Burning Glycerol Emulsion in Liquid Fossil Fuel

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The basic properties of glycerol, viscous liquid, chemically stable, biodegradable, flammable with high flash point, no toxicity and no irritating effect, recommends it like component for the preparation of fuels. The viscosity of glycerol is close to that of fuel oil and, on increasing temperature, it has the trend similar to that of fuel oil. Compared to liquid fossil fuels, technical glycerol has a much higher mineral mass content. Possible mineral compounds in glycerol are sodium or potassium chlorides, sodium or potassium carbonates, potassium sulfate, potassium phosphate. There have been several series of experiments performed using two experimental plants, the burner used being the type RIELLO PRESS 45N. All combustion tests carried out have shown good behavior in the ignition and combustion of the emulsion. Overall differences were not significant compared to fossil fuel burning alone basis.

Keywords: *glycerol, liquid fossil fuel, fuel emulsion*

Glycerol, a polyol with a high content in oxygen, presents a lower calorific value of 18 MJ / kg, considerably lower than that of fuel oil placed around the value of 38MJ/kg. Thus to obtain the same thermal power the amount of glycerol ratio to the oil is 2,22:1.

The basic properties of glycerol, viscous liquid, chemically stable, biodegradable, flammable with high flash point, no toxicity and no irritating effect, recommends it like component for the preparation of fuels [1]. Elemental composition of glycerol is significantly different from that of liquid fossil fuels. In Table 1 the main components of emulsion fuel based glycerol are presented, compared, [1,2].

The viscosity of glycerol is close to that of fuel oil and, on increasing temperature, it has the trend similar to that of fuel oil, as can be seen from figure 1. Consequently glycerol can not be sprayed at ambient temperature, prior preheating being required. The level of preheating, as can be observed from the diagram of figure 1, is very close to that of fuel oil.

There are major difficulties in ignition and self-sustaining combustion of glycerol [4]. In order to use glycerol as a substitute for part or all of the fuel oil, a particular concern is the combustion air necessary to achieve the same power output. A calculation of required quantities of combustion air and combustion products, using composition values from table 1, led to results that are presented in summary table 2.

Lower calorific value report is 1:2,24 implying approximately an inverse of the flow. At the same time

Table 1
ELEMENTAL COMPOSITION OF GLYCEROL AND LIQUID FOSSIL FUELS

Element	UM	Pure Glycerol	Oil
Carbon	%	39,13	84…86
Hydrogen	%	8,7	10…13,5
Oxygen	%	52,17	cca 1

Table 2
SPECIFIC FEATURES OF COMBUSTION OF GLYCEROL AND OIL

Nr.crt		UM	Pure Glycerol	Oil
1	Lower calorific power	KJ/kg	18000	40374
2	Theoretical volume of air needed for combustion	N m^3/kg	4,46	11,56
3	The actual volume of wet flue gas	N m^3/kg	5,32	12,18
4	Theoretical enthalpy of combustion	KJ/N m^3	3385	3315
5	The theoretical combustion temperature	°C	1988	1997

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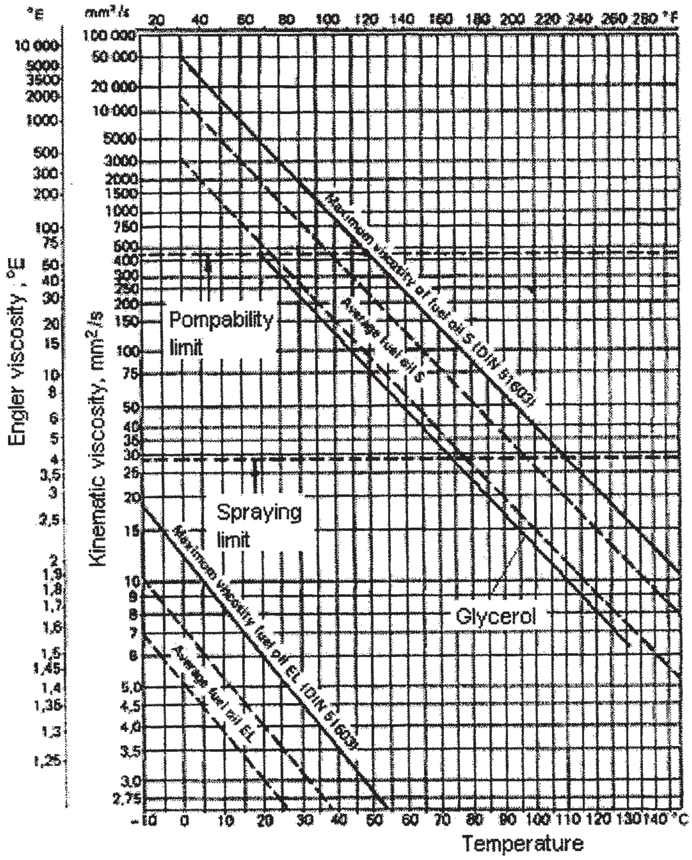

