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Impacts of Operation Conditions on the Performance of the Fired Heater

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Abstract

Simulation of the process of the fired heater located in the south of Iraq is conducted utilizing Aspen HYSYS. The simulation shows a perfect agreement with the datasheet of the fired heater. Different parameters in the case study examine their effect on the performance of the fired heater and improve the performance. The results report decreasing the flow rate of inlet hot oil maintains almost as equal as the value of outlet temperature of hot oil in the practical results. Reduction of fuel flow rate is showed reducing the temperature of the fuel gas and emission of carbon dioxide. Thus, reducing the flow rate could be worth doing to obtain a clean and safe environment. Also, such a reduced flow rate maintains the temperature of outlet hot oil close to the desired temperature.

Disciplinary: Fuel and Energy Engineering, Furnace Engineering, Sustainable Energy Engineering.

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1 Introduction

The most important instrument in the oil and gas industrials is process fired heaters, or furnace, utilized to deliver the heat liberated by fuels' combustion to transfer such heat to the flowing process fluid via tubular coils which their configuration are placed along the roof and wall of the firebox, or radiant, section (Sutton, 2017). Furnaces' number relies on the plant size and complexity that are the most important parameters. In the radiant section, heat is primarily transferred by radiation. Helical, vertical, arbor, and horizontal are examples of configurations' coil of a tube in the radiant section. Heat convection mostly transfers heat to the section above the radiation section known as the convection section primarily added to the furnace for recovery of waste heat. Generally, heat transfers to the surface of the tubes' wall by radiation or convection based on the location of tubes through the wall by conduction, and then to the internal fluid by convection, and eventually remaining heat to the stack. Cabin, multicell box, and cylindrical fired heater are examples of shapes' structure (Tiwari *et al.,* 2018; Ibrahim and Mourhaf, 2010; Ibrahim and Mourhaf, 2008; Ibrahim, 2010; and Garg, 2004). The furnace is considered the highest consumer of energy in the industrials of oil and gas such as refinery and gas companies. A furnace has generally a control system for the combustion to control the flow of the product and the rate of heat for the duration of the operation. Thus, reducing the emission of fuel gas and the efficiency of process fired heater will have extremely inflected on the environment and the economy (Sutton, 2017). The managing combustion has the highest willpower on both emission and efficiency because they are one relied on others. Soot's coating on tubes has less impact on the performance. The fuel of natural gas or oil, source of heat, and air are the requirements of the combustion process in the burner. (Tiwari et al, 2018; Garg, 2004; Sutton, 2017; Wildy, 2000; Platvoet and Baukal, 2013; and Underwood, 2017).

The optimum combustion being extremely clean and efficient happens once the amount of fuel and air are in perfect stoichiometric ratio. For unit used natural gas as fuel, two molecules of oxygen and one molecule of methane react perfectly to produce two molecules of water and one molecule of carbon dioxide. However, such a ratio is constantly not the situation without using suitable control and the mixture could be too rich in fuel. Simply, moving unburned fuel out stack can occur in extreme situations. Insufficient oxygen affects the complete combustion and makes it incomplete combustion (Underwood, 2017; Salih et al., 2018). Hydrogen and carbon monoxide produce and depart the stack to the atmosphere Thus, emission and wasted fuel increase (Underwood, 2017; Khodabandeh et al., 2016). A mixture of fuel-lean is employed in some furnaces permitting more excess air which guarantees usually extra complete combustion. However, using such a mixture has also unwanted side-effects such as the reduction in efficiency due to excess air and promotes forming compounds of nitrogen oxide (NOx). Burners of low NOx are applied to control the combustion diffusing the air and fuel mixture that leads to a decrease in the temperature of peak flame and as a result the furnace efficiency (Platvoet and Baukal, 2013; Underwood, 2017; Salih et al., 2018; Garg, 1988; Ditaranto et al., 2013; Cala et al., 2015; and Al-Lagtah et al., 2015).

This work intends to improve the efficiency of process fired heater by minimizing the amount of consuming fuel essential to heat the process fluid; besides, the goal of reducing the emission of fuel gas such as carbon monoxide and nitrogen oxide by investigating how specific parameters of operation conditions affect the fired heater.

