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Study On the Performance of Plastic Waste Oil in CI Engines: A Review.

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ABSTRACT

A sustainable energy and environment needed to be created by using alternate energy \instead of fossil fuels, creating a sustainable energy and environment. The consumption and production of plastic has been rising very rapidly due to its strength, durability, lighter weight and flexibility. The disposal of plastic has become a major problem due to its non-biodegradable nature. Pyrolysis is one of the common processes used to treat plastic waste. This paper deals with the study of pyrolysis process to convert plastic waste into crude oil. Comparison of various catalysts used for the pyrolysis process was also studied. The effects of the Plastic waste oil on the performance of diesel engines were also discussed in this study. It was observed that the pyrolysis process is the effective method to treat plastic waste and the obtained oil can be used as alternate fuel for CI engine.
Keywords: Pyrolysis, waste plastic oil, Catalyst, Fly ash and Diesel engine.

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INTRODUCTION

Development of alternate energy sources such as Biomass, hydropower, geothermal energy etc. to be focused due to crisis of fossil fuels. Some of the alternative fuel technologies includes bio ethanol, bio diesel lipid derived bio fuel, waste oil recycling, pyrolysis, gasification, dimethyl ether and biogas. Due to industrial growth and change in the production patterns, plastic waste generation in the world is continuously increasing. Management of plastic waste has become a major problem due to higher population growth rate. Plastic material contributes major percentage in plastic packaging material, poly shopping bags, P E T bottles and other house hold items.Due to light weight, cheap, flexible, reusable, do not rust or rot properties, plastic production rate grown up by 10% every year on global basis since 1950's. Figure 1 shows global per capita consumption of plastics.

Plastics are non-biodegradable in nature. A number of research works has been carried out due to the disposal and decomposition of plastics. Land filling, mechanical recycling, biological recycling, thermal recycling, & chemical recycling are some of the plastic disposal methods which are in current use. Chemical recycling is one of the advantageous methods of all the above mentioned. In order to dispose the mixed waste plastic, some of the alternate methods should exist. Among those alternate methods, pyrolysis is one of the best methods. As the conversion rate of fuel from plastic waste is high, pyrolysis process is favored. To reduce CO2 burden on environment, hydrocarbon polymers can replace fossil fuels. Incineration of plastic waste is an alternate method to recover energy from waste polymers.

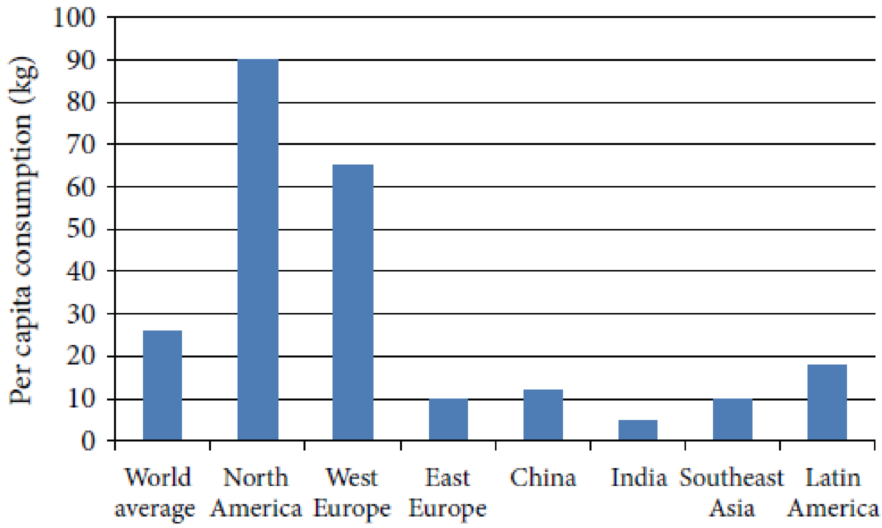

Figure 1 Global per capita consumption of plastics [4]

Pyrolysis is a conversion process by which waste is converted to energyin order to deliver bio fuel which replaces fossil fuel. It is the process of thermal degradation of plastic waste in absence of oxygen. Pyrolysis process is a cracking process which breaks the polymeric chains into useful smaller molecular weight compounds. Products of this process utilized as fuels or chemicals in various applications. A cylindrical chamber was designed in order to treat plastic wastes and a condenser system was specially designed to condense the produced paralytic gases. The above process yields hydrocarbon distillate comprising straight, branched chain aliphatic, cyclic aliphatic & aromatic hydrocarbon.

