Experimental Study on the Performance and Emission Parameters of a Dual Fuel Diesel Engine

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Abstract
Concerns about health risks from harmful emissions, rising fuel prices, and fuel depletion have all been linked to the use of fossil fuels in internal combustion engines. The use of acetylene as an alternative fuel has drawn the attention of numerous researchers due to its advantages, including ease of availability, improved combustion, and a decrease in harmful emissions. A diesel engine operating in dual fuel mode with a constant CR of 17.5 and acetylene flow rates ranging from 1 LPM to 3 LPM was used for the current experimental study. When performance parameters and emission were taken into account, the lower amount of biodiesel and 4 LPM of acetylene produced better results. Brake thermal efficiency and mechanical efficiency were found to have increased by 19% and 30%, respectively. Additionally, a 19% decrease in brake-specific energy consumption was observed. Although CO_2 and HC emissions dropped by 4% and 56%, respectively, higher CO and NO_x emissions were noted at high load levels and low CR, as other researchers have found in related studies.

Keywords**:** Alternative fuel; Diesel engine; Dual fuel; Performance; Emission

1. Introduction
The global energy crisis has become a pressing issue, impacting economies, societies, and the environment. As fossil fuel reserves dwindle and climate change accelerates, the requirement for sustainable and innovative energy solutions has never been more critical [1]. The energy crisis is characterized by rising energy prices, supply shortages, and increased demand for energy resources. Factors contributing to this crisis include geopolitical tensions, natural disasters, and the ongoing effects of the COVID-19 pandemic, which have disrupted supply chains and energy production [2]. As countries strive to recover economically, the demand for energy continues to surge, leading to heightened competition for limited resources [3]. This is happening due to excessive usage of fossil fuels, the adverse effect of combustion of fossil fuel on human being and environment etc. The dual fuel engine operation is shown in figure 1.