2 Description of Fired Heater

A unit in consideration is a Unit 59 fired heater in the LPG plant of South Gas Company of Basra, Iraq. The schema of the direct-fired heater, cabin type, is shown in Figure 1. A fired heater is used to heat a fluid that is a desulphurized light-gas oil, and this hot fluid supplied heat to preheaters or boilers. The fired heater is separated into three sections which are the radiant section, convective section, and economizer section. The characteristics of hot oil are listed in Table 1.

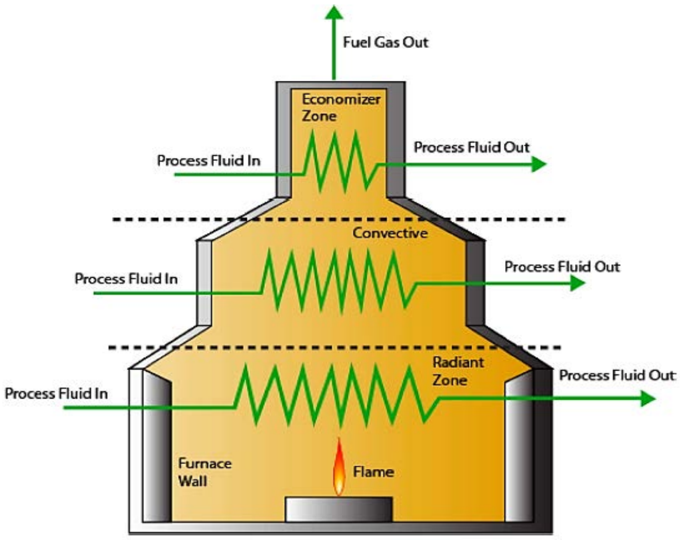

Figure 1: Schema of direct fired heater (courtesy of HYSYS (2014)).

Table 1: Properties of hot oil.

Property		Value
Specific gravity at 15.6°C		0.831
Flashpoint at 50°C		65.5 °C
Viscosity		6.5 mm^2/s
ASTM of out point		228 °C/ 325 °C
Sulphur		0.15% wt. basis
ASTM distill:	I.B.P	228 °C
	5%	242 °C
	10%	250 °C
	50%	276 °C
	90%	310 °C
	F.B.P	325 °C

The pump is utilized to circulate the hot oil (closed system) from surge vessel to the fired heater and deliver to the different units such as preheater or reboiler. The main properties of the hot oil stream that entered the fired heater at normal conditions are summarized in Table 2 while the properties of the fuel gas also are listed in Table 3.

Table 2: Properties of input hot oil stream.

Property	Value
Flow rate	2750 m^3/h (Design)
	1650 m^3/h (Minimum)
Inlet temperature	150 °C
Outlet Temperature	220 °C (Normal)
	250 °C (Design)
Inlet pressure	10.7 bar (Normal)
	11.7 bar (Design)
Operation pressure	8.5 bar
Total duty heater absorber	70×10^6 kcal/h (Normal)
	84×10^6 kcal/h (Design)
	25×10^6 kcal/h (Minimum)

Table 3: Properties of fuel gas.

Property	Value
Burnt	22239 kg/h
Blanketing	No consumption (Normal)
	5200 kg/h (Maximum)

Heat is provided to the heater by combustion of fuel gas in 36 burners gathered in six zones. Also, the fired heater is supplied with one distinct burner with two guns which are one for sour gas which is produced by spent caustic's stripping drum, and the other for fuel gas. Stream of nitrogen is provided with the heater in circumstance of fire the nitrogen is directed inside firebox and stack.

3 Simulation of Fired Heater

Four steps studies are conducted by software package (Aspen HYSYS V.11®) to simulate and evaluate the performance (efficiency and emission of fuel gas) of process fired heater. These steps are organized as follows:

1) Simulate the fired heater and validate the results with the practical results.
2) Investigate the effect of fuel pressure utilizing between 0.9 – 5 bar.
3) Investigate the influence of the flow rate of fuel with ranged from 7000 to 3500 kg/h.
4) Investigate the impact of the flow rate of hot oil employing from 1.720 × 106 to 1.540 × 106 kg/h.

