

Production of Acetylene gas for use as an Alternative fuel

Sri Sathya Sai S V¹, Rahul Ranganath², Shane Shaju³, Ajay J Nayar⁴

^{1,2,3}B.Tech Students, Department of Mechanical Engineering-PES University, Bangalore – 560085, Karnataka, India

⁴Independent Researcher & Assistant Professor-PES University, Bangalore, Karnataka, India

Abstract - The primary goal of this research is conducting various production tests on Acetylene gas and ascertaining the maximum yield at optimum conditions. Since Acetylene can be thought of as a clean replacement in place of fossil fuels and hence, various methods of Acetylene production are studied. Acetylene formation from the exothermic reaction between Calcium Carbide (CaC₂) and water is found to be expedient. This method of production is preferred over others, because of its feasibility and relative ease. The production rates using various types of water, such as normal tap water, salt water and distilled water are tabulated. The same was attained by varying the temperature of normal tap water. The respective production curves were plotted and the trends were analyzed. The plots were compared with one another and the optimal yield was substantiated. With reference to the results, Acetylene is advocated to be a strong contender to be used as an alternative fuel in internal combustion engines.

Key Words: Acetylene, Calcium Carbide, Normal Tap water, Distilled water, Salt water, Temperature, Calcium Hydroxide (slurry).

1. INTRODUCTION

Acetylene is an achromatic and a highly reactive gas with a distinctive odor. In its purest form, it is said to be odorless but that is hardly the case when we work with the gas. It is the simplest alkyne, with the formula being C₂H₂. From desirable properties like high combustibility to ease of production, Acetylene has become a suitable candidate for a much-needed alternative fuel. Its properties not only parallel those of conventional fossil fuels but it has certain advantages of its own. Firstly, the ease of production cost is highly feasible, Acetylene can be easily produced. Using Calcium Carbide and water are normally used as reactants. The reaction between the two is exothermic, which results in Acetylene formation. Even the minimal ratio of the reactants results in a considerable amount of Acetylene gas. Hence, the process is very economical. Acetylene gas has a low heating value as well. It is a non-polluting fuel which is thermally and practically efficient. Its non-polluting and non-toxic nature are of great benefit to us. It is very importantly self-sufficient. Acetylene aspiration reduces smoke and exhaust temperature. Fossil fuels are known to be non-renewable, that is they take millions of years to form. Acetylene on the other hand, is obtained from renewable sources like all the other gaseous fuels. These are the properties which make

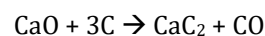
Acetylene a very effective and suitable replacement for fossil fuels.

2. METHODS OF ACETYLENE PRODUCTION

The various methods of producing Acetylene are studied and stated as follows.

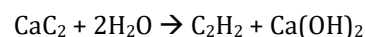
2.1 From Calcium Carbide and Water

Production of Calcium Carbide (CaC₂): At 2200°C, Calcium Carbide is produced from an amalgam of Coke and Lime in an electric arc furnace.



As the above mentioned temperature is not practically achievable, a graphite electrode is used in the process. The carbide product produced generally contains around 80% calcium carbide by weight.

Production of Acetylene (C₂H₂) [1]: The main governing chemical equation is given below [6]



When any grade of Calcium Carbide comes into contact with water, a chemical reaction immediately begins, which is Acetylene. An important reaction of Acetylene is its combustion. Acetylene has a relatively high pH but it is still less when compared to water. Countries such as China, use large amounts of Acetylene as an Industrial fuel, mainly because it is cheaper to make and use domestically than to import Petroleum for the same purpose.

2.2 From Thermal Cracking process

Another very effective way of producing Acetylene is by Thermal Cracking Process [2]. Thermal Cracking process is where Acetylene gas is generated by raising the temperature of several suitable hydrocarbons to the point where their atomic bonds crack. After the original hydrocarbon atoms break apart from each other, they are made to re-bond to form different desired materials. Gas mixtures are usually formed as a result of the Thermal cracking. This is a very widely used process, where natural gas or oil in the raw form is used to get converted into a variety of chemicals.

Thermal Cracking is highly advantageous in that it is highly energy-efficient compared to other similar processes and that it provides relatively high selectivity for Acetylene. It permits relatively flexible control of the product composition. There are numerous dissimilarities regarding this process, wherein different primal matters might be utilized and different methods might be used for raising the temperature to that required. One such variation is where the hydrocarbon is thermally cracked in the presence of CO₂. some of the cracking processes use a combustion chamber which burns a fuel and an oxidizer to produce energy. A liquid hydrocarbon maybe cracked by means of a plurality of arcs burning under the surface of the liquid hydrocarbon being used, wherein the total energy acting on the system is distributed by an arrangement of the electrical components (which is in turn responsible for the stability of the arcs, over a plurality of localized burning points).