Fig.1 Viscosity evolution with temperature

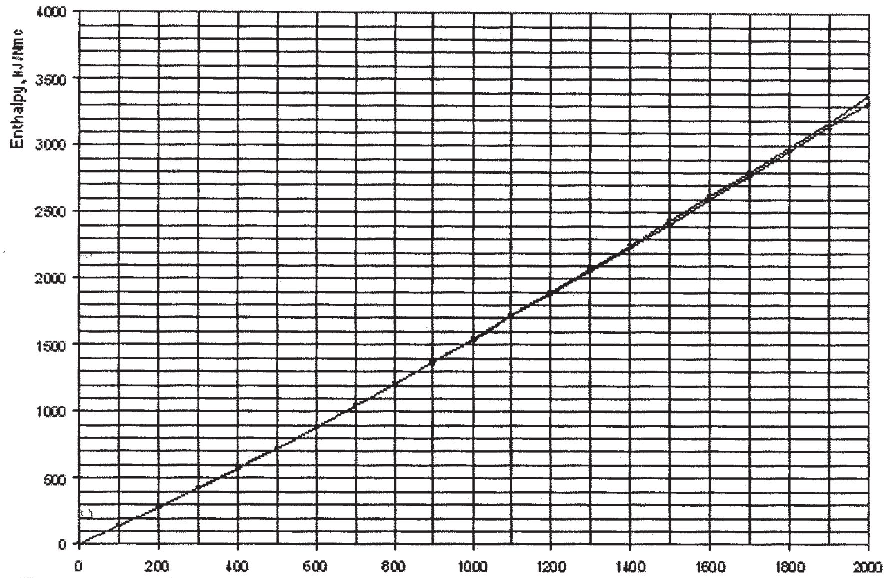

Fig.2 H-T charts for oil and glycerol technique (standardized reporting on unit volume of flue gas)

theoretical ratios of air combustion is 1:2,59 and flue gas quantities 1:2,29. Therefore at the same thermal power of heat generator, combustion air requirements and combustion gas production varies in very low limits.

$$\frac{V_{g,1}}{V_{g,2}}=\frac{Hu_1}{Hu_2}\cdot\frac{v_{g,2}}{v_{g,1}}=0,979 \text{ (1.1 excess air).}$$

Hence the values approximately equal of theoretical enthalpy and the theoretical temperature. The consequence is that the temperature curves (T) - enthalpy (h) for glycerol and oil are virtually identical (fig. 2).

Compared to liquid fossil fuels, technical glycerol has a much higher mineral mass content. Possible mineral compounds in glycerol are sodium or potassium chlorides, sodium or potassium carbonates, potassium sulfate, potassium phosphate.

Compounds based on alkali metals Na and K have low melting temperatures and softening. As a result, outbreaks where the glycerol burn slagging potential and pollution is increased compared with that of liquid fossil fuels [3].

Experimental part

There have been several series of experiments performed using two experimental plants. The first experimental combustion facility consisted of an industrial burner connected to a power plant with liquid fuel. The burning took place in space providing total visibility on the phenomena related to ignition and combustion. The burner used is the type RIELLO PRESS 45N whose characteristics are presented in table 3. Experimental scheme is shown in figure 3.

The burner was connected to a fuel tank with capacity of about 25 liters in which the fuel (emulsion) was

Table 3
GENERAL CHARACTERISTICS OF THE BURNER RIELLO PRESS 45 N

Size	UM	Features
Operating mode	-	two steps
Thermic power	kW	114/205…513
Fuel pressure on injector	bar	20
Fuel viscosity at 50°C	cSt	50 (7°E) to 150 (20°E) if equipped with fuel kit
Fuel pre heating	-	yes