4 Result and Discussion

The furnace of South Oil Company is simulated and analyzed as showed in Figure 2. The temperature of outlet hot oil obtained from the simulation software is close to its value in the practical results. This alteration in the value of temperature between obtained results from simulation and practical results is due to several parameters such as loss of heat or dissociation of the combustion products at high temperatures (Ibrahim and Mourhaf, 2013).

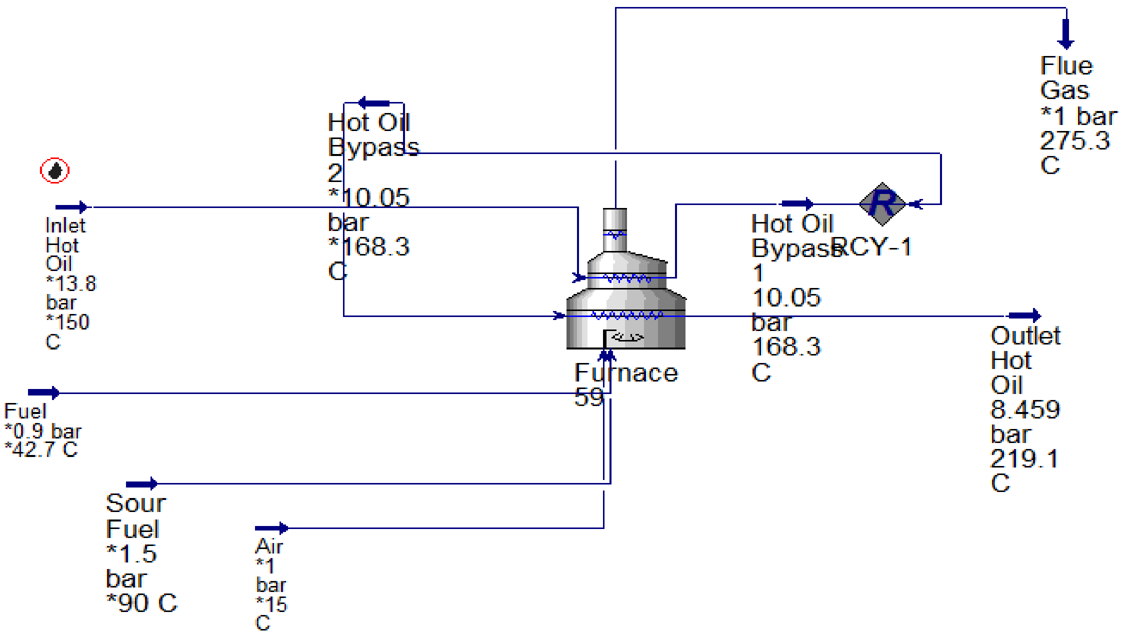

Figure 2: Simulation of the fired heater.

4.1 Influence of Fuel Gas Pressure

Regarding the impact of fuel pressure on the performance of the fired heater is carried out. The results show that altering such pressure does not affect increase the temperature of outlet hot oil, CO_2 composition in fuel gas, and temperature of fuel gas as well. This may attribute to the direction of gas that is in the direction of volatility of gas in the normal way. Thus, fuel gas pressure is indicated as an independent parameter and cannot generally affect the efficiency of the fired heater. Figure 3, 4, and 5 represent the effect of fuel pressure on the temperature of hot oil, fuel gas, and the emission of CO_2 Ibrahim and Mourhaf, 2010, Ibrahim, 2010, Khodabandeh et al., 2016, Garg,1988, Feldbauer,2009, Fialová and Jegla, 2019, and Arachchige, 2012). Garg (1997) reported that one of the most parameters that need to be controlled with the excess of air and draft of furnace is the pressure of fuel gas. However, the pressure of fuel gas is not a significant parameter when the draft of the furnace is natural.

