ALTERNATE FUEL OPTIONS IN THE KILN

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ABSTRACT

The sources of fossil fuels are depleting each day and thus there is a need for the search of alternative fuels for the kiln. Nowadays, paper industry faces a major problem with the increasing cost of furnace oil. Furnace oil is used in the kilns as fuel for firing for the production of lime. The objective is to substitute an alternative fuel for furnace oil. In the present work used engine oil is blended with furnace oil in the ratio of 75 to 25 (by weight) and is used as an alternative fuel for furnace oil. The paper focuses on the study of calorific value, flash point, ash content, viscosity of the furnace oil and the blended oil samples. The pollution policies of the industries are also taken into account.

Keywords - Blend, Combustion Properties, Furnace Oil, Lime Kiln, Used Engine Oil

I. INTRODUCTION

The depletion of world petroleum sources and increased environmental concerns have stimulated recent interest in alternative sources for petroleum based fuels for firing. With rising energy costs and new environmental regulations in the past years, many paper industries have made it a priority to reduce their energy consumption and operation expenses. Lime reburning kiln is the biggest user of fossil fuels and only part of the mill, which needs significant purchasing of fuel. Fluctuating prices for fossil fuels and more stringent carbon taxes has made lime kiln energy consumption an important issue impacting the overall pulp mill profitability.

Lime kiln operating expenses can be decreased with increasing the thermal efficiency of the kiln and using new fuels for the combustion process. Most of lime kilns use heavy fuel oil as their energy source, but many mills have interest to replace them with alternative renewable fuels in the future. Operation of the lime kiln affects the whole pulp mill and it must stay stable to produce acceptable quality lime and to keep pulp products from the mill good-quality.

Many things have to be considered when replacing the traditional fuels used in the kiln. Availability, heating value, chemical composition and combustion behaviour of the alternative fuels are important matters when examining the effects of replacing on combustion, flue gas emissions and economy of the pulp mill.

Aim of this study is to examine the requirements of lime kiln fuel and to find the best fuel substitutes for the kiln. This study focuses on the blend of used engine oil and furnace oil. The waste engine oil can be obtained from the industry itself. The engine oil is used as lubricating oil in pumps and gears of various equipments and is removed and replaced periodically with fresh engine oil. This used engine oil is disposed of after use. Thus, this used oil can be used as a substitute.

The used oil may be considered as a hazardous waste and have to be disposed of according to Environmental Protection Agency (EPA) regulations. The used oil have the advantage of being inexpensive as compared to conventional fuels and they are readily available at garages and oil change service centers, vehicle dismantlers, machine shops and industries. This paper describes a new approach to lime kiln fuel for firing that combines furnace oil and used engine oil in the ratio of 75 to 25(by weight).

II. OVERVIEW

Production of diesel fuel from used engine oil involves chemical filtrations and blending process. It could solve some of the energy problem with increasing the blending percentage of pre-treated used engine oil.

Used engine oils from vehicles, machinery have high heat value and can fit into many greenhouse operations. It is found that when even a small amount of used engine oil is co fired with the gaseous fuel it significantly enhances thermal radiation capabilities of the gaseous fuel flame.

III. DESCRIPTION OF THE KILN OPERATION

3.1 Recauticizing Process In Kraft Pulp Mill

Efficient and closed chemical recovery is great benefit of the paper mill process. It makes recirculation of cooking chemicals in the process possible while using only little amount of makeup chemicals. Recausticizing plant is important part of chemical recovery at pulp mill.

