Chapter 27

# Air Plasma Coal Gasification Technology: A Closer Look

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## 27.1 Introduction to Plasma-assisted Coal Gasification

### 27.1.1 What is plasma?

Plasma is forth state of matter. Plasma is basically ionized gas and different from three common states of matter: solid, liquid and gas. It is said that 99% of the universe is plasma. Plasma is produced naturally by lightning when it superheats surrounding air. Plasma is classified in two categories: thermal and non-thermal. Thermal plasma jet is essentially highly concentrated beam of thermal energy at very high temperature consisting of electrons, ions and neutrals, can meet the high temperature requirement of gasification process in the most convenient manner [254]. Air plasma is the most suitable as air is freely available in environment

### 27.1.2 What is plasma-assisted coal gasification?

Coal gasification is a thermo-chemical technique which converts carbonaceous materials of coal into gaseous product in presence high temperature and suitable gasification medium [255–260]. Coal is converted into fuel gas by means of various gas-gas and gas-solid reactions. The gaseous product is called syngas mostly contains majorly carbon monoxide, hydrogen, carbon dioxide, and methane. Also, a little amount of tar, organic carbon, and other gaseous pollutants are generally present with syn gas. Syngas produced from the coal gasification is to be cleaned and then it can be utilized as a gaseous fuel either being combusted it in a gas engine or gas turbine to produce electricity. Also, alternatively it can be used as a starting material for synthesis of valuable chemicals such as and methanol, ethanol and liquid fuel. Plasma assisted coal gasification technology has several potential benefits over

traditional fossils fuel-based coal gasification technology. The presence of ions, electrons and other chemically active species offers superior thermo-chemical environment for efficient coal gasification process.

## 27.2 Brief History of Coal Gasification

Conventional gasification technology is age old technology it was discovered way back in 17th Century. However, it was widely practised in 19th century for synthesis of town gas. Historically, coal was gasified for production of coal gas, also known as "town gas" which was transported to burn for lighting up street, heating and cooking [260, 261]. Coal gas was

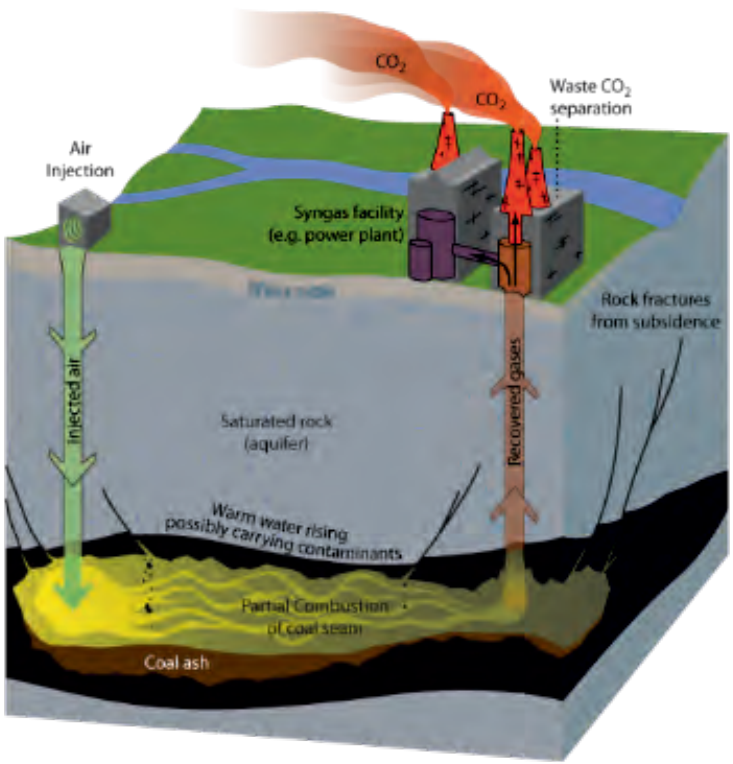


Figure 27.1: Underground coal gasification process [261].

used for domestic heating and municipal lighting, before invention of technology to produce gaseous fuel from crude oil [260]. During World War II, German people were forced to use of the gasification process as the supply of oil was cut down. Over the years gasification of coal appears as a fascinating alternative for energy as conventional fossil resource. Currently most of the conventional coal gasification plants are mainly for power generation and for various chemicals production. Hydrogen is considered to be 'future fuel of the world'. The hydrogen gas generated from coal gasification can be used for various applications such as synthesis of ammonia and other chemicals [260–262].

## 27.3 Underground Coal Gasification

Underground coal gasification (UCG) (Fig. 27.1) is an unique gasification technology which is done in underground. Generally non-mined coal seams are used. In this process an oxidizing agent, usually oxygen or air, are injected and resulting coal gas are brought to the surface using a well drilled from the surface [261–263]. The coal gas can be used as a fuel for electricity generation or to produce chemicals.