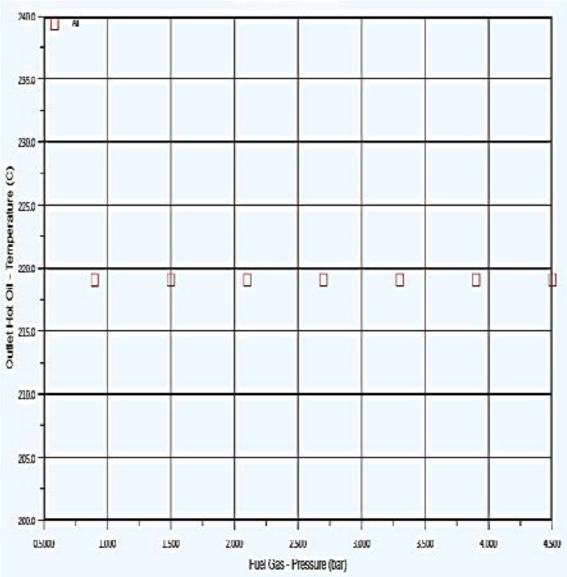

Figure 3: Influence of fuel gas pressure on outlet hot oil temperature

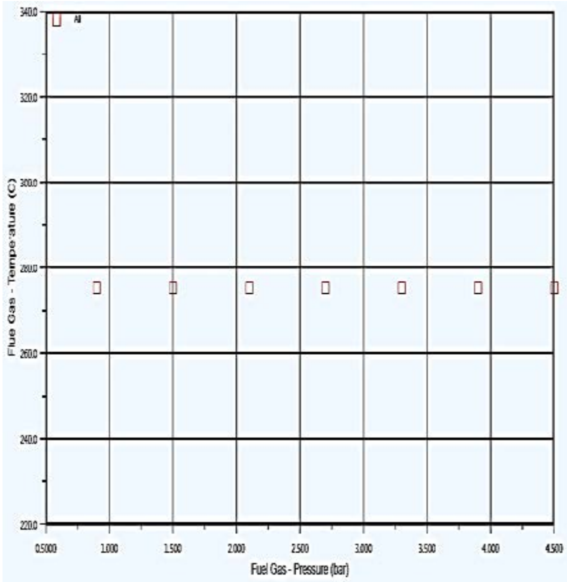

Figure 4: Influence of fuel gas pressure on fuel gas temperature.

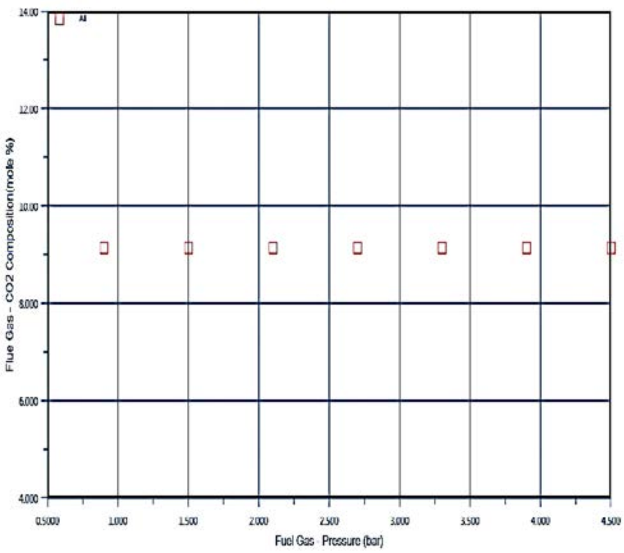

Figure 5: Influence of fuel gas pressure on CO_2 composition.