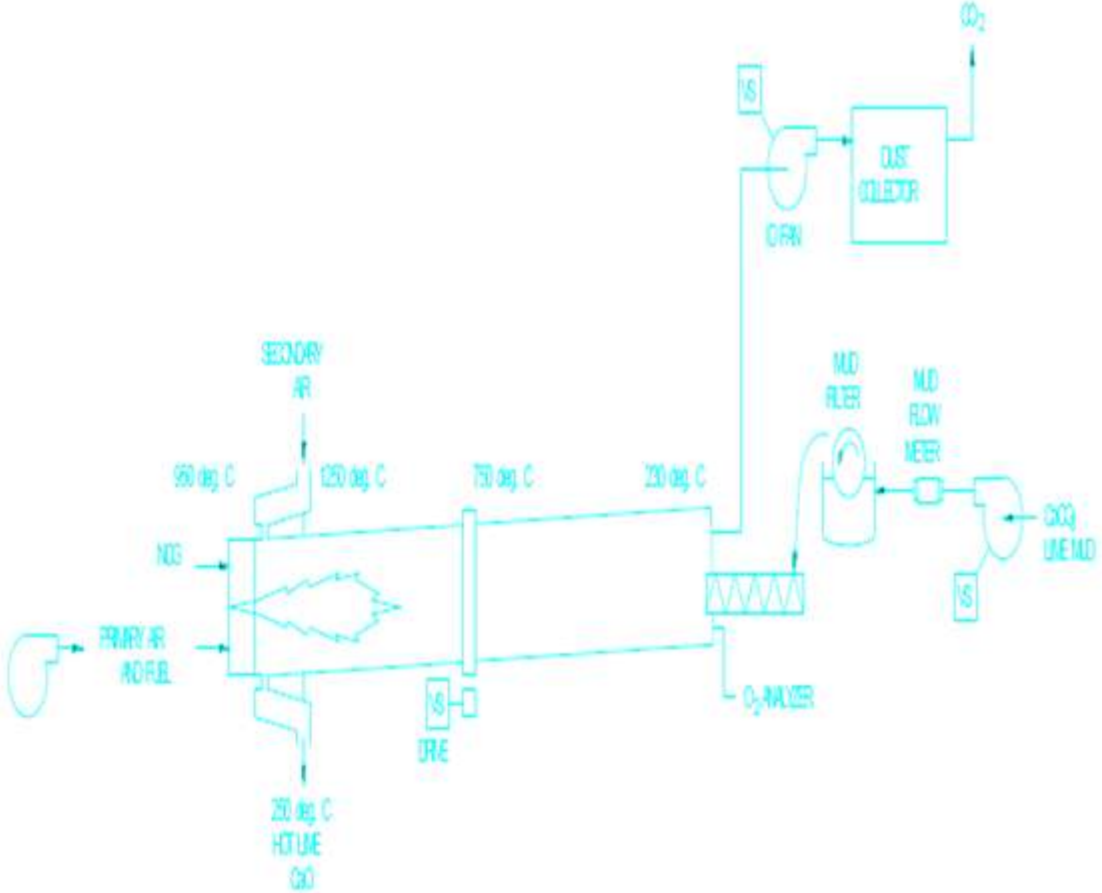

Figure 1 Lime Kiln Installation

Sodium hydroxide, which is mixed with the wood chips and cooked in the digester, is recovered in the recovery boiler and regenerated in the recausticizing plant. This is done by exchanging the sodium ion in the green liquor (sodium carbonate stream) from the recovery boiler with a calcium ion from calcium hydroxide. After the exchange, sodium hydroxide is mixed with wood chips in the digester and the calcium carbonate is calcined to form CaO in the rotary kiln. The calcium oxide is then slaked to form calcium hydroxide. The calcium hydroxide is mixed with the sodium carbonate from the recovery boiler and the whole cycle is repeated. The lime calcining process used by most kraft pulp mills uses a rotary lime kiln to convert the calcium carbonate mud from the clarifiers to quick lime or calcium oxide.

A typical kiln installation is shown in Fig. 1. It uses green liquor from recovery boiler as raw material and consumes lime, calcium oxide (CaO) to produce white liquor, which is an important chemical used in pulping.

The recauctisizing process has two targets, to produce clean, hot white liquor containing minimum amount of unreactive chemicals for the cooking process, and prepare clean and dry lime mud to burn in the lime kiln for reuse as lime with minimum energy usage.