One such variation of the process, using the combustion chamber to heat natural gas is very popular today. In order to be mixed with oxygen, Natural gas is heated to a lofty temperature. The mixture then goes through a diffuser, which slows down the speed of the mixture. The mixture ignites itself, thus causing a flame. The burning mixture then quickly flows into the prescribed leeway where its tremendous temperature causes a third of the methane to get completely converted into Acetylene. Methane which is left behind gets ignited. The blazing gas is then quenched with water. It is then passed through a water scrubber and a second scrubber, the former removing the carbon soot and the latter, where it is sprayed with a solvent absorbing only Acetylene and not any other gas. A detached tower is maintained, where the solvent gets pumped off to. Here, the desired Acetylene gas is boiled off and collected at the top of the tower in the gaseous form.

3. PRODUCTION OF ACETYLENE FROM CALCIUM CARBIDE AND WATER

3.1 Theoretical prediction of Acetylene production

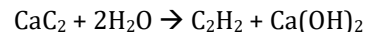
The Acetylene formed here as a product of the reaction between Calcium Carbide and water would be generated in quite a big amount. Hence, the process is economical. The Calcium Hydroxide, which is essentially the by-product here would be in the form of a slurry, which would then have to be disposed in an efficient manner. There are many properties of Acetylene which makes it a very effective replacement in the place of fossil fuels.

Some of these properties as mentioned in [3][4] are as follows:

- Auto Ignition Temperature: 581°C
- Air fuel ratio: 13.2: 1
- Minimum Ignition: 0.019MJ
- Combustibility

- Flammability limits: 2.5% - 81%
- Low heating value

The governing chemical equation for the production of Acetylene is shown below.



Atomic Weights of all the reactants and products

1. Calcium Carbide: 64.099 g/mole
2. Water: 18.01528 g/mole
3. Acetylene: 26.04 g/mole
4. Calcium Hydroxide: 74.093 g/mole

64.009g of Calcium Carbide Produces 26.04g of Acetylene.

Hence, 1g of CaC₂ produces 0.40681g of C₂H₂.

$$\text{Number of Moles} = \text{Given Mass/Molecular Mass}$$

Moles of Calcium carbide = 0.015622

Moles of Acetylene = 0.015622

It can be seen that,

$$\text{Number of Moles of CaC}_2 = \text{Number of Moles of C}_2\text{H}_2$$

Number of moles for 1000g of CaC₂ = 15.6228 moles of C₂H₂

Let 'n' be the number of Moles of Acetylene formed for 1000g of Calcium Carbide.

By Ideal Gas Equation,

$$PV = nRT$$

where,

P = Absolute Pressure = 101325Pa (Atmospheric Pressure)

V = Volume

n = Number of Moles

R = Universal Gas Constant = 8.314 J/K.mole

T = Absolute Temperature = 273.15K

By substituting all the above standard values,

$$V = 350.149 \text{ litres}$$

3.2 Experimentation

The method adopted for the production of Acetylene is the hydrolysis of Calcium carbide as shown in the figure below. The main aim is to get the maximum production of Acetylene gas. The apparatus which were used in measuring the volume of Acetylene formed are: Measuring Cylinder, Conical Flask, Cork, Water, Calcium Carbide pieces, Digital Weighing scale (with accuracy 0.01g), Flexible tube, Water Bath tub, Syringe (for accurate measurement of water), Forceps, Gloves for safety, Face masks for safety, Protective glasses for safety.

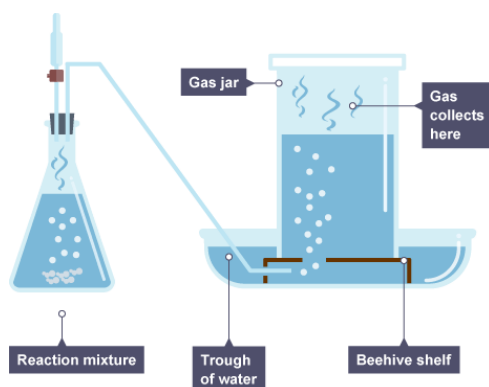


Fig-1: Collection of gas by water displacement (Picture Courtesy: askiitians.com) [5]

