

Acetylene Powered Steam Turbine

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Abstract:- Humans have proved themselves of being a superior species and stands on top of food chain. But this position was attained on the cost of ever depleting natural resources and flooding the environment with pollution. Herewith the pollution has affected the land masses as well as water bodies. About 75% of earth is filled with water and only 0.08% of water is available for domestic purpose. Now to recycle this water and treat those, Sewage/effluent treatment plants were introduced. But there is setback to this system i.e. consumers have known the after-form (i.e. mixture of toxin, organic inorganic wastes mixed with water) of the water they have used and refuses to use such water (after treatment) for drinking purposes. Now the question was asked, where this water can be used and the answer given was to restore the ground water saturation level. Engineer's task is to identify the problem and think of the solution. The problem identified in this system was the deficient use of the treated water. The paper here deals with using this purified/treated water as primary fuel and make power/energy out of it. The paper suggests that using the treated water for reaction with calcium carbide which releases the acetylene gas i.e. highly combustible when ignited. The combustion energy of acetylene can be used to produce steam which can be used to turn the steam turbine. A proper system/flowchart is shown in the paper. Thus, generating electricity. There is a by-product from water and calcium carbide reaction i.e. calcium hydroxide (hydrated lime) can be used back again in STP for treating sludge. Hence making the system a closed loop and increasing the overall efficiency of the system.

Keywords:- STP- Sewage treatment plant, g- grams, aq- aqution state, Photo-chemical Ozone Creation Potential (POCP), steam generator.

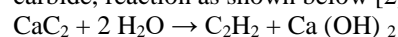
1. INTRODUCTION

Coal is abundantly available in India though it is depleting in alarming level due increasing demand and increasing load on the generation sector. The challenges we face here is by product which is obtained after burning the fuel is Ash. Major problem India is facing dust and on that the ash handling makes it difficult for environment therefore locating the plant in the outskirts. Our paper proposal suggests two by-products after combustion a) Carbon Dioxide and b) Calcium Hydroxide. Here carbon dioxide can be controlled through passing the emissions through the carbon nano tubes. And the Calcium Hydroxide (hydrated

lime) can be frequently used to raise the pH of raw water before the water is treated with alum or ferric sulphates for coagulation/flocculation. [1] Technology is now available to treat wastewater to the extent that it will meet drinking water quality standards. However, direct reuse of treated wastewater is practicable only on an emergency basis. This treated water from the treatment plant can be used for power generation purposes.

1.1 ABOUT ACETYLENE:

Acetylene is the chemical compound with the formula C_2H_2 . This is colourless and odourless and has a density of 1.097kg/m^3 . It is prepared by a hydrolysis of calcium carbide, reaction as shown below [2].



Acetylene is not especially toxic but, when generated from calcium carbide, it can contain toxic impurities such as traces of phosphine and arsine, which give it distinct garlic like smell. It is also highly flammable, as most light hydrocarbons, hence its use in welding. Consequently acetylene, if initiated by intense heat or a shockwave, can decompose explosively if the absolute pressure of the gas exceeds about 200 kilopascals (29psi). Hence pressure gauges are installed as well as non-return valve to safety purpose.

As acetylene is highly flammable, it can be used as alternative fuel to run a steam turbine. In which we can generate electricity by coupling the steam turbine and generator to generate electricity.

2. WORKING:

For generation of electricity working is done by a step by step process, there will be a multiple stage. First stage follows the purification process of water in which savage water is purified and stored. In the second stage from the calcium carbide acetylene gas is produced from the hydrolytic process. At the third stage formation of steam is done by passing the acetylene into the boiler to heat the water. Then at the fourth stage turbine is run by passing the steam into the turbine. And at last stage (i.e. fifth stage) steam turbine is coupled with generator to generate electricity.