Two important reactions of recausticizing are slaking and causticizing. When green liquor is mixed with lime (CaO) it slakes with water and forms calcium hydroxide ($Ca(OH)_2$). Calcium hydroxide continues to react with sodium carbonate (Na_2CO_3) in green liquor forming sodium hydroxide (NaOH), main compound in white liquor and also calcium carbonate ($CaCO_3$), called lime mud as by-product. Fig. 2 shows caustisizing process as a part of the kraft pulp mill chemical recovery circuit.

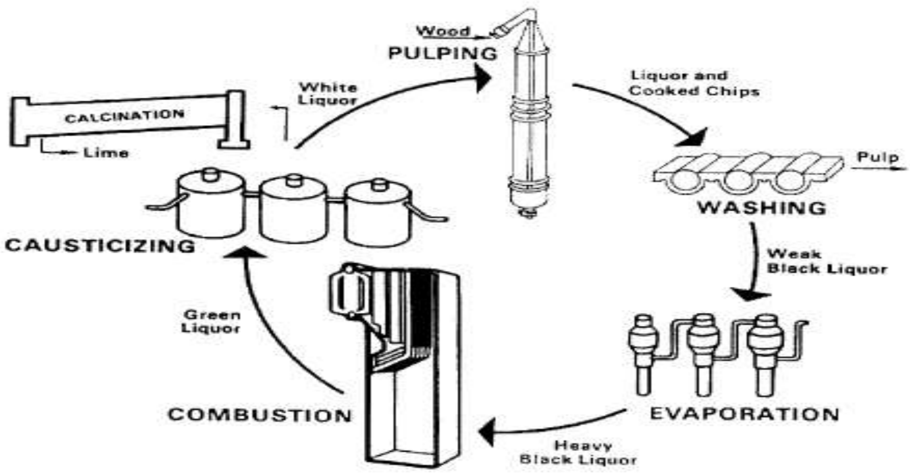

Figure 2 Causticizing process of the pulp mill recovery circuit

3.2 Function And Construction Of Lime Kiln

Lime reburning is a part of chemical circuit called lime cycle. Lime regeneration is called reburning because it involves treating lime mud in high temperatures in a lime kiln. The function of the lime kiln is to convert lime mud back to lime for reuse in the causticizing process. Equation 1 shows the conversion from lime mud to lime.

$CaCO_3\,(s) + \text{heat} \leftrightarrow CaO\,(s) + CO_2\,(g).$ (1)

Lime kiln is a rotary combustion kiln where heat transfers from combustion gas to lime particles. Lime kilns are typically 2-4 m in diameter and 50-120 m in length with typical rotational speed of 0.5-1.5 rpm. Lime mud is fed to the kiln from cold end and the kiln slopes slightly, about 1-4 per cent toward the firing end. Lime mud moves slowly through the bottom of the kiln towards the firing end as result of inclination and rotation. Flue gases and lime dust exits the kiln from the cold end. Flue gases pass through electrostatic precipitator and wet scrubber and lime dust captured in the precipitator is fed back to the kiln.

Figure 3 Rotary kiln

Lime retention time in the kiln is approximately 2.5-4 hours depending on kiln dimensions, rotational speed and lime mud properties. Lime kiln can be divided to four process zones according to the temperature profile of solids and fuel gases:

1) Thermal drying: moisture in the lime mud evaporates.
2) Heating: lime mud gets heated to the reaction temperature.
3) Calcination: calcium carbonate dissociates into calcium oxide and carbon dioxide.
4) Sintering and cooling: formed fine powder agglomerates into nodules and then cools before leaving the kiln.