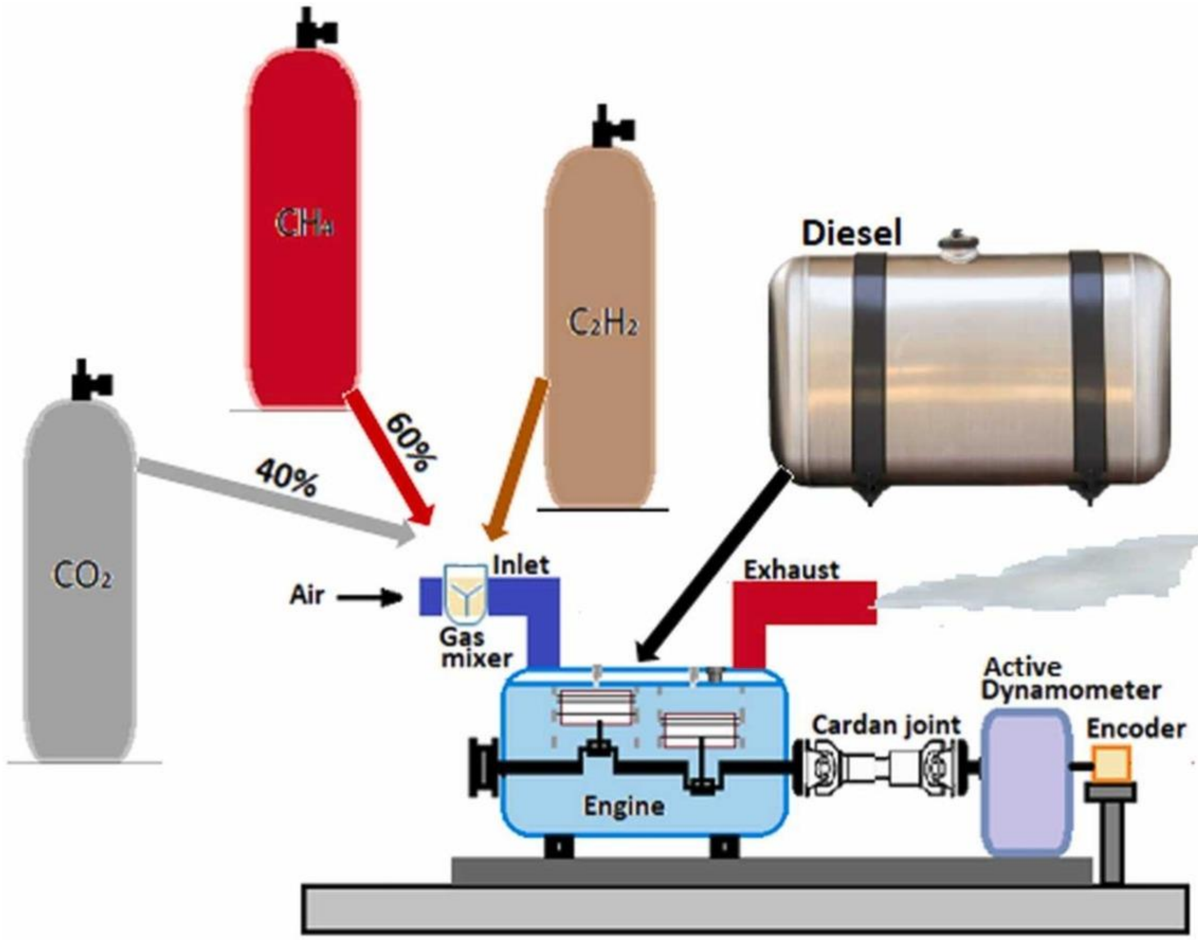

Fig.1 Dual fuel mode engine operation

Fossil fuels are the primary source of greenhouse gas (GHG) emissions, which are the leading contributors to climate change. The burning of coal, oil, and natural gas releases carbon dioxide (CO_2) and other harmful pollutants into the atmosphere, resulting in global warming and severe weather patterns [4]. The Intergovernmental Panel on Climate Change (IPCC) has warned that if we do not transition away from fossil fuels, we could face catastrophic consequences, including rising sea levels, extreme heatwaves, and increased frequency of natural disasters. Moreover, the extraction and transportation of fossil fuels have devastating impacts on ecosystems [5]. Oil spills, coal mining, and fracking can lead to habitat destruction, water contamination, and loss of biodiversity [6]. For instance, oil spills can devastate marine life, while coal mining can result in soil erosion and the destruction of landscapes. These environmental consequences not only harm wildlife but also affect human health and livelihoods, particularly in communities that depend on natural resources for their survival. Overall, it can be understood that the energy crisis is a multifaceted problem exacerbated by the reliance on fossil fuels, which have severe negative impacts on the environment [7]. Addressing this crisis requires a collective effort to shift towards sustainable energy solutions that prioritize ecological health and the well-being of future generations. The time to act is now, as the consequences of inaction will only deepen the challenges, we face in securing a sustainable and healthy planet [8][9].

This research paper explores the utilization of biodiesel and acetylene in a dual fuel mode, examining their performance and emission parameters. The combination of these two fuels presents a promising alternative to conventional diesel, potentially enhancing engine efficiency while reducing harmful emissions. The analysis includes the benefits and challenges associated with this dual fuel system, as well as its impact on engine performance metrics and environmental outcomes.

2. Test fuels

The alternative fuel can be majorly classified as first-generation biofuels, second generation biofuels and third generation biofuels [10]. Biofuels have emerged as a sustainable alternative to fossil fuels, offering a renewable source of energy that can help mitigate climate change and reduce greenhouse gas emissions [11]. Many studies explore the various types of biofuels, including their production methods, characteristics, and performance metrics, specifically focusing on brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) [12][13] [14]. Understanding these parameters is crucial for evaluating the viability of biofuels in internal combustion engines. In this work biodiesel derived from Jatropha oil and its blend with waste derived fuel has been considered as alternative to diesel fuel.
The core of the biodiesel production process is transesterification, which involves the following steps:

- **Mixing**: The feedstock is mixed with an alcohol (usually methanol or ethanol) and a catalyst (commonly sodium hydroxide or potassium hydroxide).
- **Reaction**: The mixture is heated and stirred, allowing the triglycerides in the feedstock to react with the alcohol. This reaction produces fatty acid methyl esters (biodiesel) and glycerol.
- **Separation**: After the reaction, the mixture separates into two layers: biodiesel (top layer) and glycerol (bottom layer).