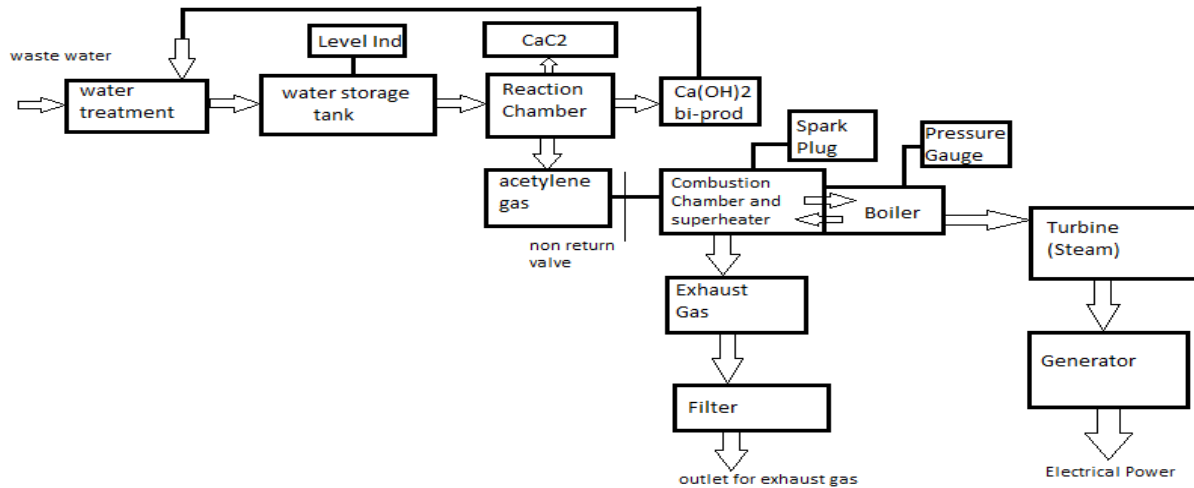


Fig1: Block diagram of system

2.1. Stage 1: -STP Plant

Sewage is a mixture of domestic and industrial wastes. It is more than 99% water, but the remainder contains some ions, suspended solids and harmful bacteria that must be removed before the water is released into the sea.

The treatment of wastewater is divided into three phases: pre-treatment, primary treatment and secondary treatment.

2.1.1. Pre-treatment

Large solids (i.e. those with a diameter of more than 2cm) and grit (heavy solids) are removed by screening. These are disposed of in landfills.

2.1.2. Primary treatment

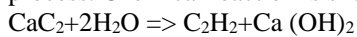
The water is left to stand so that solids can sink to the bottom and oil and grease can rise to the surface. The solids are scraped off the bottom and the scum is washed off with water jets. These two substances are combined to form sludge.

2.1.3. Secondary treatment

The sludge is further treated in 'sludge digesters', in which the sludge is treated with calcium hydroxide to eliminate organic impurities. Calcium hydroxide with a 90% purity is used in the secondary treatment process.

2.2. Stage 2: Generation of acetylene gas.

The second stage involves the production of acetylene gas through the Calcium Carbide reacting with water in the reaction chamber; this process is also called as hydrolysis process. Chemical reaction is shown below.



Where,

CaC₂ - Calcium carbide

Ca(OH)₂ - Calcium hydroxide

C₂H₂ - Acetylene gas

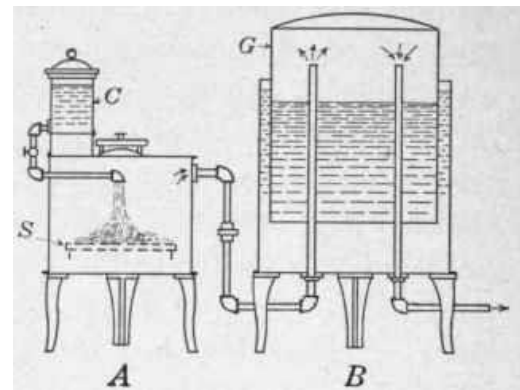
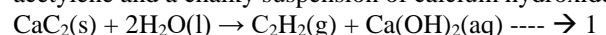


Fig2: Schematic diagram of reaction chamber

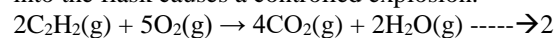
The reaction tank constitutes two chambers:

- In first (upper) chamber the water is kept.
- In second (lower) chamber the calcium carbide is kept. The water from the first chamber is released in such a way to precede the reaction spontaneously. The water is passed through the control valve. In the second chamber the calcium carbide is kept in desirable amount to react with water. Through second chamber a valve is connected to the storage tank where the gas produced during reaction is stored. In this reaction the by-product formed calcium hydroxide which can be used for the water treatment plant to purify the savage water.