Fig. 4 shows the lime kiln heating zones. Red line in the figure is fuel oil. Calcination reaction occurs in the actual burning zone where gas temperature increases to 1100°C. The endothermic calcination occurs spontaneously when lime mud reaches 800°C and sufficient reaction rate is reached approximately at 1100°C. The flue gas temperature needs to be significantly higher because of the poor heat transfer in the kiln. Lime mud from lime mud silo is mechanically dried in filter plant before feeding it to the kiln. This is called lime mud dewatering and its purpose is to increase the dry solids in the mud. The moisture in lime mud has a significant effect on the energy consumption of the kiln. It consists of a mud filter where the moisture content is reduced to about 30 to 35%, a rotary kiln and dust collector. In LMD dryer the lime mud is fed to a flue gas stream where the heat of the gases dries the mud. Then a cyclone separates dry mud and feeds it to the kiln. Lime mud has also to be sintered in the kiln to make usable product for further processing. The kiln generally consists of three sections. The first section is a preheater or chain section where the calcium carbonate mud is dried and nodulised. In the final zone, lime powder agglomerates into lime nodules with diameter of 10-50 mm. The second section is a calcining zone where the feed is heated to about 1150°C and converted to calcium oxide.

Most kilns have a third section where the quick lime is cooled before leaving the kiln and the secondary combustion air is preheated. The cooler consists of a number of tubes arranged around the circumference of the kiln at the firing end of the kiln where lime heat is recovered to combustion air. Production lime move through the product cooler and the temperature at the outlet is $(70\text{-}90)^{o}$ C. The burned lime from the kiln has a wide particle size distribution. Oversized particles are crushed by a lump crusher or hammer mill after leaving the kiln.