Catalysts with high cracking property are needed to pyrolysis plastics such as polyethylene and polypropylene of olefin series.

Literature review

DohareDevendra [1] has introduced the blend of waste plastic pyrolysis oil with diesel as alternate fuel in a direct injection diesel engine. It was observed that engine could operate with pure waste plastic oil. A study on pyrolysis process was carried out by PawarHarshal [2] to convert plastic waste into fuel without oxygen. He concluded that, engine can run by using fuel derived from plasticwaste and it reaches full efficiency.

Omprakash et al. [3] investigated the fuel oil produced from plasticwaste and the variation of polymer material structurewith effect of temperature on L.D.P.E (Low Density polyethylene) fuel oil was also studied. Christine Clectus [4] synthesized petroleum based fuel by catalytic pyrolysis of waste plastics. Different catalysts were used to produce plastic waste oil samples from plasticsunder different reaction conditions and they have been subjected to parametric study based on various parameters.

The conversion of polyethylene to transportation fuel using different catalysts such as HY, rare earth metal exchanged y type (REY) etc. was performed by Songip et al [5]. He has found that REY Zeolite was the most suitable catalyst for the production of plastic oil with highest octane number and gasoline yield. Jan et al [6] compared the effect of non- acidic catalysts for pyrolysis of plastics.

C. Wongkhorsub [7] assessed the engine performance by using tire pyrolysis oil, plastic pyrolysis oil and diesel oil in single cylinder multipurpose agricultural diesel engine and compared the properties of the above oils. The performance of a constant speed, stationery diesel engine has been evaluated experimentally using different combination of blend of plastic oil- diesel by V I Narayana [8]. He examined that the volumetric efficiency decreaseswith increase in brake thermal efficiency and mechanical efficiency.

Soo Hyun Chung [9] carried out an experimental work by using synthesized catalysts for the pyrolysis process and compared the results with the performance of other catalysts. This research work deals with the study of pyrolysis method with & without catalysts. The effect of plastic waste oil on C.I. diesel engine performance was also studied from the above literature and the results were compared to select the best optimum reaction condition.

Production of waste plastic oil

The source of waste plastic selected is plastic as it comprises prominent percentage. Silica Alumina, Zeolite, Barium carbonate, Titanium chloride are identified as catalystsfor the waste plastic oil production. Polymer to catalyst ratio carried is 4:1 with the reaction temperature of 350^{0}C to 450^{0}C. The specifications of reactor parameters were given in Table 1 shown below.

Table 1 Specification of Reactor

REACTOR PARAMETES	*SPECIFICATION*
Loading Capacity of Reactor	1.5 kg of waste plastic
No. of ceramic heaters	3
Power range of each heater	2000 W
Arrangement of heater	Series
Diameter of CI pipe	17cm
Length of CI pipe	60 cm
Type of heat exchanger used as condenser	Double pipe counter flow heat exchanger
Length of Heat exchanger	90 cm
Coolant temperature in 1st condenser	28C
Coolant temperature in 2nd condenser	10C
Waste plastic storage container	Steel container with diameter 15 cm; Height 20 cm; Packing density 424 kg/m3

Nitrogen is used as carrier gas to provide inert atmosphere for pyrolysis and the flow rate should be fixed. Ceramic electric heater, steel container, two condensers, two oil collectors & nitrogen source are the components of the setup. The container mentioned above is placed inside the heater. Melted waste plastic can move downwards under gravity and it blocks the passage of Nitrogen gas. In order to prevent the blockage waste plastic is kept in the container.

Working of Reactor

Waste plastic was mixed with catalyst in a twin round mill, before it is being supplied to the heater. To get devoid of moisture content, plastic gets heated during mixing. Air from reactor is replaced by flowing nitrogen to carry out pyrolysis under anaerobic condition. During the pyrolysis of the plastic inside the reactor, vapor fraction formed and flows out along with N_2 out of reactor. Figure 2 shows the schematic diagram of batch reactor.

