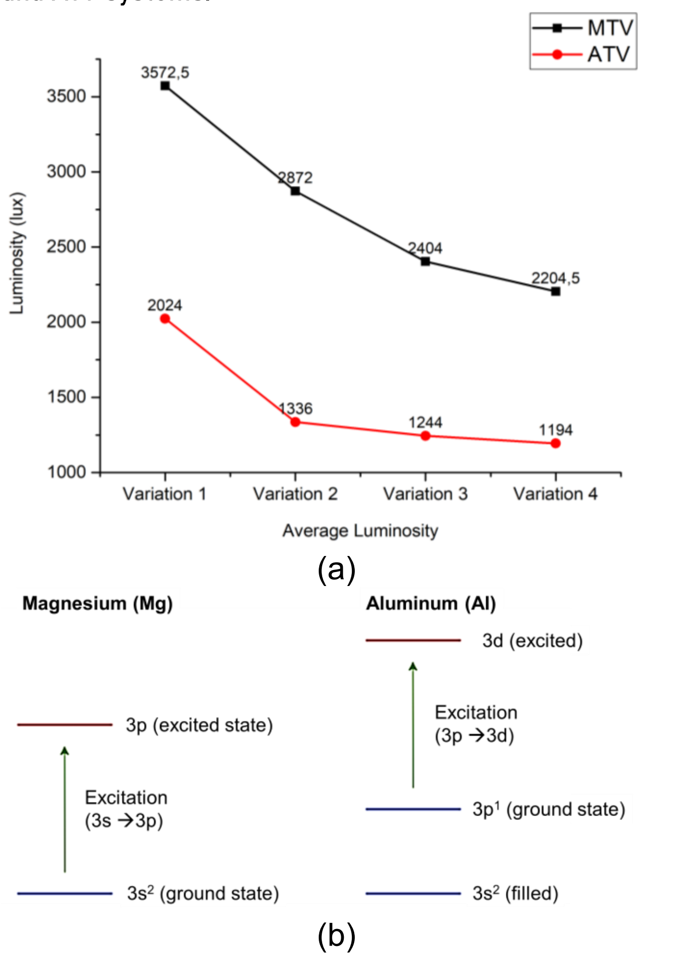

Fig. 1 (a) Experimental analysis of MTV & ATV luminosity performance; (b) Simplified energy level diagram for Mg and Al excitation during combustion

The observed difference in luminosity between Magnesium-Teflon-Viton (MTV) and Aluminium-Teflon-Viton (ATV) flare compositions arises fundamentally from differences in electronic structure, orbital excitation behavior, and energy dissipation mechanisms at the atomic level during combustion. Under the high-temperature conditions typical of combustion reactions (~1400–1600°C as measured in MTV samples), electrons from the 3s orbital are thermally excited to the 3p orbital. This 3s → 3p excitation is a dipole-allowed transition, meaning it adheres to quantum mechanical selection rules that favor photon emission [10,11].

In contrast, aluminium, with its electronic configuration of [Ne] $3s^2$ $3p^1$, presents a different scenario. The presence of a single electron in the 3p orbital results in excitations typically occurring to the 4s or 3d orbitals (**Fig. 1b**). These 3p → 4s or 3p → 3d transitions are inherently higher in energy and often less direct in terms of radiative relaxation pathways [12].

Magnesium's simple s→p transitions ensure a high quantum yield for photon emission, whereas aluminium's more complex electronic transitions introduce multiple non-radiative decay channels, further decreasing the net visible light emitted during combustion [13]. These electronic behaviors are further influenced by thermochemical properties. Magnesium combustion with PTFE releases ~33.89 kJ/g, which is higher than aluminium's ~29.85 kJ/g. This difference in enthalpy supports a more energetic excitation environment for magnesium atoms, enhancing the probability of electron promotion to excited states [4]. Additionally, magnesium's combustion forms porous MgO, allowing continued combustion and light production, whereas aluminium forms dense Al_2O_3 layers that passivate the surface and reduce light-emitting reactions [14].

3.2. Temperature Analysis of MTV & ATV Flares

The dominant temperature data for ATV and MTV flares reveals fascinating thermal characteristics that further differentiate these two technologies. In examining the average temperatures, MTV I exhibits the highest temperature among MTV variants at 1639.5°C, followed by MTV II (1520°C), MTV III (1409°C), and MTV IV (1403°C) (**Fig. 2**).