Acetylene is a colorless gas that is highly flammable and is primarily used in welding and cutting applications [15]. In the context of dual fuel engines, acetylene can serve as a supplementary fuel that enhances combustion efficiency. Acetylene has a high calorific value, which can improve overall engine performance [16]. When burned, acetylene produces fewer emissions compared to traditional fossil fuels. In a dual fuel engine, biodiesel serves as the primary fuel while acetylene is injected as a secondary fuel. This configuration allows for better combustion characteristics and can lead to improved thermal efficiency.

3. Experimentation

One method to address the issue of scrap tires is through biological processing or recycling. Thermochemical conversion plants can be used to turn these used tires into carbon material and energy. JME and TPO, the test fuels, were sourced from a commercial enterprise. A single-cylinder diesel engine with a maximum power productivity of 4.4 kW was used for the research. The experimental setup layout is depicted in figure 2. In order to obtain a baseline analysis, diesel was used for the first set of tests, followed by the dual fuel mode operation. Diesel was used to start the experiments, and once the engine had warmed up, it was switched to biodiesel and then biodiesel with acytelen gas in dual fuel mode operation at the initial injection timing of 23 ˚CA bTDC (as specified by the engine manufacturer) in order to collect reference data. Additionally, experiments with the different flow rates of acetylene and biodiesel a piolet fuel were carried out at standard injection timings. By adding or removing shims, the number of shims installed beneath the pump's plunger was changed, changing the initial injection timing. A probe inserted into the engines' exhaust was used to measure the emissions of HC, CO, O_2, and NO using a AVL instruments gas analyzer. A type-K thermocouple coupled to an Energy combustion analyzer was used to measure the exhaust temperature. Using a 2000 ml fuel reservoir set on a 5000 gm Ohaus digital balance, fuel consumption was calculated. A digital stop watch was used to measure the amount of time that had passed. The standard operating procedure for all runs was to put the engine under the desired load for about ten minutes in total, with the exhaust temperature and emissions readings being taken after about eight minutes. Diesel fuel at room temperature was used for the diesel tests.