In condenser 1, gas mixture is first cooled with water at room temperature. Vapor fraction is condensed & collected in a collector fitted to condenser. Remaining uncondensed vapour flows into second condenser and cooled by water at 10^0C. Coolant is cooled by external refrigeration set up. Then vapor is condensed and collected in collector tank.

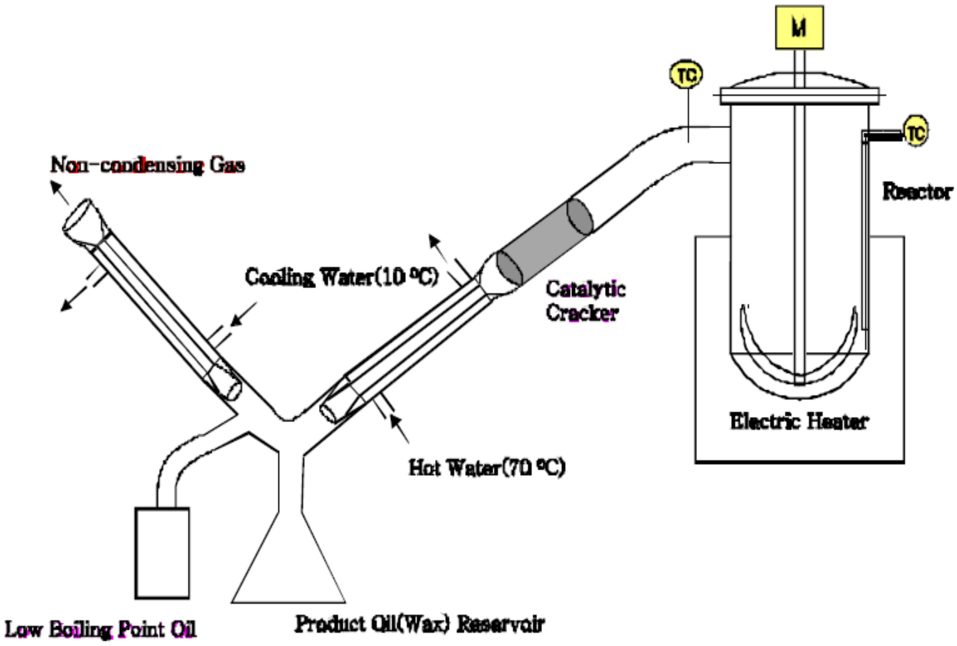

Figure 2 Batch Type Reactor for Pyrolysis of Waste Plastics [9]

From the surveyed literature reviews shown above, some of the catalysts were identified for efficient pyrolysis process to get more oil yield. Some of the catalysts used in this study were Flyash, Zeolite (Z2), Silica Alumina (SA1) (83.3% Si, 16.7% Al), SA1+Z1 (70% SA1, 30% Z1). Chemical composition of the above mentioned catalysts used in this study was given in Table 2 shown below

Table 2 Chemical composition of catalyst

Component	Flyash(%)	Z2(%)	SA1(%)	SA1+Z1(%)
SiO_2	59	33	57.2	50
Al_2O_3	21	28	29.4	30
Na_2O_3	0.37	17	1.55	10
Fe_2O_3	3.7	-	-	-

RESULTS AND DISCUSSION

Oil yield by using different catalysts

Oil Samples were produced without using catalysts and also in presence of catalysts such as flyash, Z2, SA1, SA1+Z1 (70% SA1+30% Z1) at reaction temperature between 400°C and 550°C through pyrolysis process. Different optimum properties of plastic oil derived by using the above catalysts were shown in Table 3.

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Table 3 Optimum properties of Plastic oil

Catalyst	Optimum properties of plastic oil				
	Temperature °C	Liquid collected (mL)	Calorific Value (MJ/kg)	Flash point °C	Fire point °C
None	450°C	80	41.35	<32°C	≤32°C
Z2	450°C	100	42.24	<32°C	34°C
SA1	425°C	145	41.36	<32°C	34°C
SA1+Z1	425°C	130	44.52	<32°C	35°C
Flyash	480°C	125	43.37	<32°C	38°C

Liquid yield was available only at temperature above 400°C for all catalysts. Increase in temperature further decrease the yield for different catalysts at different temperatures. Optimum temperature level for oil yield is between 400 °C& 550°C.