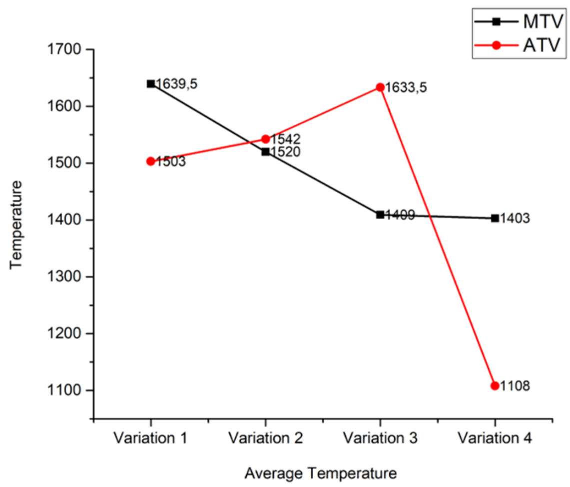

Fig. 2 Experimental analysis of MTV & ATV temperature

This creates a clear descending temperature gradient across MTV versions. Comparatively, the ATV temperature profile shows a different pattern, with ATV III reaching the highest average temperature (1633.5°C), followed by ATV II (1542°C), ATV I (1503°C), and a significantly cooler ATV IV (1108°C). This striking difference in ATV IV's temperature (approximately 395°C lower than the next coolest variant) suggests a fundamental shift in thermal properties for this specific configuration.

The significant decrease in dominant temperature observed in ATV IV (1108°C), compared to the other ATV variants, can be attributed to chemical and thermophysical factors related to the composition and combustion behavior of aluminium-based pyrotechnic mixtures [4, 15]. In ATV IV, where the aluminium content is reduced to 40% (the lowest among the ATV compositions), the available fuel is insufficient to sustain a high-temperature reaction. Moreover, the ratio between aluminium and the oxidizer (PTFE) becomes less optimal, leading to incomplete combustion or inefficient oxidant-fuel interaction. From a thermodynamics perspective, this imbalance reduces the overall enthalpy of reaction, thus generating less thermal energy. Additionally, the lower fuel density in ATV IV results in lower heat release per unit mass, contributing to the dramatic temperature drop.

This temperature-luminosity relationship may help explain the previously observed color distribution differences. MTV's ability to generate higher luminosity at comparable or lower temperatures likely contributes to its broader color gamut and warmer tones, as it potentially operates at a more optimal temperature range for diverse color production. Conversely, ATV's higher operating temperatures (particularly in ATV II and III) may push its emission spectrum toward cooler, whiter light with less color variation, explaining its more vertically concentrated color distributions and brightness-focused characteristics.

3.3. Burn Rate Performance Analysis

The burn rate data presented in the graph provides quantitative validation of the qualitative observations from the combustion imagery, offering critical insights into the performance differences between Magnesium-Teflon-Viton (MTV) and Aluminium-Teflon-Viton (ATV) flare compositions. The data reveals a clear pattern where ATV compositions consistently demonstrate higher burn rates compared to their MTV counterparts across both experimental conditions, with values ranging from 3.55 to 4.86 g/s versus 1.90 to 3.39 g/s for ATV and MTV formulations, respectively (**Fig. 3**).

In experiment 1, the ATV compositions show remarkably consistent burn rates across variants I, II, and III, with ATV IV exhibiting a slightly elevated rate of 4.86 g/s. This quantitative uniformity directly correlates with the visual observations of controlled, predictable flame structures seen in the combustion imagery. The consistency in ATV burn rates supports the earlier microscopic analysis showing more continuous, uniform aluminium-polymer interfaces that promote stable reaction front propagation. The slight elevation in ATV II's burn rate aligns with its visually more volumetric and diffuse flame pattern observed in the previous combustion images, indicating a formulation modification that enhances combustion efficiency while maintaining controlled progression. By contrast, MTV compositions in experiment 1 demonstrate a progressive increase in burn rates from variant I (1.90 g/s) through variant IV (3.40 g/s), but still remain significantly below their aluminium counterparts.