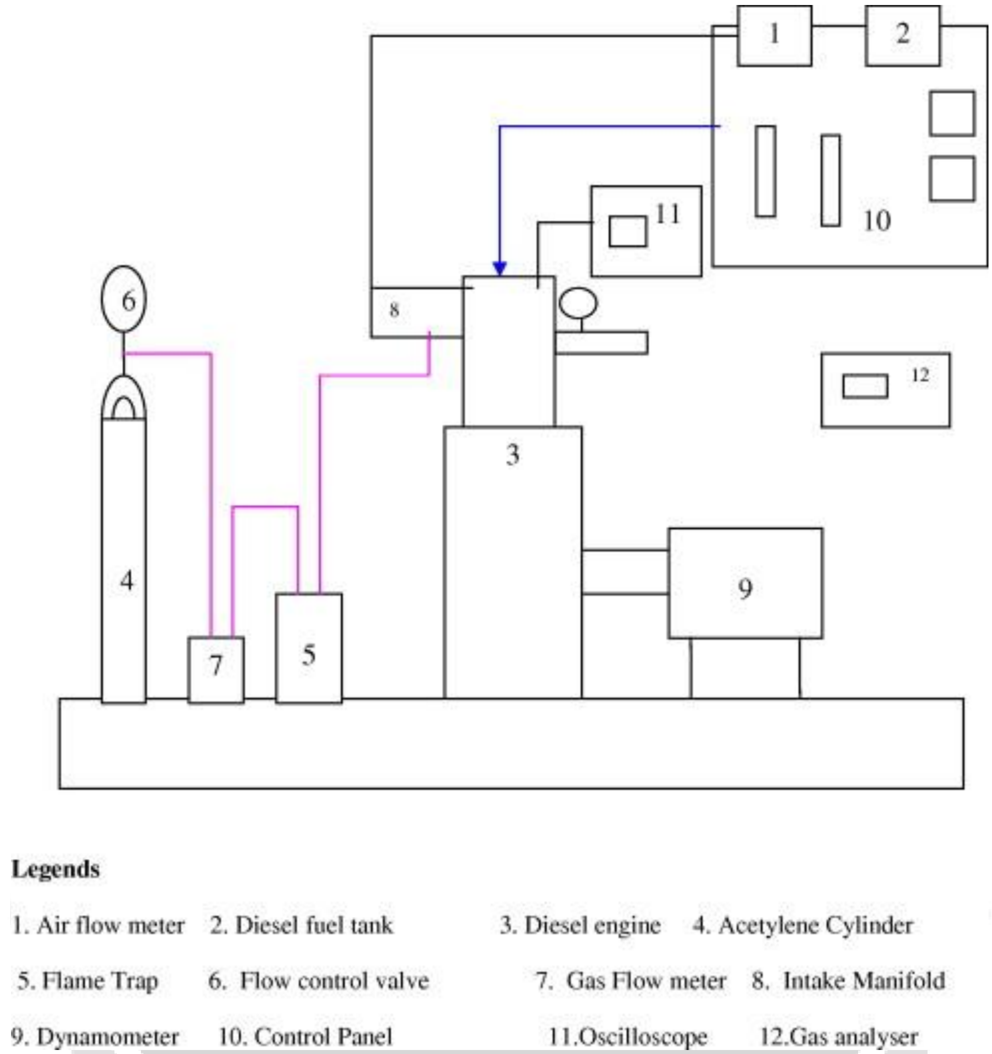

Fig.2 Schematic diagram of the set up

4.Performance parameters

Brake thermal efficiency (BTE) is a measure of the efficiency of an engine in converting the heat from fuel into useful work [17]. It is defined as the ratio of the brake power output to the heat input from the fuel. Higher BTE indicates better engine performance and fuel utilization. Generally, shows comparable or slightly higher BTE than petroleum diesel, attributed to its higher cetane number and better combustion characteristics[18]. Brake specific fuel consumption is a measure of the fuel efficiency of an engine, defined as the amount of fuel consumed per unit of power produced. Lower BSFC values indicate better fuel efficiency. Figure 3 illustrates how, a engine gives output when it is operated with biodiesel-acetylene in dual fuel mode operation. The BTE is calculated by multiplying the fuel's lower heating value by the power output to mass flow rate ratio [19]. Between all the fuels used in this study, diesel had the highest BTE value, 29.9% at rated BP. At rated BP, it was 29.8, 29.8, 29.9, and 31.4% for the different flow artes of acetylene, respectively. When two different fuels with different densities and calorific values are blended, the engine's BTE rises with the appropriate term. Figure 4 shows about the amount of energy goes in waste without utilizing for useful form of work.