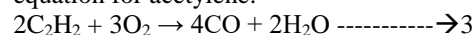
The reaction of calcium carbide and water produces acetylene and a chalky suspension of calcium hydroxide.



When a lit match is brought up, the combustion of the acetylene occurs inside the container. The resulting rapid expansion of the gaseous products followed by air rushing into the flask causes a controlled explosion.



Incomplete combustion results in the dangerous build-up of poisonous carbon monoxide gas, shown in the following equation for acetylene.



2.3. Stage 3: Boiler.

Here steam is generated by using the water tube boiler. Water tube boiler is a type of boiler in which water circulates in tubes heated externally by the fire. Fuel is burned inside the furnace, creating hot gas which heats water in the steam-generating tubes. In smaller boilers, additional generating tubes are separate in the furnace, while larger utility boilers rely on the water-filled tubes that make up the walls of the furnace to generate steam. The general schematic representation of the water tube boiler is shown below (in fig2).

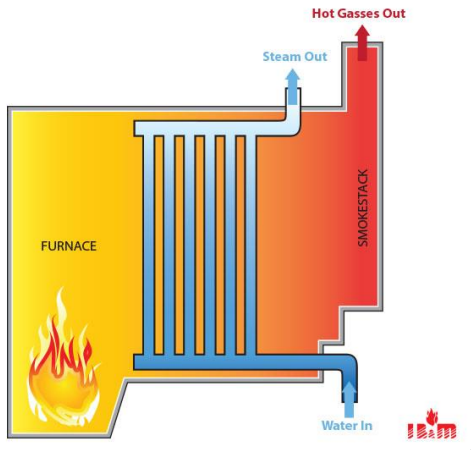


Fig3: Water tube boiler

$$\text{Boiler Efficiency } (\eta) = \frac{Q \times (h_g - h_f)}{q \times GCV} \times 100$$

Parameters: quantity of steam generated per hour (q) in kg/hr. quantity of fuel used per hour (q) in kg/hr. [3] Enthalpy of steam at (h_g) at working pressure (kg/cm²) and superheat temperature, if any enthalpy of feed water (h_f) at the temperature of feed water type of fuel and gross calorific value of the fuel (gcv) in kcal/kg of fuel.[x] [4].

2.4. Stage 4: Running turbine.

Generated steam from the boiler is passed to the steam turbine, a steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft.

Steam turbines are made in a variety of sizes ranging from small <0.75 kW (<1 hp) units and other shaft driven equipment, to 1.5 GW (2,000,000 hp) turbines used to generate electricity[4].

Blade efficiency η_b can be defined as the ratio of the work done on the blades kinetic energy supplied to the fluid.

$$\eta_b = \frac{\text{Workdone}}{\text{Kinetic Energy}}$$

A stage of an impulse turbine consists of a nozzle set and a moving wheel. The stage efficiency defines a relationship between enthalpy drop in the nozzle and work done in the stage.

$$\eta_{\text{stage}} = \frac{\text{Work done on blade}}{\text{Energy supplied per blade}}$$

Practical thermal efficiency of a steam turbine varies with turbine size, load condition, gap losses and friction losses. They reach top values up to about 50% in a 1200 MW turbine; smaller ones have a lower efficiency. These types

include condensing, non-condensing, reheat, extraction and induction. Condensing turbines are most commonly found in electrical power plants. These turbines receive steam from a boiler and exhaust it to a condenser. The exhausted steam is at a pressure well below atmospheric, and is in a partially condensed state, typically of a quality near 90% [5].

Non-condensing or back pressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by a regulating valve to suit the needs of the process steam pressure. These are commonly found at refineries, district heating units, pulp and paper plants, and desalination facilities where large amounts of low pressure process steam are needed.

The control of a turbine with a governor is essential, as turbines need to be run up slowly to prevent damage and some applications (such as the generation of alternating current electricity) require precise speed control. Uncontrolled acceleration of the turbine rotor can lead to an over-speed trip, which causes the governor and throttle valves that control the flow of steam to the turbine to close. The control of a turbine with a governor is essential, as turbines need to be run up slowly to prevent damage and some applications (such as the generation of alternating current electricity) require precise speed control. Uncontrolled acceleration of the turbine rotor can lead to an over-speed trip, which causes the governor and throttle valves that control the flow of steam to the turbine to close [6].