Initially, a specified amount of Calcium Carbide is taken in a completely dried conical ask (1g). A tub is filled with water up to the brim. A measuring cylinder (500mL) is filled with water up to the brim and is carefully inverted into the water bath without any air leaking into the measuring cylinder. A hole is drilled in the cork so that the flexible tube can fit inside it without any clearance. The free end of the flexible tube is placed inside the inverted measuring cylinder, so that when Acetylene is passed through it, the water is displaced inside the measuring cylinder and the volume of the gas is obtained. Now a known volume of water is added to the conical ask containing calcium carbide in turn producing Acetylene gas. The Acetylene gas so formed travels through the flexible tube and enters the measuring tank. The water inside the measuring tank is displaced by the Acetylene gas and corresponding value is noted. The same procedure is repeated for various amounts of calcium carbide and water and a plot is generated of the same.

1. Acetylene production with Normal tap water at various temperatures

The same procedure is followed by taking 1g of Calcium Carbide and 5mL of Water and varying the temperature.

Table-1: Amount of Acetylene produced by varying the temperature of Normal tap water

Sl. No	Amt of CaC ₂ (in g)	Vol. of Water (in mL)	Temp (in °C)	Vol. of C ₂ H ₂ (in mL)	Amt of Ca(OH) ₂ (in g)
1	1	5	8	210	5.62
2	1	5	26.7	212.5	5.49
3	1	5	45	160	5.69
4	1	5	60	195	5.69
5	1	5	75	150	6.19

2. Acetylene production with Salt water

The above procedure is followed by taking 1g of Calcium Carbide and varying the volume of salt water.

Table-3: Amount of Acetylene produced with Salt water

Sl. No	Amt of CaC ₂ (in g)	Vol. of Water (mL)	Vol. of C ₂ H ₂ (mL)	Amt of Ca(OH) ₂ (in g)	Slurry Condition
1	1	1	200	2.02	Not Dissolved
2	1	5	235	5.92	Dissolved

3. Acetylene production with Normal Tap water

The above procedure is followed by taking 1g of Calcium Carbide and varying the volume of normal tap water.

Table-2: Amount of Acetylene produced with normal tap water

Sl. No	Amt of CaC ₂ (in g)	Vol. of Water (in mL)	Vol. of C ₂ H ₂ (in mL)	Amt of Ca(OH) ₂ (in g)	Slurry Condition
1	1	0.5	35	1	Not Dissolved
2	1	1.0	200	2	Not Dissolved
3	1	1.5	275	3	Not Dissolved
4	1	2.0	415	5	Not Dissolved
5	1	2.5	320	13	Not Dissolved
6	1	3.0	440	15	Not Dissolved
7	1	3.5	340	4	Dissolved
8	1	4.0	275	5	Dissolved
9	1	4.5	440	7	Dissolved
10	1	5.0	335	5	Dissolved
11	1	6.0	180	7	Dissolved
12	1	7.0	245	8	Dissolved
13	1	8.0	275	9	Dissolved
14	1	9.0	455	11	Dissolved
15	1	10.0	235	11	Dissolved

4. Acetylene production with Distilled water

The above procedure is followed by taking 1g of Calcium Carbide and varying the volume of distilled water.

Table-4: Amount of Acetylene produced with Distilled water

Sl. No	Amt of CaC ₂ (in g)	Vol. of Water (in mL)	Vol. of C ₂ H ₂ (in mL)	Amt of Ca(OH) ₂ (in g)	Slurry Condition
1	1	0.5	110	1.64	Not Dissolved
2	1	1.0	165	2.07	Not Dissolved
3	1	1.5	150	2.63	Not Dissolved
4	1	2.0	245	3.2	Not Dissolved
5	1	2.5	250	3.79	Not Dissolved
6	1	3.0	365	4.41	Not Dissolved
7	1	3.5	305	4.69	Dissolved
8	1	4.0	285	5.67	Dissolved
9	1	4.5	290	6.19	Dissolved
10	1	5.0	270	6.53	Dissolved
11	1	6.0	180	7.56	Dissolved

12	1	7.0	360	9.2	Dissolved
13	1	8.0	180	10.29	Dissolved
14	1	9.0	70	11.76	Dissolved
15	1	10.0	55	13.31	Dissolved

As inferred from the above tables, the maximum or optimal yield of Acetylene gas is obtained from using normal tap water instead of distilled or salt water.