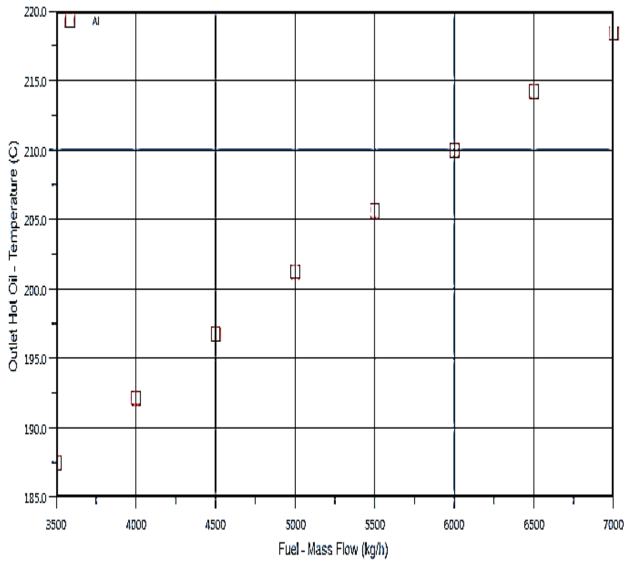

Figure 6: Influence of fuel gas flow rate on outlet hot oil

4.2 Influence of Fuel Flow Rate on Oil Temperature

Investigation of the flow rate of fuel on the performance of the fired heater is conducted in this study. Results show that increasing the flow rate of fuel gas resulted in increases in the temperature of outlet hot oil. The highest set value of flow rate according to this study is at 7000 kg/h. Reduction of flow rate means lower the consumption of fuel resulting in minimizing the cost of the process fired heater. As a result, it could be suitable to minimize the flow rate by about 6500 kg/h to reduce the amount of consumption of fuel. The reason for decreasing the flow rate affects the performance of the fired heater is related to a decrease in the amount of combustion fuel in an applicable way. as exhibited in Figure 6 (Ibrahim and Mourhaf, 2010; Ibrahim, 2010; Garg,1988; Cala et al., 2015' Feldbauer, 2009; and Fialová and Jegla, 2019).

4.3 Influence of Fuel Flow Rate on Fuel Gas Temperature

The temperature of fuel gas is an important parameter being investigated in this study. The case study of the mass flow rate of fuel ranged from 3500-7000 kg/h to show the impact of reducing such flow rate on fuel gas temperature. The temperature is decreased by minimizing the fuel flow rate and as a result, it is a benefit for the environment. The concentration of emissions from flow gas is also decreased. Therefore, decreasing 500 kg/h in each step leads to a drop in the temperature of flue gas about 20°C as presented in Figure 7 (Ibrahim, 2010; Cala et al., 2015; Feldbauer, 2009; and Fialová and Jegla, 2019).

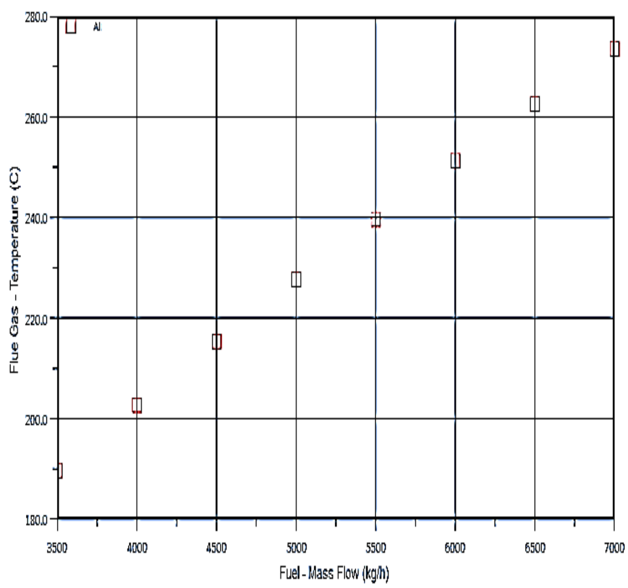

Figure 7: Influence of fuel gas flow rate on fuel gas temperature.

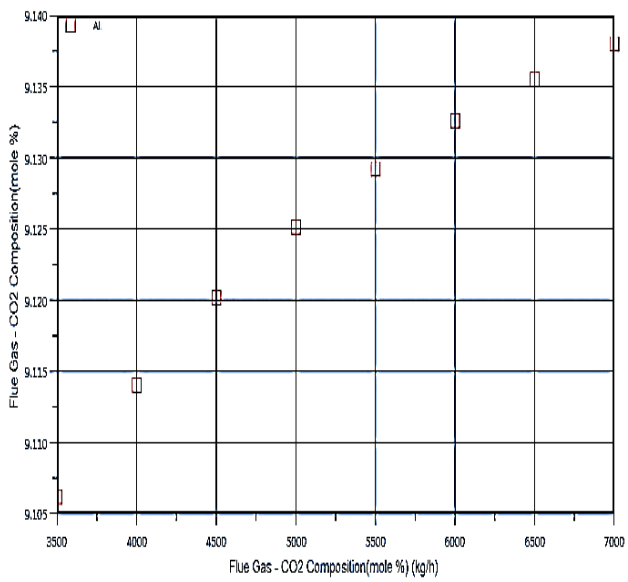

Figure 8: Influence of fuel gas flow rate on CO_2 emission.

