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A PRACTICAL METHOD OF REDUCING SMOKESTACK CARBON DIOXIDE EMISSIONS

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ABSTRACT: *Climate change is not an esoteric subject. It has important impacts to our living. Bush fires and floodings have reduced our usable land areas for agriculture and housing development, causing rapid inflation. Climate scientists and environmental scientists emphasize the importance of reducing the load of CO_2 in our atmosphere. We try to present a practical method to reduce CO_2 emissions of power plant smokestack by channeling the treated and filtered flue gas through a cooling chamber and then a photosynthesis chamber that turns carbon dioxide and steam components into oxygen and glucose. Required special instruments are illustrated with figures, and heat exchanges are illustrated with data and equations. Near the end, application aids are provided by comparing the data with real power plant data. In conclusion, reasons are given for why applying the method will stimulate the economy and prevent contamination of drinking water. Although the examples presented here are for the U.S., the methodology can be generalized to all highly industrialized countries.*

KEYWORDS: practical method, smokestack, carbon dioxide, emissions

INTRODUCTION

In highly industrialized countries, like the U.S., it is important to be able to use fossil fuels, e.g., coal. As pointed out by Lisa Palmer[1], coal burns at a slow rate for a long time; it is also efficient as an energy source. U.S. has about 25% of the world's known coal reserves, mainly in Wyoming, West Virginia, Pennsylvania, Illinois, and North Dakota. For simplicity, we will use coal as an example in the present discussion. In recent years, the blessings of coal reserves have turned into a question mark, if not entirely negative, as majority of environmental and climate scientists that study the changes in solar energy, ocean circulation, volcano activity and the amount of greenhouse gases in the atmosphere agree that climate change is caused by human activities. An important activity has been the burning of coal at power plants with smokestacks that emit a large amount of CO_2.

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The main purpose of the present discussion is to describe the required new set of structures and functional units to reduce CO_2 emissions, and the heat exchange processes involved in terms of theoretic equations and basic assumptions. It is also important to point out that there is no need to destroy the existing smokestacks, wasting labor and money, as the existing stacks can be used while doing new system check-up and collecting the end products of planned treatment for analysis during short periods of time, presumably in the evenings. However, this implies that there are control lids installed to do 'close this, open that' at the outlet of flue gas to the stack and the outlet to the new cooling chamber, from outside.

Basic Structures and Functional Units

To be specific, a new structure will be added to further treat the already treated and filtered flue gas of the power plant, so that it can go through a photosynthesis process that turns its carbon dioxide and water into oxygen and glucose.The advantage of a man-made photosynthesis unit is obvious. It is efficient and does not need large areas of land to plant trees near the power plant; and it does not require the right wind direction and sunny hours to work. However, we do need to increase the water content and decrease the temperature of the flue gas because we do not know that the artificial silk leaves[2] can work at temperatures significantly higher than the lowest steam temperature of 100˚C. Before entering the new structure, the flue gas has temperature of 150˚C and approximate composition of 13% CO_2, 9% steam, 4% O_2, and 74% N_2, according to U.S. EPA report[3] and the recent document[4] from the Energy Information Administration (EIA) of U.S. Department of Energy.

Cooling Chamber

The chamber can be a horizontally elongated cylinder made of copper enclosed in a cement or brick enclosure for safety and simplicity of analysis. The chamber will have an opening for cold water feed on the flue gas entry side. In our analysis presented in section 3, the water temperature is set to be 20˚C. There are many controlling factors for heat transfer in our case, such as the rate of heat transfer to the copper wall from the source, the rate of feed water falling on chamber bottom being evaporated into steam which has higher temperature and lower specific heat than water, making it hard to get cooling effect. In addition, we will use a special water feeder to cool the flue gas as follows.