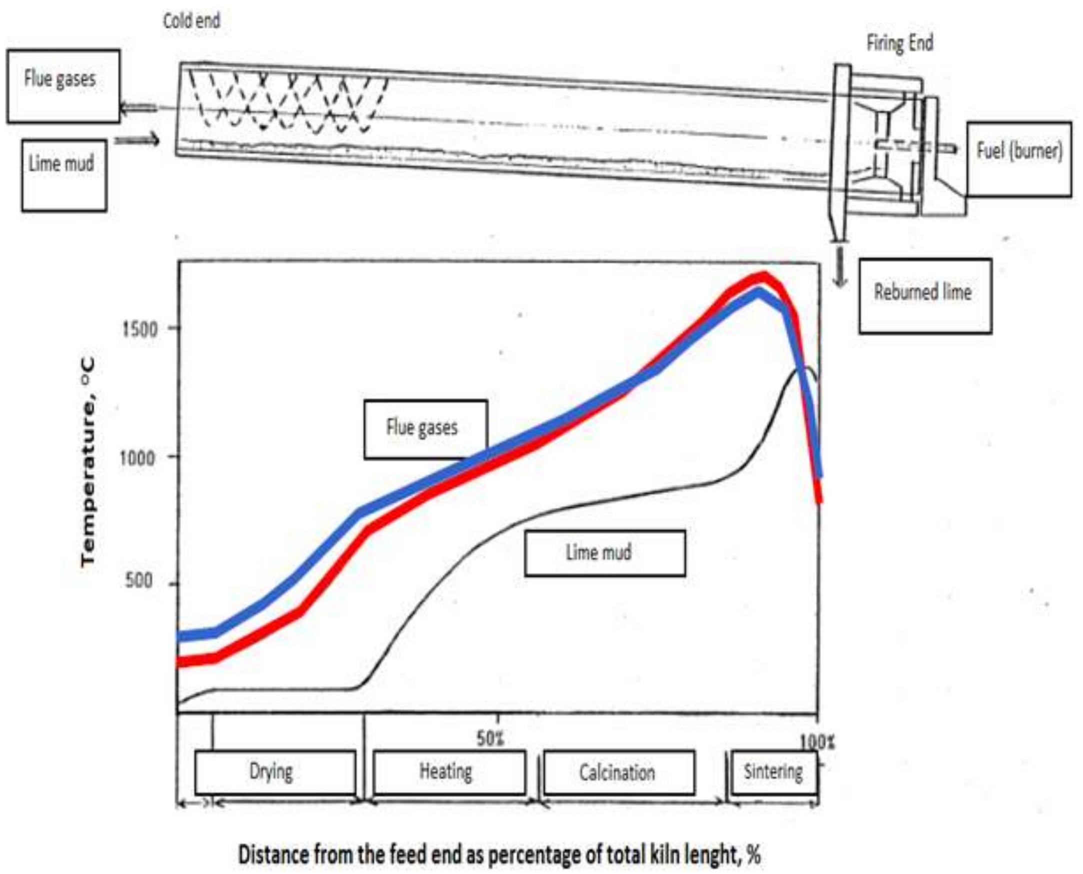

Figure 4 Lime Kiln Heating Zones

Atmospheric air is used as coolant. The lime before stabilization is not pure and contains certain lime sludge thus the drainer portion at the product end drains the impure lime and lime mud. Secondary air is used in normal and parallel to the kiln to achieve maximum purity and proper burning. All lime kilns have a refractory lining that protects kiln shell from overheating and limits heat losses. . Refractory system consists of bricks that are composed of special heat-resistant and chemical-attack resistant materials, such as alumina or silica components. Each kiln zone has a lining of a certain material and thickness.

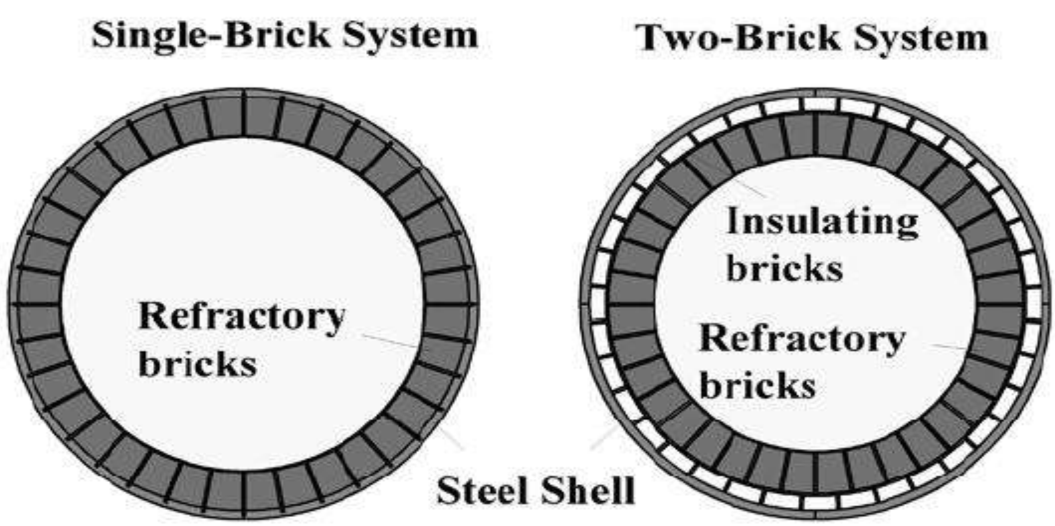

Figure 5 Brick Lining In Lime Kiln

Treatment of lime mud in the lime kiln requires external heat and this requires high fuel combustion temperature. Higher flame temperatures mean higher production capacity and efficiency, but too high temperatures cause refractory damage and over-burned, slow-reacting lime product. Therefore stability and control of the combustion temperature are also important to make good quality lime and to maintain stable operation of the kiln.

3.3 Fuels Used And Their Emissions

Main fuels used in lime kilns are heavy fuel oil or natural gas. Lime kiln is the biggest user of fossil fuels in production process and the only part of the paper mill that needs substantial purchasing of fuel. Carbon dioxide (CO_2) emission from the kiln is directly proportional to the carbon (C) in the kiln gas. This comes from two sources: lime mud conversion and combustion of fuel. Two thirds of the carbon emissions come from the lime mud conversion and one third from the fuel combustion. Carbon in lime mud originates from wood and can be considered as carbon neutral. Carbon dioxide from fuel combustion has positive carbon footprint and if fossil fuels are used for combustion, they are counted as greenhouse gas (GHG) emissions.

Lime kiln always need some amount of makeup lime to cover lime losses and lime containing impurities and thus sea shells are fed to the kiln, after washing, through the cold end.