The respective graphs of the above table are plotted using scilab and their trends are scrutinized.

Chart -1: Volume of Acetylene formed V/S different types of waters used

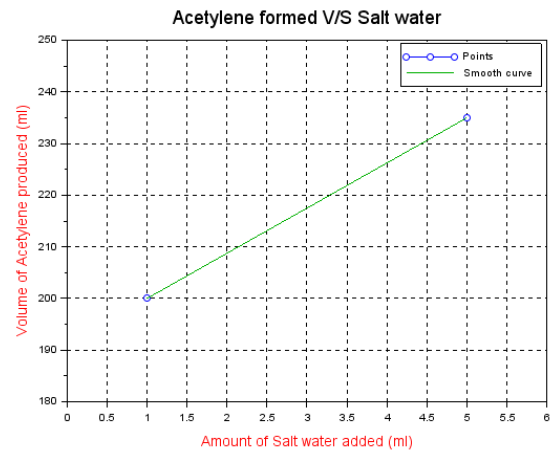
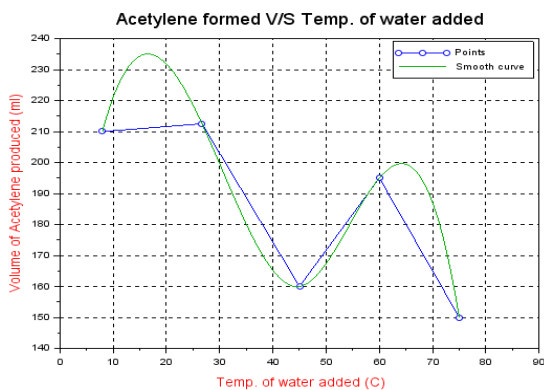
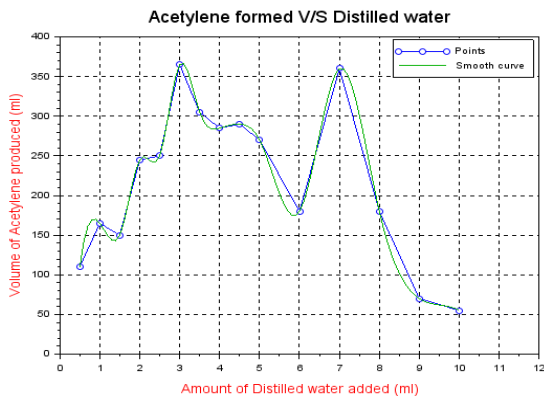
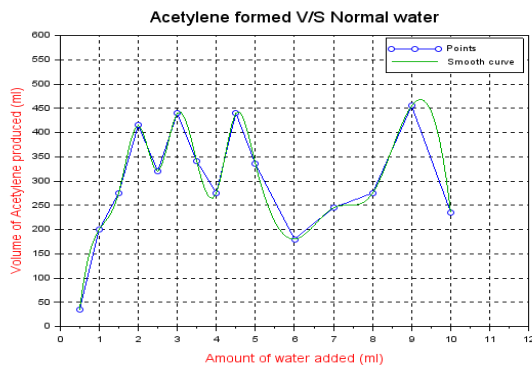
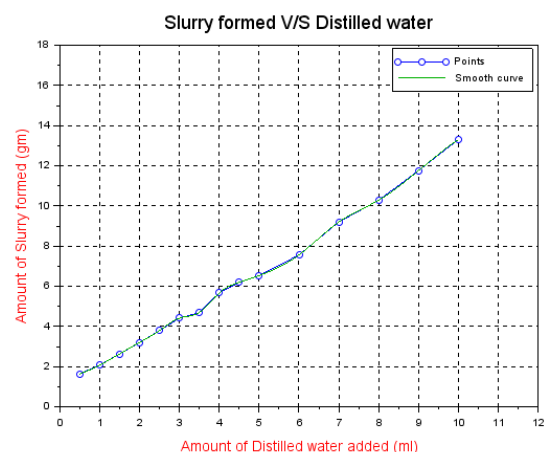
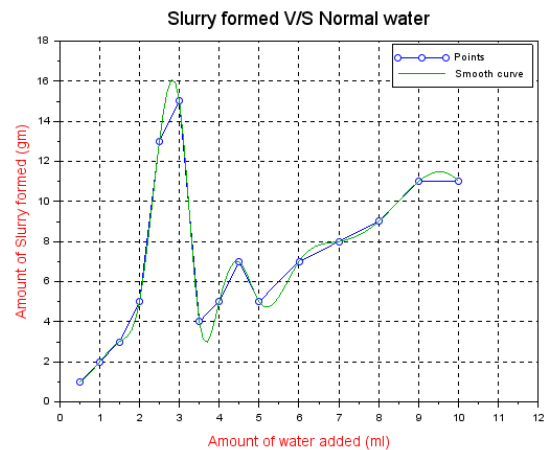
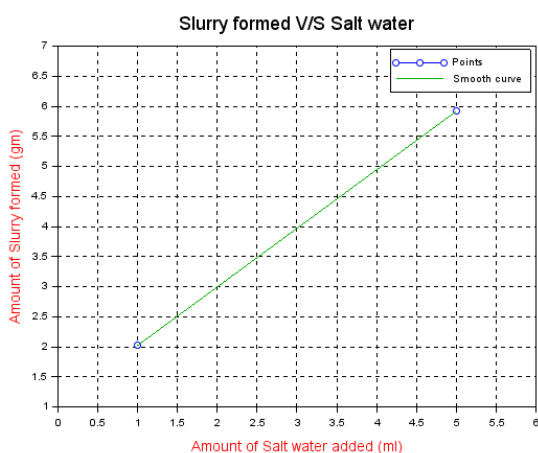
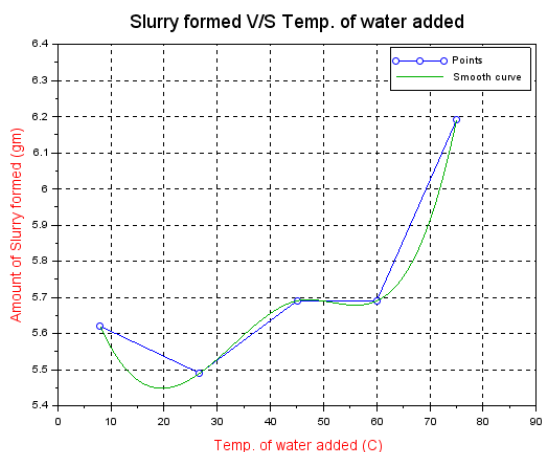