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Water Feeder

We have decided not to use the commercial water sprayers that make cone shaped water droplet clouds with nozzles controlled by pressure settings, which are good for watering lawns and vegetated areas. We recommend an opening caliber-controlled water feeder (Fig. 1), with the feed rate controlled by a turning handle (TH), and measured by a digital water meter (DWM), and the feed water coming out in cold water fog, such as the Dramm Cold Fogger. The produced water clouds contain water droplets in size 100-400 microns, should be able to effectively absorb the heat content carried by the N_2 molecules that constitute 74% of the treated and filtered flue gas.

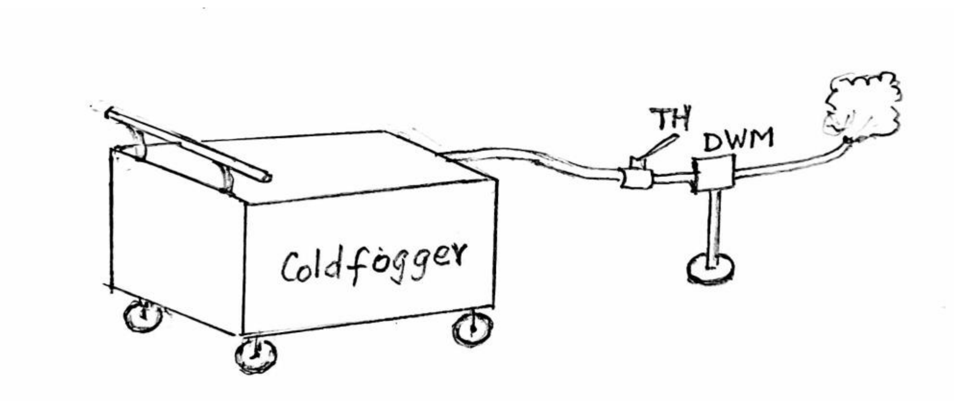

Fig. 1

Photosynthesis Chamber

After adding cold fog, which helps to lower the temperature of the mixture, the modified flue gas will be released into the photosynthesis chamber that is designed to trap and reflect sun light to culminate the photosynthesis of the incoming gas mixture's CO_2 and H_2O molecules. The inner wall is made of mirror plates to reflect sunlight to instigate the following reaction:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

The important ingredient in the chamber is the aggregate of green silk leaves[2] on artificial tree branches that provide pigments and chlorophyll molecules in proteins that instigate the electron transfers and photon absorptions required in the photosynthesis of CO_2 and H_2O.

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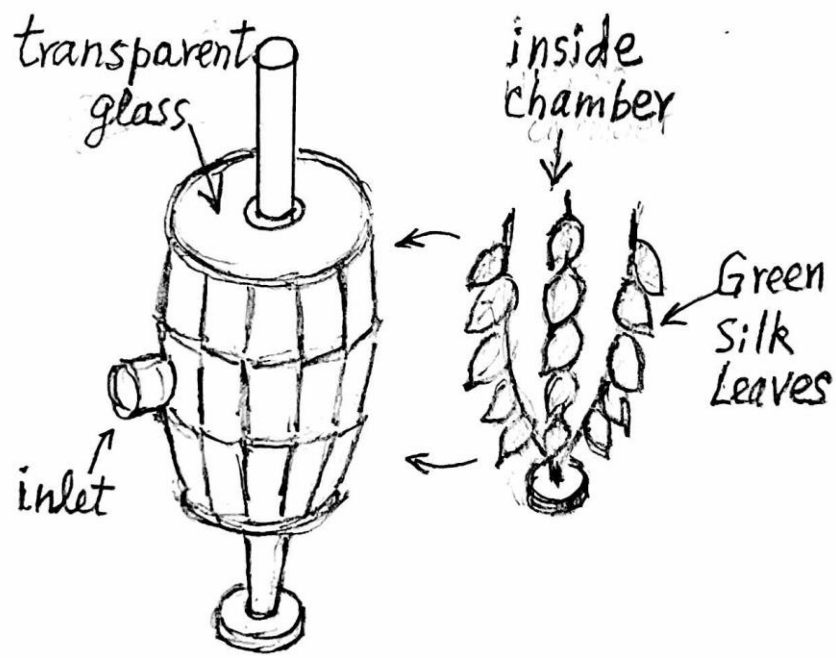

Fig. 2

It is necessary to have a pump that links the two chambers so that the cooled and treated flue gas is sent to the photosynthesis chamber continuously.