Although losses of calcium from recovery system are usually made up using fresh lime, some amounts of make-up $CaCO_3$ are used in the kiln. Carbon contained in $CaCO_3$ is usually fossil origin and escapes as CO_2 from the kiln. This is also counted as fossil CO_2 emission.

Rising and unstable price of fuel oil has increased production costs in paper mills. Therefore, there is a need for paper mills to find more economical, carbon neutral alternative fuels that have minimal impact on lime kiln operation and chemical recovery process.

IV. EXPERIMENTAL DETAILS

Initially, the used engine oil was filtered using centrifugation at ambient temperature and humidity. The used oil was taken in four test tubes and placed inside the centrifuge. Due the rotation of the oils at high speed the impurities are settled at the bottom of the test tubes and filtered engine oil is obtained.

TABLE I. ENGINE OIL FILTERATION

Sl. No.	**Activity**			
		Time (minutes)	***Speed (rpm)***	***Observation***
1)	Centrifuge process	10	3,300	No sediments separated
		20	3,300	Sediments separated- lesser volume
		20	4,000	Sediments separated- higher
		20	4,000	

Sl. No.	Activity			
		Time (minutes)	*Speed (rpm)*	*Observation*
		20	4,000	volume
		20	4,000	
		20	4,000	
		20	4,000	
		20	4,000	
2)	Centrifuge after filteration	30	4,000	Moisture (mist) separated
		40	4,000	Moisture (droplets) separated

V. RESULTS

The calorific value of the furnace oil and filtered engine oil were tested separately using bomb calorimeter and the test results are explained in Table II.

The furnace oil and filtered engine oil was blended in two different ratios by weight for testing. The ratios are

1) 75: 25
2) 60: 40

In the ratio of 75 :25(by weight) means 0.375L of furnace oil and 0.125L of filtered engine oil is mixed together and in the 60: 40 ratio(by weight) means 0.3L of furnace oil and 0.2L of filtered engine oil is blended together. The blended oils are tested for calorific values for selecting the desired blend of the oil to be used an alternate fuel in the kiln.

TABLE II. TEST RESULTS

Sl. No.	***Results***	
	Sample	*Calorific value in KJ/ Kg*
1)	Furmace oil	46,938.215
2)	Filtered engine oil	49,676.382

TABLE III. BLENDING OF OILS

Sl. No.	Results			
		Furnace oil in L	*Filtered engine oil in L*	*Observation*
1)	Blending	0.375	0.125	There is no much difference

Sl. No.	Results			
		Furnace oil in L	***Filtered engine oil in L***	***Observation***
		0.3	0.2	between the ratios by visual

TABLE IV. TEST RESULTS

Sl. No.	***Results***	
	Sample	***Calorific value in KJ/ Kg***
1)	Furmace oil and filtered engine mix in the ratio 75:25	46,645.139
2)	Furnace oil and filtered engine oil mix in the ratio 60:40	46,929.841

The blended oil with less filtered engine oil concentration was selected as the flash point increases with the increase in concentration of filtered engine oil. Thus, the blended oil in the ratio of 75: 25(by weight) was taken for further testing of the combustion properties.

The blended oil was tested for relative density, kinematic viscosity, flash point, calorific value, ash content, acidity, sulphur and moisture content.

5.1 Density

Density is the ratio of the mass of the fuel to the volume of the fuel at a reference temperature of 15^{o}C and is measured using a hydrometer.

5.2 Kinematic Viscosity

Viscosity plays a key role in handling and storing the fuels. Viscosity is an internal property of fluid that offer resistance to flow. Viscosity depends on temperature and decreases as the temperature increases. Any numerical value for viscosity has no meaning unless the temperature is also specified. The lower the viscosity is, the better the liquid flows and is usually measured the instrument called using saybolt viscometer. It influences the degree of pre-heat required for handling, storage and satisfactory atomization. If the oil is too viscous, it may become difficult to pump, hard to light the burner, and tough to operate. Poor atomization may result in the formation of carbon deposits on the burner tips or on the walls. Therefore pre-heating is necessary for proper atomization.