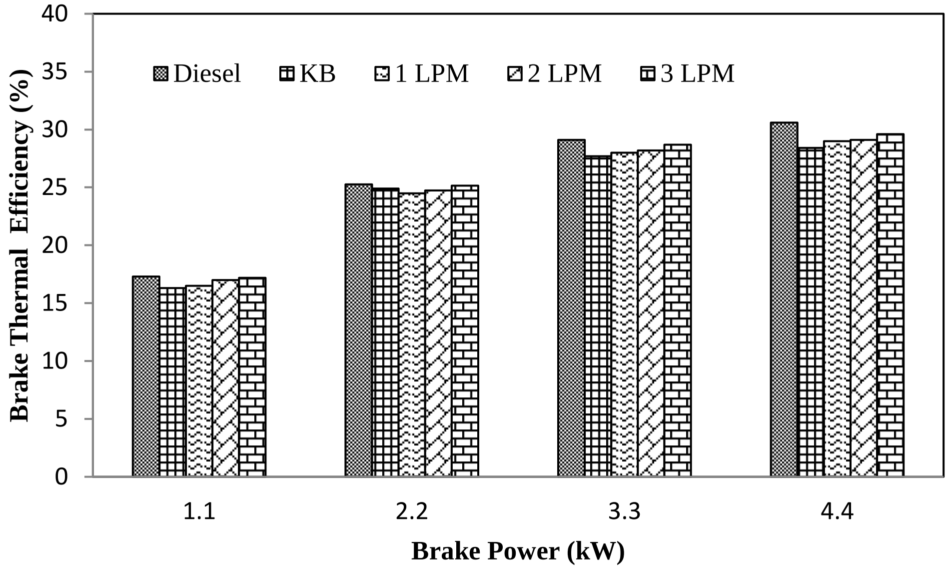

Fig. 3 Load Vs BTE

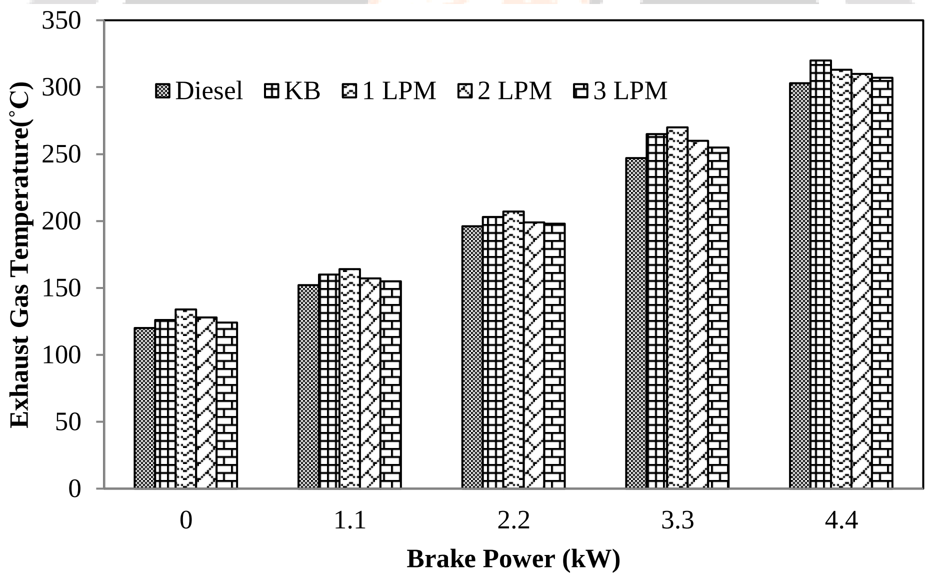

Fig. 4 Load Vs EGT

5. Emission parameters

Nitric oxide is a precursor to nitrogen dioxide (NO_2), which contributes to the formation of ground-level ozone [20]. The impact of biodiesel blends on NO emissions is complex and can vary based on the blend ratio and engine type [21]. Generally, lower NO emissions are observed with biodiesel blends due to the lower combustion temperatures associated with biodiesel. However, some studies report increased NO emissions at higher biodiesel concentrations, suggesting that the combustion characteristics of biodiesel can influence NO formation. It should be mentioned that the majority of vegetable oils have trace amounts of proteins that contain nitrogen [22]. Through combustion, this tiny quantity of nitrogen, in addition to atmospheric nitrogen, produces additional NOx emissions. This could be one of the reasons why vegetable oils emit more NO than diesel fuel.

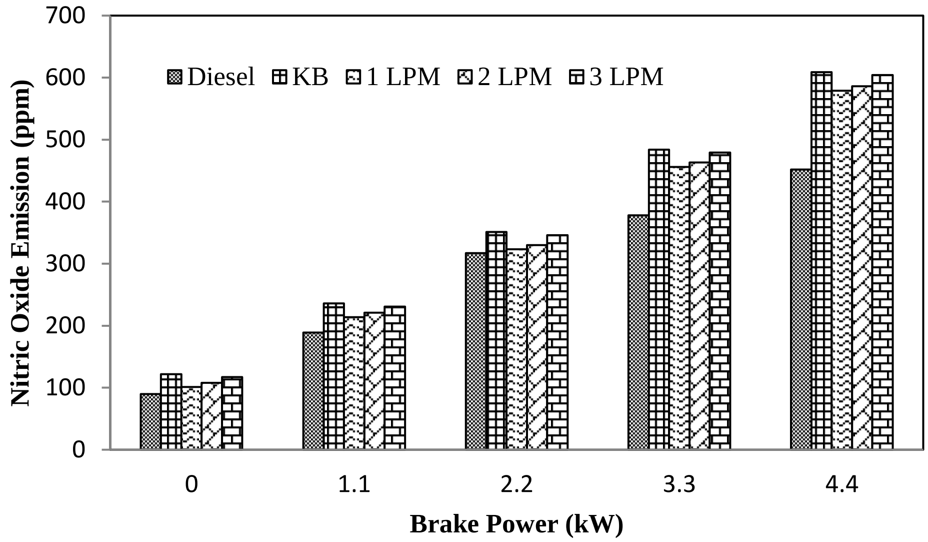

Fig. 5 Load Vs NO

The result of incomplete combustion is these emissions. Carbon monoxide is a colorless, odorless gas that is harmful to human health and the environment [23]. Studies have shown that biodiesel blends generally result in lower CO emissions compared to conventional diesel [24]. The oxygen content in biodiesel facilitates more complete combustion, leading to reduced CO formation. However, the extent of CO reduction can vary depending on the biodiesel blend ratio and the engine operating conditions.