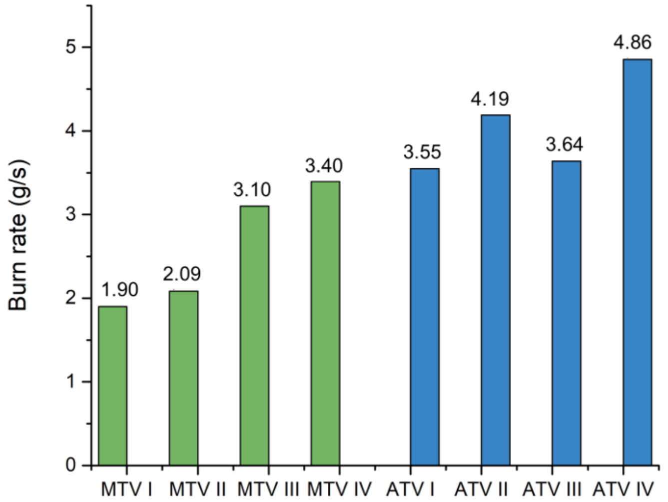

Fig. 3 Average burn rate output of MTV & ATV type flares

3.4. Colour Distribution Analysis

The visual data representing color distributions for ATV and MTV flares reveals nuanced differences in chromatic characteristics that extend beyond simple brightness variations. In experiment I, ATV flares demonstrate a distinctive vertical progression pattern, with color points forming a near-linear trajectory from orange-yellow tones at the base toward pure white at the apex. This vertical alignment indicates that ATV I through IV maintain color consistency while primarily varying in luminance values. Particularly in ATV II, the distribution appears remarkably concentrated, suggesting strict color standardization with minimal deviation from the prescribed color profile.

Under experiment I conditions, ATV compositions primarily exhibit spectral emissions concentrated in the yellow-orange range, with moderate luminosity gradients (**Fig. 4**). ATV I follows a sequential spectral shift from bright orange at the reaction zone to diffuse yellow at the flame periphery, creating a relatively narrow spectral band with minimal color variation. This limited spectral range aligns with its directed, particulate-rich combustion behavior observed in the corresponding images. ATV II displays a broader spectral profile with stronger emissions in the yellow-white region, reflecting its more diffuse and volumetric flame structure with higher overall brightness. ATV III demonstrates the most concentrated spectral output among all ATV variants, with emissions densely clustered in the yellow-white high-luminosity region, matching its visually uniform and intense combustion column. ATV IV, on the other hand, returns to a more distributed spectral pattern align to ATV I but with slightly higher intensity points, indicative of its energetic yet less uniform combustion behavior.