## 27.4 Chemistry of Coal Gasification

The coal gasification involves complex chemical reactions. It involves both homogeneous and heterogeneous reactions. Around fifteen numbers of reactions are involved in coal gasification process. The main chemical reactions of coal gasification are presented in the following Eqs. (27.1)- (27.5):

$$C + CO_2 \rightarrow 2\ CO \tag{27.1}$$

$$C + H_2O \rightarrow CO + H_2 \tag{27.2}$$

$$C_nH_m + n\ H_2O \rightarrow (n + m/2)\ H_2 + n\ CO \tag{27.3}$$

$$CO + H_2O \rightarrow CO_2 + H_2 \tag{27.4}$$

$$CO + 3\ H_2 \rightarrow CH_4 + H_2O \tag{27.5}$$

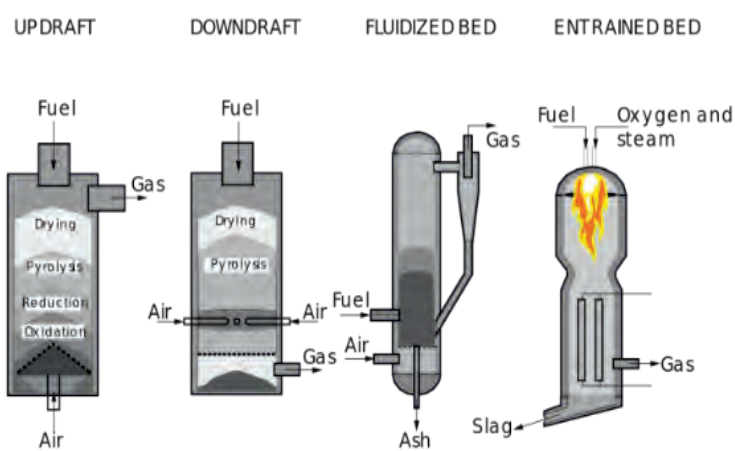


Figure 27.2: Different types of gasifiers [262–264].

## 27.5 Coal Gasifier Reactor

Coal gasifiers are classified in four types based on geometry namely downdraft fixed bed, updraft fixed bed, bubbling fluidized bed, circulating fluidized bed, entrained flow [257, 258, 261–264]. In updraft gasifiers, the coal is fed from the top of the gasifier. The gasifying agent which may be air, oxygen or steam, is fed from the bottom of the reactor in counter current

manner. In downdraft gasifiers, the coal is fed from the bottom of the gasifier. In the case of fluidized bed gasifiers, the gasifying agent allows the suspension of coal. Different types of gasifier are presented in Fig. 27.2.

## 27.6 Lab Scale Demonstration of Coal Gasification using Air Plasma Torch Developed by BARC

Recently, BARC, Mumbai has invented a simple hafnium cathode based low cost technology of air plasma torch. The torch, based on plasma thruster principle can deliver larger volume of air plasma at much higher temperature (~8000 °C) and lower gas flow rate, consuming electrical power significantly lower compared to those available in the market. A patent has been filed on the technology and the technology has been transferred to industry. The present proposal is to exploit the advantage of this invention in coal gasification and understanding the possible degree of complexity, issues, and advantages that may arise in developing a plant scale unit of the same. Details of the proposed setup are shown in Fig. 27.3.

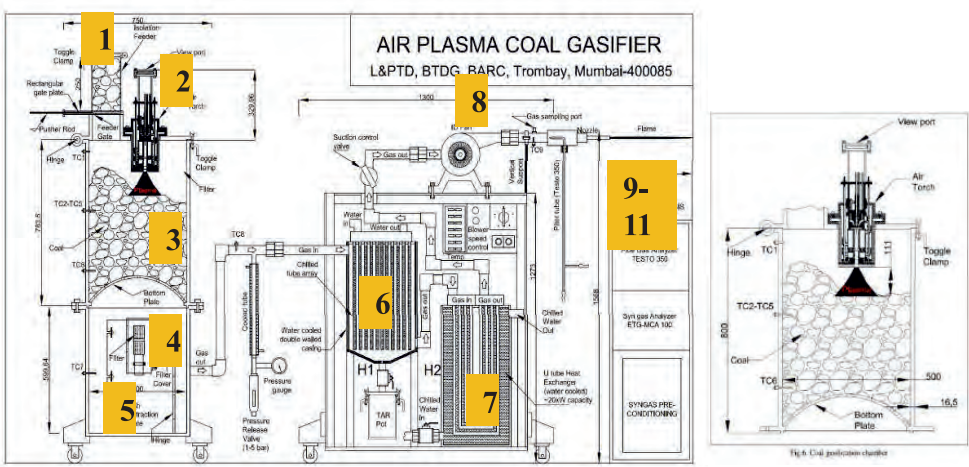


Figure 27.3: Proposed lab scale coal gasification demonstration unit: 1) coal feeding unit with isolation gate, 2) plasma torch unit, 3) main gasification chamber facilitated with water shift reaction and control, 4) filtration and syn-gas collection unit, 5) ash collection unit, 6) tar condenser unit, 7) heat exchanger, 8) ID fan gas suction unit with speed control, 9) temperature and pressure monitoring unit and control, 10) exhaust gas velocity measurement unit, and 11) online syn-gas composition and quality analysis unit.

### Frequently Asked Questions

Q1. What are the benefits of plasma assisted coal gasification?

Q2. What are the final products of coal gasification process?

Q3. What is underground coal gasification?

Q4. Write three main chemical reactions of coal gasification.

Q5. What are different types of coal gasifier?

Q6. What are the components of typical coal gasification unit?