The incomplete burning of working fuel within the combustion chamber is indicated by the emission of HC. HC emissions for various blends at 75% load for a range of fuel injection temperatures are displayed in Fig. 5. As the preheating temperature increases, the amount of HC emissions decreases. This is because the JME contains oxygen molecules, which promote better combustion within the engine's cylinder. As the blend temperature rises from 50 °C to 70 °C, the HC emission for blend decreases, as seen in figure. Hydrocarbon oxides, including unburned hydrocarbons, are a significant contributor to air pollution and smog formation [25]. Biodiesel blends typically exhibit lower HC emissions due to improved combustion efficiency. The presence of oxygen in biodiesel enhances the oxidation of fuel, resulting in fewer unburned hydrocarbons. However, some studies indicate that higher blends of biodiesel may lead to increased HC emissions under certain conditions, highlighting the need for further research.

Smoke opacity is a measure of the particulate matter emitted during combustion, which can affect air quality and visibility [26]. Biodiesel blends have been shown to reduce smoke opacity compared to conventional diesel fuel. The higher cetane number and lower aromatic content of biodiesel contribute to more complete combustion, resulting in lower particulate emissions [27]. However, the reduction in smoke opacity can vary depending on the specific biodiesel blend and engine settings [7].

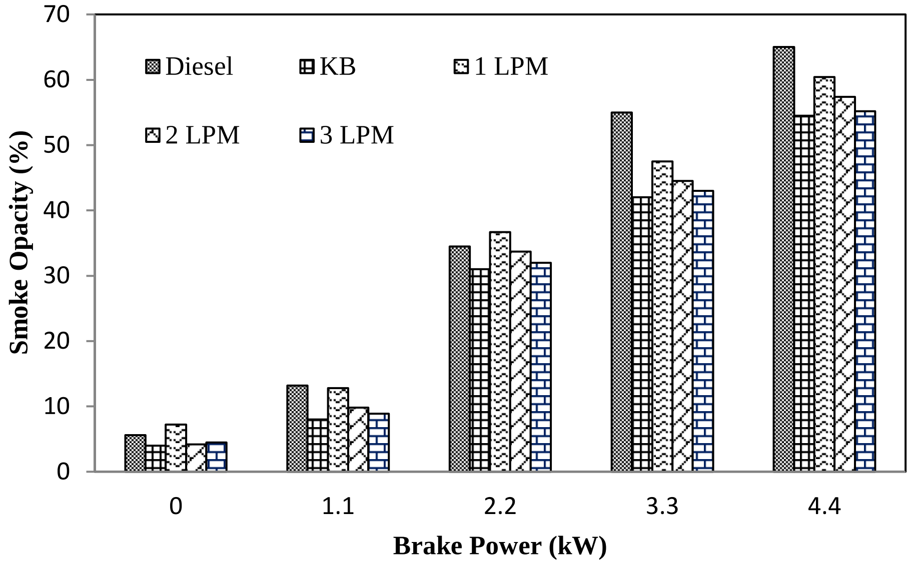

Fig. 6 Load Vs Smoke Opacity

6. Conclusion

The performance of biofuels in terms of brake thermal efficiency and brake specific fuel consumption varies significantly based on the type of biofuel and the engine configuration. While biofuels present a promising alternative to fossil fuels, ongoing research and development are essential to optimize their performance and integration into existing energy systems. Understanding these performance metrics is crucial for assessing the potential of biofuels in reducing reliance on fossil fuels and achieving sustainability goals. Overall, it can be understood that the energy crisis is a multifaceted problem exacerbated by the reliance on fossil fuels, which have severe negative impacts on the environment. Addressing this crisis requires a collective effort to shift towards sustainable energy solutions that prioritize ecological health and the well-being of future generations. The time to act is now, as the consequences of inaction will only deepen the challenges, we face in securing a sustainable and healthy planet.

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