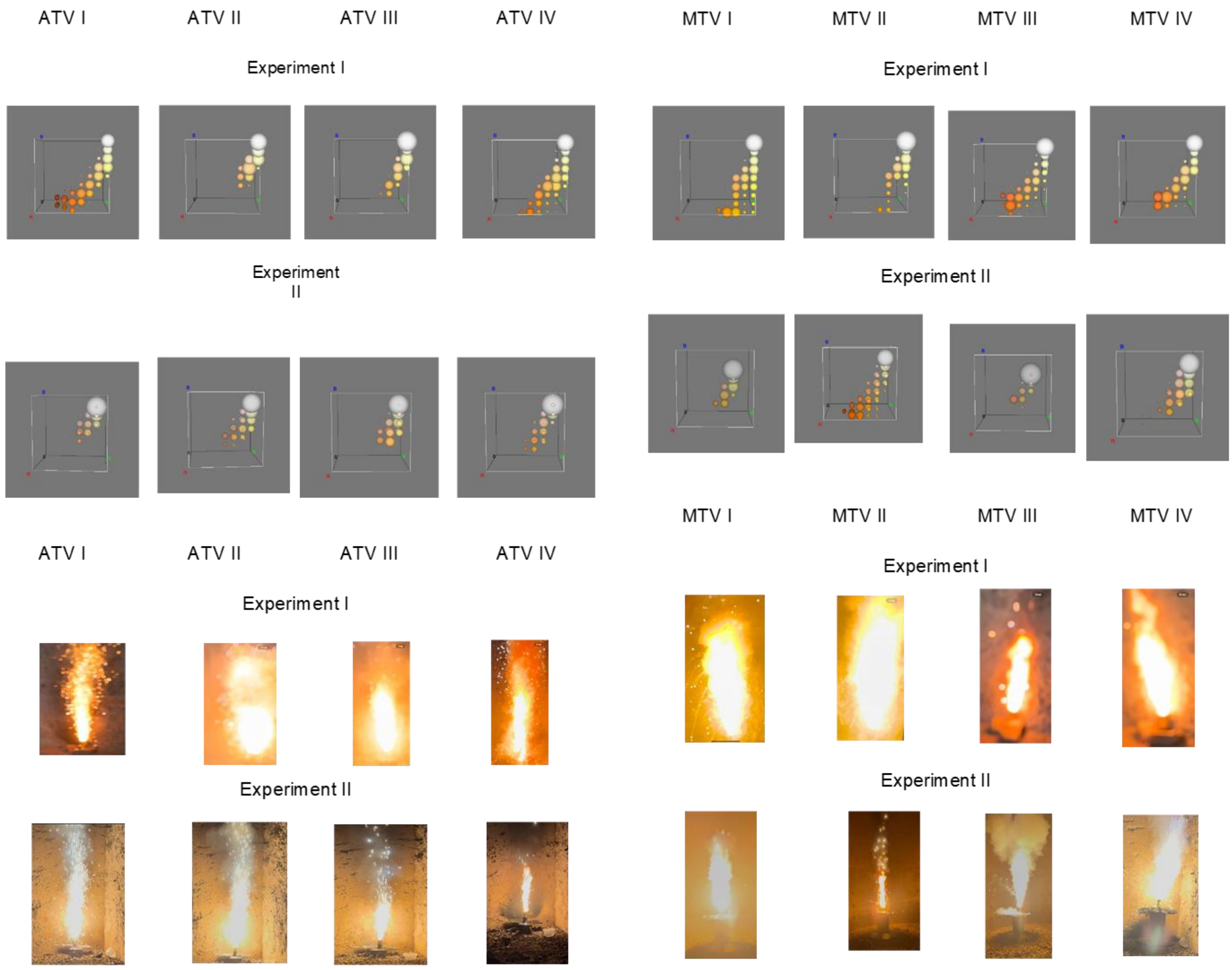

Fig. 5. Colour distribution analysis using ImageJ for ATV and MTV type flare

In contrast, MTV compositions exhibit markedly different spectral distributions, indicative of distinct reaction chemistry (**Fig. 4**). MTV I features a broader spectral range extending into the orange-red region, with high-intensity emissions characteristic of magnesium's higher combustion temperature. MTV II has the widest spectral distribution among all formulations, with strong emissions in the white-yellow high-intensity range, which corresponds with its visually overexposed and extremely bright flame. MTV III presents a unique spectral signature, where discrete high-intensity points appear across the yellow-orange-red spectrum, directly aligning with the bright emission points observed in its combustion images. MTV IV exhibits a concentrated yet intense spectral output predominantly in the orange-red region, indicative of a high-temperature combustion process that manifests in its asymmetric, high-energy flame structure.

As we could see, under experiment II conditions, both composition families experience contracted spectral distributions, though in distinctly different ways. The ATV formulations exhibit a shift toward lower intensity emissions, with a more concentrated spectral range and reduced presence in high-luminosity regions. This spectral contraction correlates with the more contained and columnar flame structures observed in the combustion images. Interestingly, ATV IV shows the least spectral reduction among ATV variants, retaining relatively higher intensity points despite its visually smaller flame volume. This suggests efficient combustion with concentrated energy release, reinforcing previous findings regarding its formulation's burn characteristics.

3.5. Determining the Density for MTV & ATV Flares

The determination of density is one of the factors that can influence pyrotechnic performance. In this experiment, the different rasio composition of materials showed a change in density in the MTV and ATV flare mixtures. The data on density changes along with their performance are presented in the **Table 2**. It also illustrates how density affects the luminosity and temperature in pyrotechnic performance.

Table 2 Density of MTV & ATV flares

Composition type	Composition density (g/cm^3)
MTV I	1.87
MTV II	1.89
MTV III	1.93
MTV IV	1.98
ATV I	2.49
ATV II	2.46
ATV III	2.41
ATV IV	2.36

MTV and ATV flares show opposite density-performance relationships due to their different metal fuels. MTV flares, containing magnesium, perform better at lower densities (1.87 g/cm^3) because the more porous structure allows magnesium's high reactivity and low boiling point to create effective vapor-phase combustion, producing greater light and heat. As MTV density increases to 1.98 g/cm^3, both luminosity and temperature decrease.