THEORETICAL ANALYSIS AND EQUATIONS

In the following analysis, we try to adhere to the symbolism and heat transfer related data presented by Octave Levenspiel[5] as much as we can. For simplicity, we will use 1, 2, 3, 4, and 5 as subscripts for CO_2, steam, liquid water, O_2, and N_2. For example, we use $\dot{M}_1$ for the mass rate of CO_2, and C_{p2} for specific heat of steam.

Following are the predicted rates of heat content changes in J/S. Temperature of the mixture at the chamber exit is denoted by $T_{mix.}$ The rate of heat content yielded by CO_2 flowing through the chamber will be:

$$\dot{M}_1 \text{ x } (150 - T_{mix}) \text{ x } 940. \qquad (1)$$

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The rate of heat content yielded by steam will be

$\dot{M}_2$ x (150 – T_{mix}) x 2135. (2)

The rate of heat content yielded by O_2 will be

$\dot{M}_4$ x (150 – T_{mix}) x 948. (3)

The rate of heat content yielded by N_2 will be

$\dot{M}_5$ x (150 – T_{mix}} x 1042. (4)

The rate of heat absorption of fed water through molecular interactions will be

$\dot{M}_3$ x (T_{mix} – 20) x 4180. (5)

In order to apply the first law of thermodynamics, we will evaluate each mass rate by multiplying the molecular weight by the percentage. For example, $\dot{M}_1$ = 0.13 x 46 = 5.98.

The energy conservation law then requires the sum of
(1) + (2) + (3) + (4) to be equated to (5).

The tedious but straightforward calculation then yields:

4782495 – 31883.3 x T_{mix} = 13543.2 x T_{mix} – 270864. (6)

We obtain T_{mix} = 111.2˚C.

The above result has been obtained assuming that we fed cold water into the cooling chamber with a mass rate that was twice that of the steam in the flue gas. We would like to point out that in the above analysis, we have not included heat radiation from the cooling chamber surface. The reason is that we purposely recommended copper for constructing the cylindrical chamber for its very low heat emissivity. To be very rigorous, the above exit twice treated flue gas temperature is an estimated upper limit value.

The above result is certainly unsatisfactory. We will recommend feeding at least 40% (by measure of percentage of flue gas) of cold-water fog. At 40%, application of the first law of thermodynamics yields the following equation:

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$$4783495 - 31883.3 \times T_{mix} = 30096 \times T_{mix} - 601920, \qquad (7)$$

and we obtain $T_{mix} = 86.9^{\circ}C$.

All the above selection of instruments, materials, and arrangements show that it is not easy to deal with the very significant heat content of N_2 in the flue gas.

For actual application of the new treatment of flue gas, we convert the U.S. EPA data[3] for 264 large power plants in U.S. to the average individual plant CO_2 mass emission rate in kg/s.

$\dot{M}_1 = 125.8$ kg/s.

From this emission rate, user of the method can easily determine how to adjust his or her cold-water fog feeder.

CONCLUSIONS

This article is merely a proposal. What we hope will happen are the following.

1. Economic Stimulus

a. Demand for green silk leaves will greatly increase.
b. Demand for new glass equipment will also increase.
c. Upgrades of small power stations with high temperature
flue gas to low temperature flue gas will take place.

2. As mentioned in the Introduction, it is important for countries having rich energy reserves to keep using coal and other fossil fuels.

3. The important aim of suppressing climate change by reducing carbon dioxide in the air is significantly fulfilled.

4.Health related Benefits
We should mention that reduction of atmospheric carbon dioxide has an important reason related to our health. It may produce effects[7] on drinking water by transformation to carbonic acid and bicarbonate ions making the water acid and susceptible to dissolve elements (Ca, Na, K, Si), which may affect the health of consumers.

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