Fig4: Low pressure turbine

2.5. Stage 5: Generating electricity.

Providing the mechanical link between turbine and generator shafts, electricity can be generated [7].

The output frequency of an alternator depends on the number of poles and the rotational speed. The speed corresponding to a particular frequency is called the synchronous speed for that frequency [8]. The schematic representation of generation of electricity is shown in fig (4).

The relation between speed and frequency is

$$N = 120f/P$$

Where, f=frequency in Hz, P= Number of poles

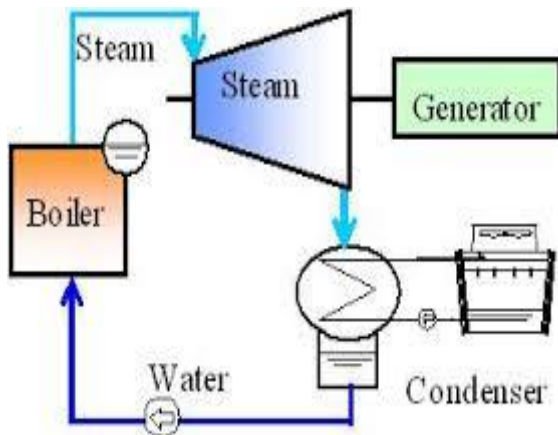


Fig5: Schematic representation of power plant

3. ENVIRONMENTAL ASPECTS

3.1. Total Emissions in Metric Tons

The molecular weight of acetylene is 26 with two carbon atoms (C₂H₂ gas density = 0.068 lb/ft³ typically the Material and Safety Data sheet will provide this detail of information) while the molecular weight of CO₂ is 44 with one carbon atom. Given that each mole of acetylene, under complete combustion, will create two moles of CO₂ (i.e., each pound of acetylene combusted will produce 3.38 pounds of CO₂(2x44/26)). Use the following conversion calculations to derive an emission factor for acetylene

$$\frac{0.068 \text{ lb}}{1 \text{ cubic feet of C}_2\text{H}_2} \times \frac{453.6 \text{ g}}{1 \text{ lb}} = \frac{30.854 \text{ g}}{1 \text{ cubic feet of C}_2\text{H}_2}$$

$$\frac{30.854 \text{ g}}{1 \text{ cubic feet of C}_2\text{H}_2} \times \frac{26.04 \text{ g}}{1 \text{ mol C}_2\text{H}_2} = \frac{1.185 \text{ mol C}_2\text{H}_2}{1 \text{ cubic feet of C}_2\text{H}_2}$$

$$\frac{1.185 \text{ mol C}_2\text{H}_2}{1 \text{ cubic feet of C}_2\text{H}_2} \times \frac{2 \text{ mol CO}_2}{1 \text{ mol C}_2\text{H}_2} = \frac{2.370 \text{ mol CO}_2}{1 \text{ cubic feet of C}_2\text{H}_2}$$

$$\frac{2.370 \text{ mol CO}_2}{1 \text{ cubic feet of C}_2\text{H}_2} \times \frac{44.01 \text{ g}}{1 \text{ mol CO}_2} = \frac{104.304 \text{ g CO}_2}{1 \text{ cubic feet of C}_2\text{H}_2}$$

$$\frac{104.304 \text{ g CO}_2}{1 \text{ cubic feet of C}_2\text{H}_2} \times \frac{1 \text{ metric ton}}{10^6 \text{ g}} = \frac{104.304 \times 10^{-4} \text{ m. ton CO}_2}{1 \text{ cubic feet of C}_2\text{H}_2}$$

Acetylene consumed (cubic feet) X Acetylene emission factor ($\frac{104.304 \times 10^{-4} \text{ metric ton CO}_2}{1 \text{ cubic feet of C}_2\text{H}_2}$) = Total emissions (metric tons)

The result obtained from this calculation illustrates that the amount of CO₂ emitted is fairly minimum and other emissions like NO_x, SO_x are highly negligible compared to CO₂. This indicates that acetylene can be relatively more environmental friendly than gasoline.

3.2. Ozone Layer Depletion POCP.

Despite playing a protective role in the stratosphere, at ground-level ozone is classified as a damaging trace gas.