In contrast, ATV flares with aluminum fuel work best at higher densities (2.49 g/cm^3), where tighter packing improves contact between aluminum particles and fluoropolymer oxidizers. This promotes efficient solid-phase combustion and better heat retention. When ATV density decreases to 2.36 g/cm^3, both luminosity and temperature drop significantly.

These opposing trends demonstrate how optimal flare formulation depends on the specific thermochemical properties of the metal fuel. Magnesium-based MTV flares benefit from porosity that facilitates rapid oxidation, while aluminum-based ATV flares require density for sustained thermal feedback due to aluminum's higher melting point and slower ignition.

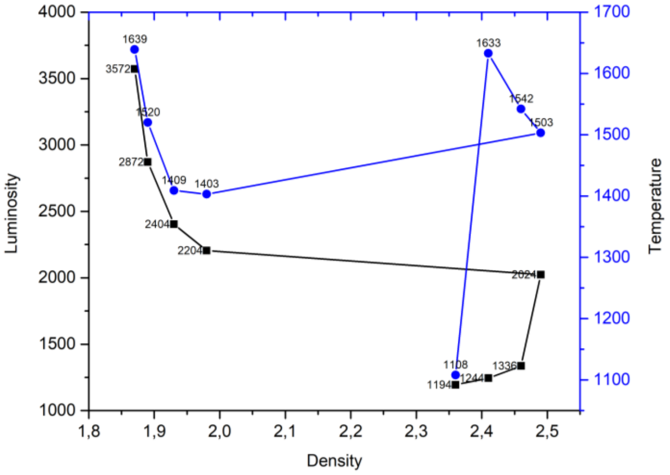

Fig. 6 Density relationship and its effect on luminosity and temperature of MTV & ATV flares

The relationship between spectral distribution and combustion performance is particularly evident in high-performing variants. ATV III's concentrated high-intensity spectral pattern corresponds with its visually uniform and efficient combustion column, while MTV II's broad high-intensity spectral range matches its exceptionally bright and expansive flame structure. The spectral data confirms that while MTV compositions achieve higher combustion temperatures with wider spectral outputs, ATV compositions maintain more consistent spectral characteristics across varying conditions (**Fig. 6**). These findings align with burn rate data and microscopic interface analyses, further reinforcing the greater stability and predictability of ATV formulations compared to the higher-reactivity but less stable MTV compositions.

The detailed experimental data comparing MTV and ATV flares reveals critical relationships between burn rate, intensity, and temperature that define the performance profiles of these technologies. This analysis examines these relationships across both flare types and their iterations to understand their operational distinctions.

CONCLUSION

The comparative analysis of Magnesium–Teflon–Viton (MTV) and Aluminium–Teflon–Viton (ATV) flare compositions demonstrates that the metal fuel type significantly influences combustion and optical performance. The MTV formulation exhibited the highest luminous intensity, reaching 3572.5 lux (MTV I), while the ATV formulations produced lower values ranging from 2024 lux (ATV I) to 1194 lux (ATV IV). In addition to luminosity, other performance parameters revealed complementary behaviors. The ATV series achieved faster and more stable burn rates (up to 5.55 g/s) and better combustion uniformity, whereas MTV maintained higher combustion temperatures and broader spectral color emissions. Density analysis indicated that MTV performed optimally at lower densities due to enhanced vapor-phase combustion, while ATV benefited from higher densities that improved metal-oxidizer contact and heat retention.

These findings highlight a trade-off between optical brightness and combustion stability. Magnesium-based MTV formulations are advantageous for illumination and signaling applications requiring high brightness and wide spectral emission, whereas aluminium-based ATV compositions are better suited for time-sensitive or decoy systems that demand rapid and controlled combustion.

Future research will focus on optimizing fuel–oxidizer ratios, exploring hybrid or alloyed metal fuels (e.g., Al–Mg or nanoparticle additives) to combine brightness and stability, and developing thermochemical and spectral models for performance prediction. Further studies on industrial scalability and local material utilization—using Indonesia's available aluminium and magnesium resources—will support the advancement of self-reliant pyrotechnic and defense material technologies.

SUPPORTING INFORMATION

This article contains no supporting material.

ACKNOWLEDGEMENTS

This work was funded by the Department of Chemistry, Republic of Indonesia Defense University and supported by research facility of PT. Dahana.

CONFLICT OF INTEREST

The authors have no conflict of interest in this publication.