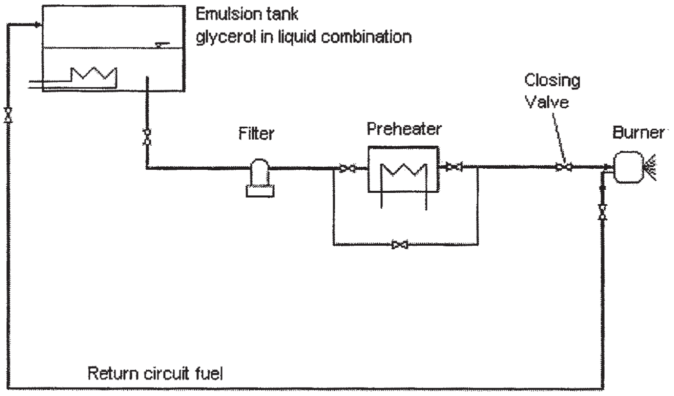

Fig. 3. Scheme for the first experimental plant

Table 4
CHARACTERISTICS OF EMULSIONS USED IN THE TESTS ON THE FIRST PLANT

Emulsion Gl-CFL	UM	Value
Fuel content PM30	%	88,5
Glycerol content	%	10,0
Emulsion content	%	1,5
Viscosity at 30°C	°E	5,9
Inflammability	°C	114
Lower calorific power	MJ/kg	39,3

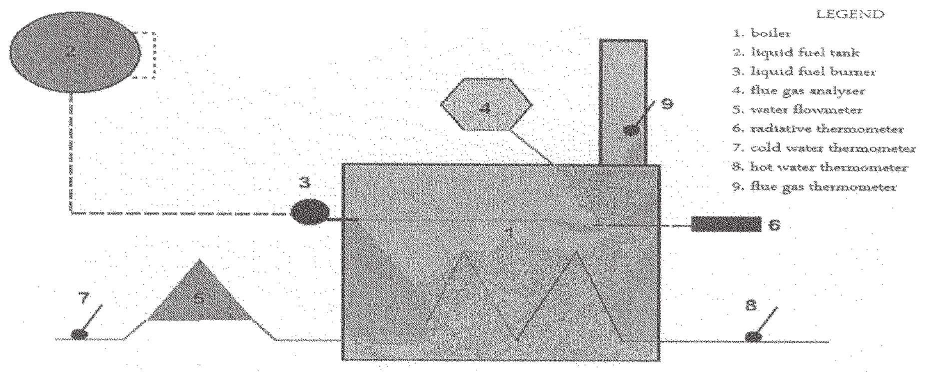

Fig.4. Scheme of the second pilot plant

introduced, where appropriate, at a temperature that viscosity does not exceed 7°E, accepted limit value at the inlet of the burner. The burner is equipped with a self preheater that can ensure maximum viscosity decreased from 7°E to 2.5 °E.

A second experimental plant (fig. 4) consists of a small furnace of 55 kW equipped with a monoblock burner GB-GANZ Thermodynamics type N-10 for M-type liquid fuel burning or CLU. Fuel flow rate can be up to 7.3 kg / h.

Requirements for fuel characteristics are: pressure 16 bar, maximum 10 cSt viscosity required for spraying. Combustion air is provided by a ventilator that is part of the burner to the following parameters: flow Nmc 620 / h, pressure 30 mbar. The burner is equipped with a fuel preheater which, by heating it, the viscosity is lowered to the optimum value required for spraying.

Usable fuels

The first series of tests was designed to obtain emulsion of glycerol in liquid fossil fuel which does not introduce special problems of ignition and combustion of fuel due to high viscosity and high ignition temperature of glycerol.

For this reason it was chosen as a fuel an oil which, at room temperature or slightly higher , the viscosity has accepted the burner at the inlet of its pump. Emulsion was prepared by mechanical mixing, emulsifying conditions were similar to those presented in previous work [6, 7, 8]. It was used a nonionic emulsifier type nonyl-phenol ethoxylate with 9 ethylene oxide molecules, NF 9 from Huntsman Company. Characteristics of emulsion used in combustion tests are presented in table 4.

For the second series of tests was prepared the emulsion composition to allow its use at room temperature without preheating, (table 5).

Table 5
EMULSION COMPOSITION USED IN EXPERIMENTS OF SERIES B AND C

Emulsion Gl-CFL	UM	Value
Fuel content PM30	%	89,5
Glycerol content	%	9,0
Emulsifier NF4	%	1,5
Density at 20°C	Kg/dm^3	0,867
Viscosity at 20°C	°E	2,2
Inflammabilitie Cleveland	°C	84
Lower calorific power	MJ/kg	43,8