Photochemical ozone production in the troposphere, also known as summer smog, is suspected to damage vegetation and material. High concentrations of ozone are toxic to humans. Radiation from the sun and the presence of nitrogen oxides and hydrocarbons incur complex chemical reactions, producing aggressive reaction products, one of which is ozone. Nitrogen oxides alone do not cause high ozone concentration levels.

4. RESULT:

The flame temperature and densities are compared with the other forms of fuel in the graphical representation.

4.1 Comparison between Acetylene and Other gasses

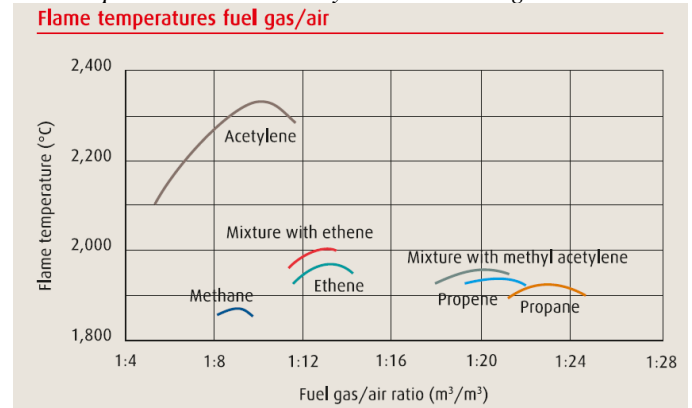


Fig6: Flame temperature vs fuel gas/ air ratio

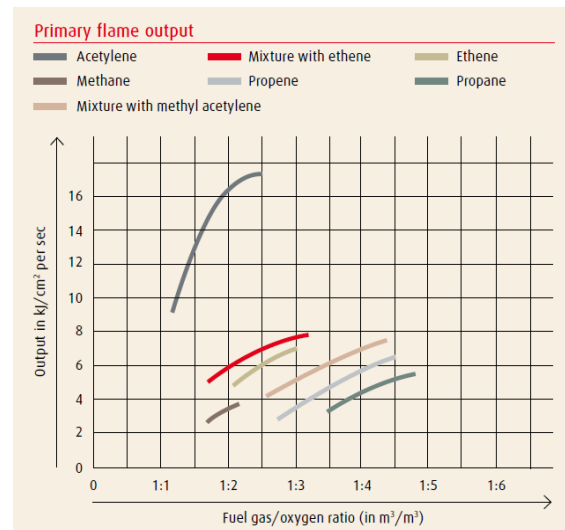


Fig 7: flame output vs fuel gas / oxygen ratio of different gasses

Acetylene is lighter than air

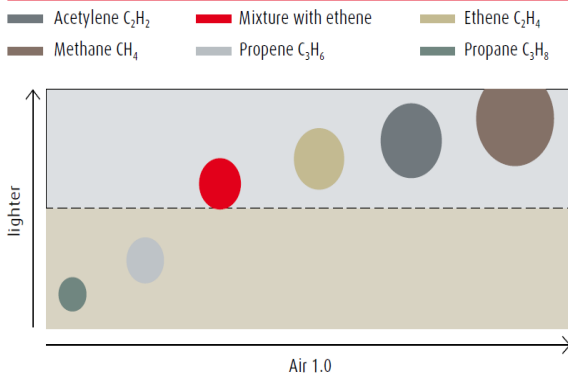


Fig 8: Acetylene and other gases density

Table 1: Percentage of moisture contents in different gasses

Fuel gas	Moisture content in flame (in %)
Natural gas (methane)	41
LPG/propane	32
Acetylene	3

Table 2: Comparison between coal and acetylene

Fuel type	Cost (Rs per kg)	Calorific value	Emission
Coal	50	2200 kcal/kg	CO ₂ , NO _x , SO ₂
Acetylene	30	11932 kcal/kg	CO ₂ , Water vapours

5. CONCLUSION:

With respect to results it is seen that the flame temperature of acetylene with respect to other gases is very high and the combustion ratio with air is also high. It is also seen that acetylene is lighter than air. The moisture content of acetylene is also very low which reduces the cost of moisture removal process. Here we have also seen the cost of calcium carbide and coal which is very low as compared to their gross calorific value and emissions.

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