AUTHOR CONTRIBUTIONS

SAW and EP conceptualized the research and finalized the manuscript. G, MW, and AM conducted the experiment, analyzed data, wrote, and revised the manuscript. All authors agreed to the final version of the manuscript.

REFERENCES

[1] Agrawal, J.P. 2010. High *Energy Materials: Propellants Explosives and Pyrotechnics.* John Wiley & Sons.

[2] Biegańska, J., & Barański, K. 2022. Experiments with pyrotechnic compositions based on a mathematical model: part ii pyrotechnic compositions producing an acoustic effect with optimum properties. *Energies.* 15(3). 794. doi: 10.3390/en15030794

[3] Bolognesi, P., Pravica, L., Veronesi, S., Fainelli, E., Avaldi, L., & Bartschat, K. 2008. An (e, 2e) study of the ionization and ionization–excitation of magnesium to the Mg^+ (3s),(3p) and (4s/3d) states. *J. Phys. B: At. Mol. Opt. Phys.* 41(6). 065203. doi: 10.1088/0953-4075/41/6/065203

[4] Chen, Z., Kuckling, D., & Tiemann, M. 2018. Porous aluminum oxide and magnesium oxide films using organic hydrogels as structure matrices. *Nanomaterials.* 8(4). 186. doi: 10.3390/nano8040186

[5] Juknelevicius, D., Alenfelt, P., & Ramanavicius, A. 2020. The performance of red flare pyrotechnic compositions modified with gas generating additives. *Propellants Explos. Pyrotech.* 45(4). 671- 679. doi: 10.1002/prep.201900322

[6] Li, J.S., Chung, C.M., Yang, T. M., Hwang, C.C., Lu, K.T., & Yeh, T.F. 2018. Combustion rate and light emission of $Mg/NaNO_3/Na_2C_2O_4$/binder-flares. *Propellants Explos. Pyrotech.* 43(5). 512-521. doi: 10.1002/prep.201700257

[7] Martínez-Martín, A., Bocho-Roas, A., Carmona-Fernández, D., Calderón-Godoy, M., Jaramillo-Morán, M.Á., & González, J.F. 2023. Influence of illumination parameters on night sky observation in rural áreas. *Sustainability.* 15(12). 9359. doi: 10.3390/su15129359

[8] Plata, G.J.D., & Delos Santos, R.M. 2022. Application of image processing programs in color analysis of wood photodegradation. *J. Phys.: Conf. Ser.* 2288(1). 012003. doi: 10.1088/1742-6596/2288/1/012003

[9] Putri, A., Suwardi, S., Suryaningtyas, D.T., Oktariani, P., Widjaja, H., & Randrikasari, O. 2024. Land reclamation technology for former bauxite mines using adaptive plant seedballs and faba-enriched compost. *Risalah kebijakan pertanian dan lingkungan Rumusan Kajian Strategis Bidang Pertanian dan Lingkungan.* 11(1). 46-62. doi: 10.29244/jkebijakan.v11i1.53149

[10] Nurrosyid, N., Fahri, M., Apriliyanto, Y.B. and Basuki, R. 2022. Novel absorber material design based on thiazole derivatives using DFT/TD-DFT calculation methods for high-performance dye sensitized solar cell. *Indones. J. Chem. Stud.* 1(1). 16-23. doi: 10.55749/ijcs.v1i1.5

[11] Sabatini, J.J. 2018. A Review of illuminating pyrotechnics. *Propellants Explos. Pyrotech.* 43(1). 28–37. doi: 10.1002/prep.201700189

[12] Tsuboi, T. 2025. *Basic Physical Parameters of Single Emitting Molecules. Organic Electroluminescence: From Molecular Structure to Device Performance*. pp. 189-192. John Wiley and Sons: New Jersey.

[13] Sabidó, M., de Andrés, J., Sogas, J., Lucas, J. M., Albertı, M., Bofill, J. M., & Aguilar, A. 2004. Electronic excitation and charge transfer processes in collisions between Mg (3 1 S) atoms and Rb^+ (1S) ions in the 0.07–4.00 keV energy range. *J. Chem. Phys.* 121(11). 5284-5292. doi: 10.1063/1.1782774

[14] Sadek, R., Kassem, M., Abdo, M., & Elbasuney, S. 2017. Novel yellow colored flame compositions with superior spectral performance. *Def. Tech.* 13(1). 33–39. doi: 10.1016/j.dt.2016.12.001