4.4 CO_2 Emission in the Fuel Gas

The influence of the flow rate of fuel gas on the CO_2 emission is also explored. It is well known that increasing the composition of carbon dioxide in the environment has mainly impact on human, weather, water, and plants. Therefore, decreasing the amount of it can save everything around such as a fired heater. The results stats that decreasing the flow rate 500 kg/h in each step results in decreasing the composition of CO_2 by 0.005 % which just decreases a little bet as indicated in Figure 8 (Ibrahim, 2010; Cala et al., 2015; Feldbauer, 2009, and Fialová and Jegla, 2019). It is stated that the fuel flow is not the most important effecting parameter on the performance of fired heaters (Gunasegran and Azarpour, 2016). However, it is an important parameter that needs to be considered in this study.

4.5 Influence of Inlet Hot Oil Flow Rate

Altering the flow rate of inlet hot oil is a significant factor to research its influence on the temperature of outlet hot oil. The purpose of the furnace in the South Oil Company is to heat the hot oil to 220 °C and maintain or raise it a little bet is the goal of the researcher in such a field. The outcomes demonstrate that decreasing the flow rate of inlet hot oil from 1.72 × 106 to 1.540 × 106 effects in obtaining almost close to 220 °C as displayed in Figure 9. Therefore, changing the flow rate of inlet hot oil is an effective factor to be considered in improving the performance of the fired heater. Effect of reduction inlet hot oil flow rate may attribute to increasing the time of staying the hot oil inside the fired heater as a result, absorbing more heat (Ibrahim and Mourhaf, 2010; Ibrahim and Mourhaf, 2008; Ibrahim, 2010; Cala et al., 2015).

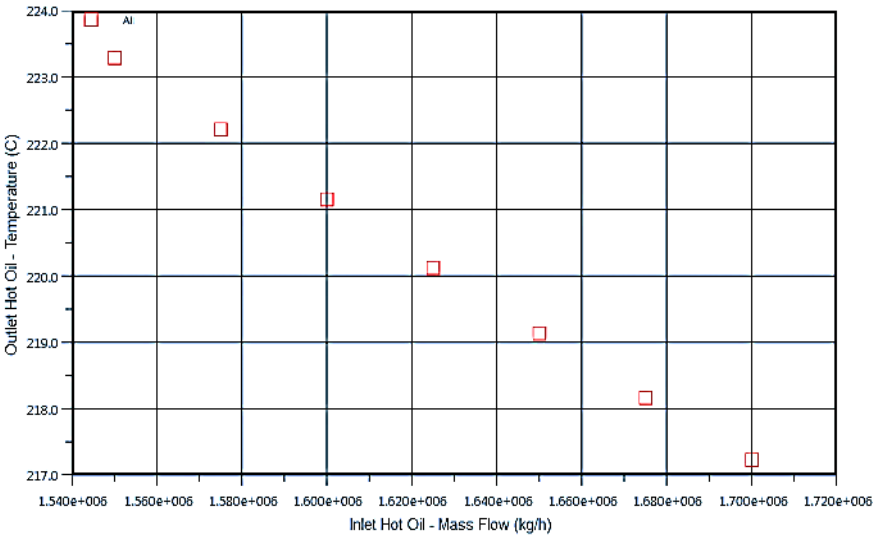

Figure 9: Impact of inlet hot oil flow rate on outlet temperature of hot oil.

5 Conclusion

After analyzing and simulating the results of the Basra Oil Company furnace and comparing results with the practical datasheet. In our study, the pressure of fuel does not affect the performance of the fired heater. Altering the flow rate of fuel impacts the outlet temperature and it is possible to reduce the flow rate to obtain almost close to the real outlet temperature of hot oil. Altering the fuel flow rate also is influences the temperature of the fuel gas and emission of CO_2 and they can reduce when decreasing the flow rate of fuel.

The reduction of the emission and temperature of fuel gas can be decreased by reducing the flow rate of fuel. Lowering the flow rate of inlet hot oil results in an increase or maintain the temperature of the outlet hot oil. Increasing the outlet of hot oil by lowering the flow rate of inlet hot oil is according to increasing the period of staying the hot oil inside the furnace and gain more heat.

6 Availability of Data And Material

Data can be made available by contacting the corresponding author.

7 Acknowledgment

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