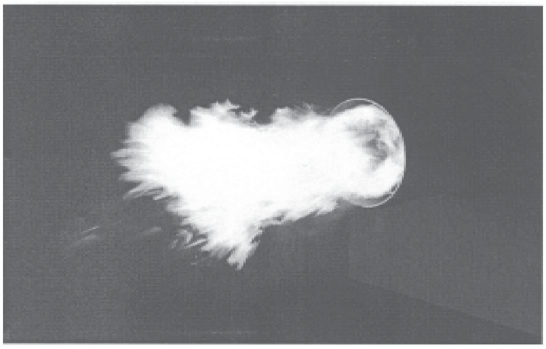

Fig.5. Flame obtained with 8% glycerol emulsion fossil fuel

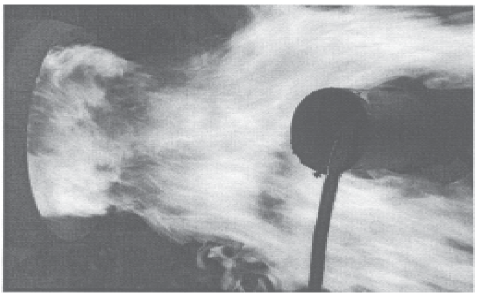

Fig.6 Samples placement for deposition in relation to the mouth of the burner and flame

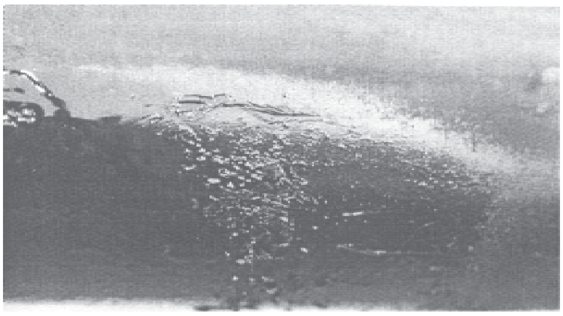

Fig.7 Deposits on the test pieces OLC45

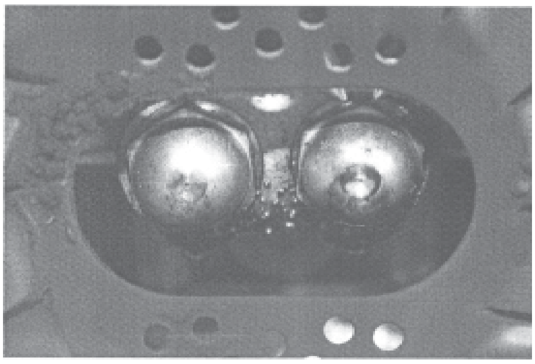

Fig.8 Appearance head injector and injection nozzles after firing tests

Table 6

INDICATORS OF COMBUSTION OF GLYCEROL IN OIL EMULSION

Parameter	UM	Value			
Oxygen	%	20	19,3	19,1	18,7
Carbon Oxide	%	0,007	0	0	0,002
Carbon Dioxide	%	0,7	1,3	1,4	1,7
Furnace gas temperature	°C	670	730	790	820
Furnace exhaust gas temperatur	°C	303	299	301	306
Ambient air temperature	°C	21,7	22	21,9	21,8

Results and discussion

The first firing tests carried out in open space, for viewing and recording (photos - video) of the flame obtained using emulsified fuel showed a good behavior of these emulsions both in terms of ignition and combustion point of view. There were no recorded extinction of the flame and its pulsations. A flame image obtained is shown in figure 5.

Tests have pursued the issue of deposits, especially by putting them out and their appearance. To highlight deposits on metal surfaces there have been made samples of 38 OLC45 and stainless steel pipe 316. Their location in the area of flame is illustrated in figure 6. The duration of the blast area was 20 min.

In all cases there were deposits, more or less pronounced. Deposits are tough but results are not entirely mineral mass in fuel. A very important part of an oven represent unburned fuel. One result of this exposure is illustrated by figure 7. It is however clear that the use of glycerol to gas must be resolved and the issue of deposits.

Deposition potential induced by the presence of glycerol is shown in fuel and burner head status. At the end of the test solid deposits were found (the same type as those of the samples) for both the spray nozzles and the flame stabilizer rosette (fig. 8).

Method of settlement is not only issues related to fuel (mineral composition, participation, etc.) but also the entire plant to generate heat. Size of outbreak (section, volume), location of heat exchange surfaces, the combustion gas temperature at their level are parameters that can lead to multiple ways to avoid or control the exterior deposition.

In the last set of tests aimed to quantify the effects of combustion, respectively the influence of excess air on combustion and the characteristics of emulsion. The amount of combustion air has been adjusted to ensure stable combustion. This was relatively high so that the CO_2 content in flue gas was low value (below 1.7%). The data is presented in table 6.