From the above results observed from Table 3 for liquid yield & its properties, catalyst combination of SA1 + Z1 and Flyash were selected as best catalysts by comparing the pyrolic properties such as Temperature, Liquid collected, Calorific value, Flash point and Fire point.

Pyrolic properties of LDPE (low density polyethylene) can be further improved with imparting NiO in Flyash (NiO/FA). Table 4 shows the yield and reaction temperature of produced pyrolysis oil using NiO/Flyash&Flyash as catalysts. Variation of reaction temperature and yield using NiO/Flyash&Flyash (FA) were shown in Fig 2.

Table 4 Pyrolic properties of oil with NiO/Flyash&Flyash

Properties	NiO/FA	FA
Temperature °C	375°Cto 520 °C	375 °Cto 520°C
Yeild (%)	85%	80%

Synthesized catalyst from flyash is more effective to pyrolyse LDPE. Time for pyrolysis is reduced. Impregnation of NiO into flyash increases the pyrolysis effects to decompose the bonding structure.

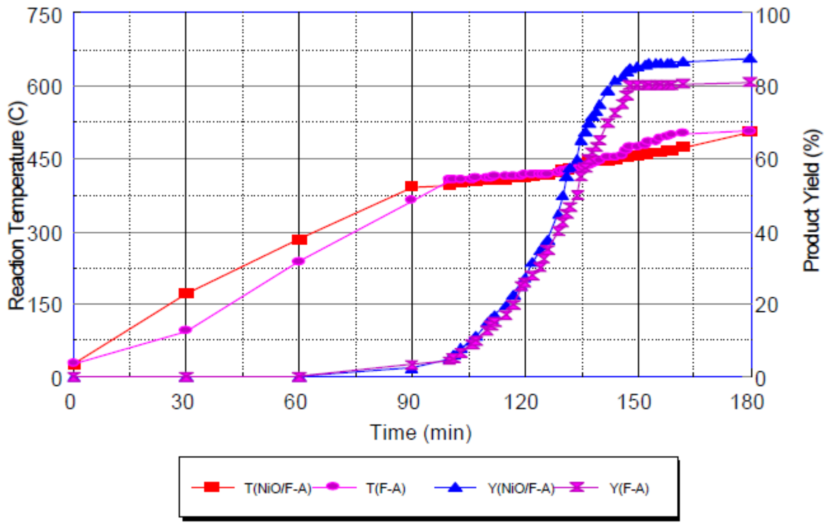

Figure 2 Comparison of Pyrolytic Properties of LDPE with NiO/Fly Ash and

Fly Ash [9]

Performance Test of blends in four stroke CI engine

The specifications of four stroke CI engine used for the performance test with different fuels were listed in Table 5 given below. The experimental setup consists of a single cylinder kirloskar CI engine which is loaded mechanically with break drum dynamometer. The performance of plastic pyrolysis oil, tire pyrolysis oil, plastic oil blends are investigated and compared with pure diesel.

Table 5 Specifications of Four stroke CI engine

Parameters	***Specifications***
Type of Engine	Compression ignition (CI)
No. of working strokes	4
No. of Cylinders	Single Cylinder
Brake horse power (Bhp)	5hp
Spe ed (rpm)	1500 rpm
Bore	80mm
Stroke length	110mm
Fuel used	Plastic Pyrolysis oil, Tire pyrolysis oil, Diesel and Diesel with blends

Three blends of oil were prepared B10 (10% oil & 90 % Diesel), B80 (80% Oil & 20 % Diesel), Tire pyrolysis oil, Plastic pyrolysis oil were prepared. The engine is made to run with five types of oil and the results were studied and compared.

Fuel consumption (kg/hr) vs Brake Power (kW)

The above mentioned oils were used in four stoke CI engine and the performance parameters were observed. Fuel consumption and Thermal efficiency were two basic parameters selected for the performance evaluation of fuels in CI engine. Table 6 indicates the variation of fuel consumption with brake power for different fuels.