Chart -2: Calcium Hydroxide formed V/S different types of waters used.





4. CONCLUSIONS

It can be inferred from the above observations that the optimal yield of Acetylene gas is obtained by reacting Calcium Carbide and Normal tap water in an exothermic fashion. From the normal tap water plot, we can conclude that the maximum volume of Acetylene obtained was 455mL with 9mL of water and the minimum value obtained was 35mL.

By extrapolating the maximum and minimum values, we get an approximate range of 35L - 455L of acetylene for 1 kilogram of calcium carbide at various amounts of water.

Similarly, for distilled water the range turned to be 55L - 365L for various amounts of water. Comparing the ranges of normal tap water and distilled water, normal tap water is better recommended as the reactant to obtain optimal yield of Acetylene [6].

The volume of Acetylene obtained at different temperatures of the reactant (normal tap water) was found to give a maximum yield (212.5mL) at 26.7°C which is close to the room temperature. Increasing the temperature of water to 75°C was found to give a lesser yield of Acetylene,

indicating that operating at about room temperature would give a better yield of Acetylene gas.

When compared with the theoretical stoichiometric calculations, we observe that the experimentally obtained ranges are more or less in sync with the theoretically obtained volumes.

ACKNOWLEDGEMENT

First and foremost, we would like to show our gratitude towards our guide Prof. Ajay J Nayar, who made the litany of our project a joy to be involved in. We would like to thank the measurement science and metrology department of PES University for letting us use their equipment. We would like to whole-heartedly thank the chairperson Dr. K S Sridhar and Dr. V Krishna, Mechanical Dept., PES University for their continuous support and valuable inputs. We would also like to thank the Dean of Research, Dr. Sudarshan for his encouragement and support. Also, we'd like to specially thank the foreman of the mechanical workshop at PES University for helping us while working. Finally, we'd like to thank Dr. K.N.B Murthy, Vice Chancellor, PES University for the financial support.

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BIOGRAPHIES



Sri Sathya Sai SV
Currently pursuing B. Tech
3rd year, Mechanical Engineering,
PES University



Rahul Ranganath
Currently pursuing B. Tech
3rd year, Mechanical Engineering,
PES University



Shane Shaju
Currently pursuing B. Tech
3rd year, Mechanical Engineering,
PES University



Ajay J Nayar
Independent Researcher, Assistant
Professor
PES University