It can be seen that the variation of carbon dioxide is largely correlated with changes in oxygen concentration in flue gas as a measure of ratio flow air / fuel. With decreasing oxygen concentration from burning gases, carbon monoxide concentration increases. Gas analyzer used could not detect CO; content ppm units in the area 19.1... 19.3 of the oxygen concentration of CO appears to be zero. At very high air flow, where the oxygen concentration is 20%, appears a high concentration of CO (70ppm). It is likely the result of relatively low temperature of the furnace (less than 700°C) that adversely affect complete combustion of CO. Evolution of concentration in the flue gas components is shown in figure 9.The NOx produced by combustion is very low. At the temperature of the outbreak, about 700°C, thermal NOx is virtually nonexistent. Very likely that only nitrogen from fossil fuels

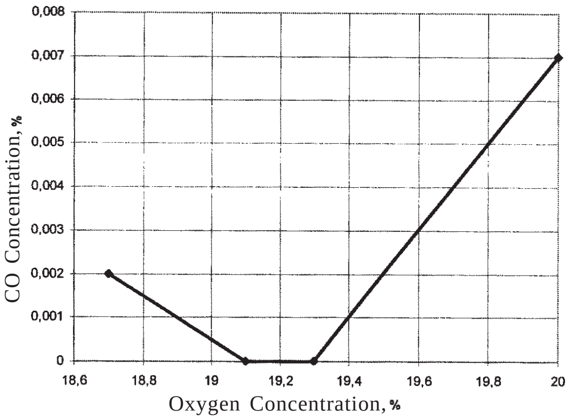

Fig.9. Variation of CO concentration with oxygen concentration

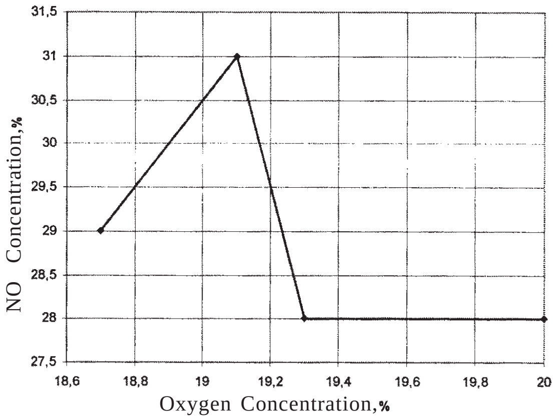

Fig. 10 Variation of NOx formation with oxygen concentration

is responsible for the presence of NOx in flue gas. This is supported by the relative constancy in the ratio of NOx concentration in flue gas oxygen (air excess). As can be seen from figure 10, to change the oxygen production the variation of NOx is about 29 ppm, with ±5%.

Conclusions

Combustion tests were conducted in three series. The first series evaluated the effect of glycerol on burning.. The second series focused on both aspects of ignition and combustion of the emulsion prepared by optimized recipe and issues related to solid deposits on pipe heat exchangers. A third series followed an outbreak of emulsion burning experiment.

All combustion tests carried out have shown good behavior in the ignition and combustion of the emulsion. Overall differences were not significant compared to fossil fuel burning alone basis.

Glycerol in oil emulsification is a viable and effective way of recovery of glycerol results in the synthesis of biodiesel:

- no problems, the burning is good for self ignition and combustion;
- you can use the same technologies and equipment designed and intended to burn fossil fuels, heavy liquid, appropriate adjustments are required the only differences existing being the properties and the integration of emulsifying plant.

References

1. *** DIIPR Project 801 : „Full Version Evaluated Standard Thermophysical Property Values". Design Institute for Phisycal Properties, department of Chemical Engineering. Brigham Young University, Provo, Utah, 2005

2. *** VDI-Wärmeatlas. Berechnungsbläter für den Wärmeübergang. 4.*** Auflage. VDI Verlag, Düsseldorf, 1991

3. SCHOPF, N., Using Glycerine as an Alternative Fuel. Simpozionul Saacke, Bucuresti, 2007

4METZGER, B., Glycerol Combustion. North Carolina State University. 2007

5.PATZER, R., Stack Emissions Evaluation: Combustion of Crude Glycerin and Yellow Grease in an Industrial Fire Tube Boiler. Agricultural Utilization Research Institute. Marshall, MN, USA. 2007

6. BOMBOS D., BOLOCAN I., BOMBOS M., VASILIEVICI, G., ZAHARIA E., Rev . Chim. (Bucharest),**61**, no.5, 2010, p.506

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