Table 6 Variation of Fuel consumption with Brake power

Fuel	**BP (W)**	**500**	**1000**	**1500**	**2000**	**2500**	**3000**
B10	**Fuel Consumption (kg/hr)**	0.3	0.5	0.6	0.65	0.7	0.82
B80		0.5	0.6	0.65	0.8	0.9	1.2
Diesel		0.38	0.35	0.34	0.33	0.32	0.31
Tire pyrolysis oil		0.5	0.45	0.4	0.38	0.35	0.33
Plastic pyrolysis oil		0.46	0.44	0.39	0.34	0.3	0.28

Figure 3 shows the variation of fuel consumption with brake power. The engine requires more energy with increase in Brake power, more fuel causes increase in fuel consumption. Increase in fuel usage is due to low calorific value of pure plastic oil than diesel. B10 & B80 shows increase in fuel consumption with increase in brake power. It shows a blend of plastic oil with diesel consumes more fuel. In case of tire pyrolysis oil, fuel consumption decreases with increase in brake power and it shows the same trend as diesel.

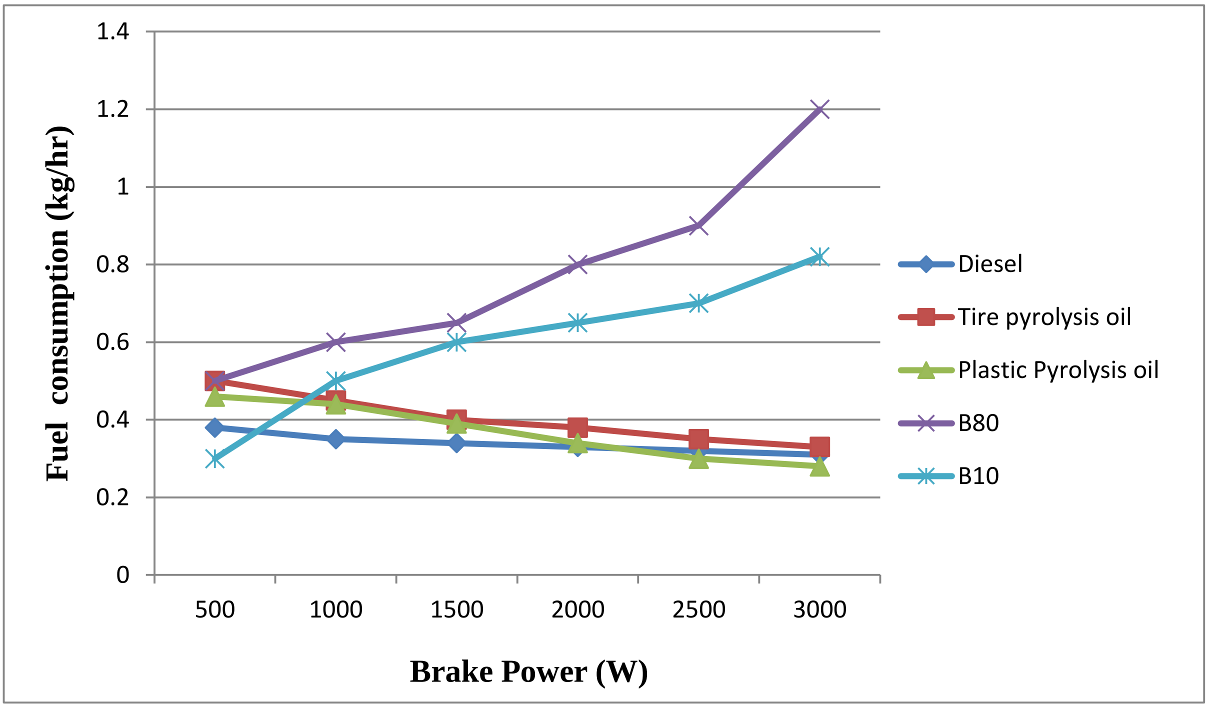

Figure 3 Fuel consumption Vs Brake Power

Thermal efficiency is defined as the ratio of net power output to the mass of fuel supplied to the engine. Thermal efficiency increases with brake power only upto a limit beyond which it drops due to incomplete combustion. Table 6 shows the results derived from the variation of thermal efficiency with different loads for the above mentioned fuels used in this study.