5.3 Flash Point

The flash point of a fuel is the lowest temperature at which the fuel can be heated so that the vapour gives off flashes momentarily when an open flame is passed over it. The instrument used in measuring the flash point is Pensky Martens closed apparatus.

5.4 Calorific Value

The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value or net calorific value. The difference being the latent heat of condensation of the water vapour produced during the combustion process. Gross calorific value (GCV) assumes all vapour produced during the combustion process is fully condensed. Net calorific value (NCV) assumes the water leaves with the combustion products without fully being condensed. Fuels should be compared based on the net calorific value and it determines the amount of fuel needed for heat transfer in the kiln.

The calorific value of coal varies considerably depending on the ash and moisture content of the fuel and is measured using bomb calorimeter.

5.5 Ash Content

The ash value is related to the inorganic material in the fuel oil. The ash levels of distillate fuels are negligible. Residual fuels have more of the ash-forming constituents. These salts may be compounds of sodium, vanadium, calcium, magnesium, silicon, iron, aluminium, nickel, etc. Typically, the ash value is in the range 0.03–0.07%. Excessive ash in liquid fuels can cause fouling deposits in the combustion equipment. Ash has erosive effect on the burner tips, causes damage to the refractory at high temperatures and gives rise to high temperature corrosion and fouling of equipments.

5.6 Water Content

Water content in the oil may be present in free or emulsified form and can cause damage to the inside furnace surfaces during combustion especially if it contains dissolved salts. It can also cause spluttering of the flame at the burner tip, possibly extinguishing the flame and reducing the flame temperature or lengthening the flame.

5.7 Sulphur Content

The amount of sulphur in the fuel oil depends mainly on the source of the crude oil and to a lesser extent on the refining process. The main disadvantage of sulphur is the risk of corrosion by sulphuric acid formed during and after combustion, and condensing in cool parts of the chimney or stack, air preheater and economiser.

TABLE V. COMBUSTION PROPERTIES OF THE BLENDED OIL

Sl. No.	**Comparison**		
	Properties	***Requirements***	***Blended oil in the ratio of 75: 25(by weight)***
1)	Relative density at 15 °C in kg/m^3	850-990	960
2)	Kinematic viscosity in μm^2/ s at 50 °C	85-125	105.41
3)	Flash point, °C	66	132
4)	Gross calorific value in KJ/Kg	43,961.4	46,733.062
5)	Ash (% by mass)	0.1	0.01

Sl. No.	Comparison		
	Properties	***Requirements***	***Blended oil in the ratio of 75: 25(by weight)***
6)	Water content (% by mass)	1	Nil
7)	Sulphur content (% by mass)	2-4.5	1.7
8)	Acidity inorganic	Nil	Nil

The blended oil from the test results conforms to the required specifications of furnace oil and thus can be used in lime kilns for firing as an alternative fuel.

VI. CONCLUSION

Due to rising price of heavy fuel oil and natural gas and increasingly stringent environmental regulations in recent years, the interest in replacing these conventional fuels used in pulp mill lime kilns with alternative fuels has become a worldwide issue. Pulp manufacturers are looking both for money savings and nowadays increasingly important environmental reputation.

Fuels used for lime kilns have a lot of requirements compared to conventional combustion in heating boilers. As the operation of lime kiln requires lot of energy and affects to the whole chemical circuit of the pulping process, the used fuel should have high heating value, good availability, constant combustion properties and should not contain much of nitrogen, sulphur and impurities. The test results of blended mix of furnace oil and filtered engine oil in the ratio of 75: 25(by weight) suggest that the blended oil have values in the permissible limit. The advantage is that the blended oil have less ash, sulphur and water content and high calorific value to that of furnace oil and thus reduces the consumption of the fuel and increases the efficiency of the kiln. The pollution policies are also satisfied. By knowing these requirements, replacing heavy fuel oil or natural gas with the blended oil is much easier and the operation of the kiln is predictable. Thus, the blended fuel can be used as alternative fuel in the lime kiln for firing.

VII. ACKNOWLEDGMENT

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