Table 6 Variation of Thermal efficiency with Brake power

Brake Power (W)	Thermal Efficiency (%)				
	Diesel	Tire pyrolysis oil	Plastic pyrolysis oil	B10	B80
500	15	13	12	10	11
1000	22	16	15	12	11
1500	23	25	19	18	18
2000	25	30	20	22	20
2500	26	32	22	25	21
3000	24	25	24	23	22

Figure 4 shows the variation of thermal efficiency with brake power. B10 & B80 shows a gradual increase in thermal efficiency with increase in brake power. In B10 concentration of plastic oil is low and it reached high efficiency at maximum load of 2500 W but in B80 concentration of plastic oil is hig , it attained lower efficiency than B10. This shows that thermal efficiency decreases with increase in concentration of plastic oil in blends.

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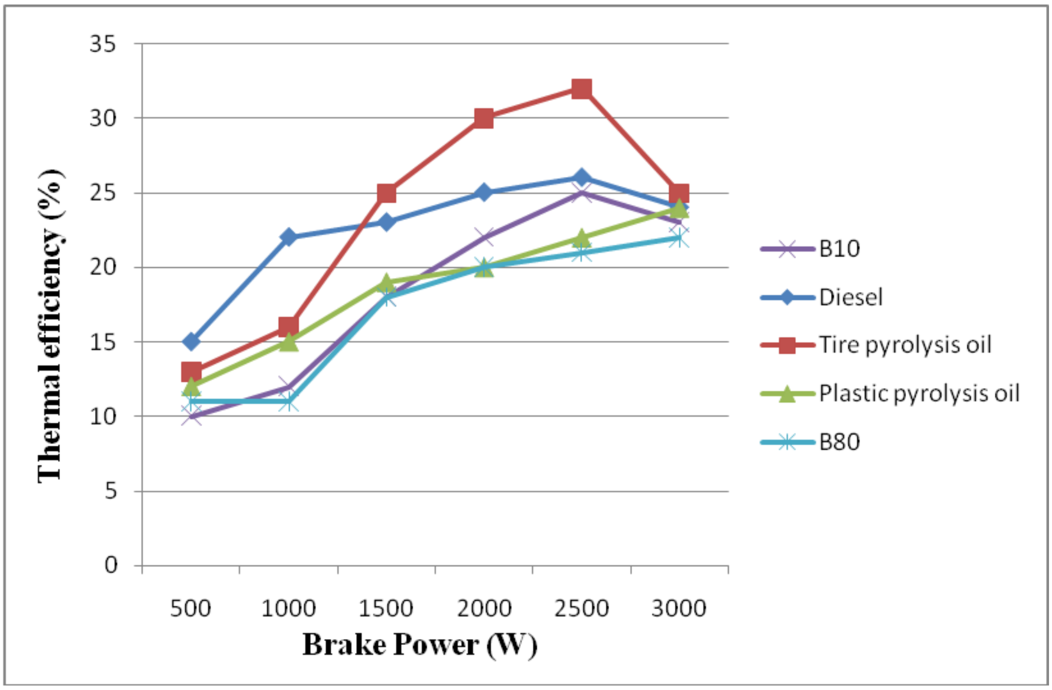

Figure 4: Thermal efficiencyVs Brake Power

Tire pyrolysis oil & plastic pyrolysis oil reaches thermal efficiency comparable to diesel oil. At medium load condition, tire pyrolysis oil reaches higher thermal efficiency while plastic pyrolysis oil offers slightly low efficiency. Due to the presence of aromatics & complex compounds, tire pyrolysis oil offers high efficiency at medium load.

CONCLUSION

Waste plastic pyrolysis oil represents a good alternative fuel from the review of all above papers mentioned in the literature review made in this study. Petroleum based fuel has been produced from tires & plastics (polyethylene & polypropylene).Fly ash is selected as the suitable catalyst among other catalysts used for the pyrolysis process based on yield & thermo physical properties. Impregnation of NiO in Fly ash shows better yield than fly ash.

Usage of plastic pyrolysis oil & tire pyrolysis oil in diesel engine proved that it can replace diesel oil in aspect of technical factor. Tire pyrolysis oil offers low fuel consumption & higher efficiency with increase in brake power in the performance analysis of the engine.

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