2. TECHNICAL DESCRIPTION OF THE PROJECT

2.1. What is a Combined Cycle Gas Turbine (CCGT) Plant?

A CCGT power plant uses a cycle configuration of gas turbines, heat recovery steam generators (HRSGs) and steam turbines to generate electricity (see Figure 2.1 below). A combined cycle is characteristic of a power producing engine or plant that employs more than one thermodynamic cycle. Heat engines are only able to use a portion of the energy their fuel generates (usually less than 50%). The remaining heat from combustion is generally wasted. The combination of two or more "cycles" such as the Brayton Cycle and Rankine Cycle results in improved overall efficiency.

In a CCGT power plant, a gas turbine generator generates electricity and the waste heat is utilised to produce steam to generate additional electricity *via* a steam turbine cycle; this last step enhances the efficiency of overall electricity generation. In a thermal power plant, high-temperature heat as input to the power plant, usually from burning of fuel, is converted to electricity as one of the outputs and low-temperature heat as another output. As a rule, in order to achieve high efficiency, the temperature difference between the input and output heat levels should be as high as possible (Carnot efficiency). This is achieved by combining the Rankine (steam) and Brayton (gas) thermodynamic cycles.

The combined cycle power plant has a boiler called a Heat Recovery Steam Generator (HRSG) which produces steam using the exhaust gas at approximately 600 °C from an open cycle gas turbine. The steam is then used to drive the steam turbine which is also linked to the generator.

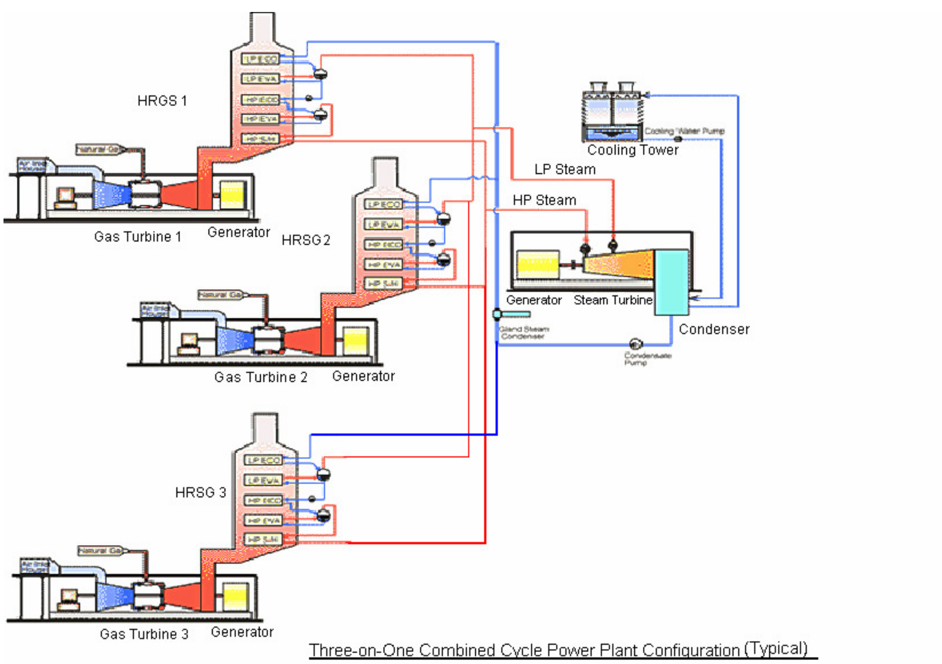

Figure 2.1 A typical 3-in-1 CCGT power plant configuration, in model form

2.2. How does a Combined Cycle Gas Turbine (CCGT) work?

The gas turbine (also called a combustion turbine) is a rotary engine that extracts energy from a flow of combustion gas and is the first stage in the process of producing electricity through the CCGT plant. It has an upstream compressor coupled to a downstream turbine, and a combustion chamber in-between. Gas turbine may also refer to just the turbine element. Figure 2.2 is the schematic of a gas turbine used for the electrical power production. A typical gas turbine unit consists of three major parts:

- **Compressor** - Compresses the incoming air to high pressure;
- **Combustion area** - Burns the fuel and produces high-pressure, high-velocity gas; and
- **Turbine** - Extracts the energy from the high-pressure, high-velocity gas flowing from the combustion chamber

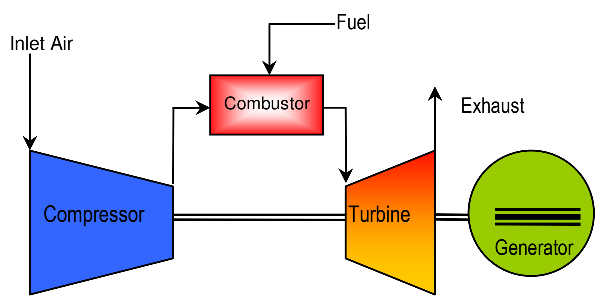

Figure 2.2 Schematic of a process of that a gas turbine undergoes in order to produce electricity.

The gas turbine compressor draws in air from the environment *via* a filter. This air is compressed in the compressor, thus being elevated to a higher pressure, and then directed into the combustion chamber. This combustible gas is then mixed in and combustion takes place generating hot gases under high pressure. The energy released is converted into a mechanical rotation which powers the compressor and the generator.

When used for power production, gas turbines can either be operated in an open cycle mode (exhaust to atmosphere) often referred to as an Open Cycle Gas Turbine (OCGT), or in a combined-cycle mode (CCGT – Combined Cycle Gas Turbine) as shown in Figure 2.3. A key feature of the thermodynamics of the gas turbine cycle is that the temperature of the turbine exhaust stream is typically in the range of 500℃ – 600℃. This heat energy is transferred to the water in the heat recovery steam generator. The heat is used to generate water vapour, which powers the steam turbine. The resulting mechanical energy is transferred to the generator. In the generator mechanical energy from the steam turbine is converted into electricity. The condenser converts exhaust steam from the steam turbine back into water by means of cooling.

The power island shown in Figure 2.3 overleaf clearly illustrates the proposed CCGT operation mode for the Majuba site which is to also house the UCG production and syngas processing plants (as illustrated in Figure 2.3). When the gas production and combined cycle occur at the same site as shown in Figure 2.3, then one may refer to this configuration as Integrated Gasification Combined Cycle (IGCC).

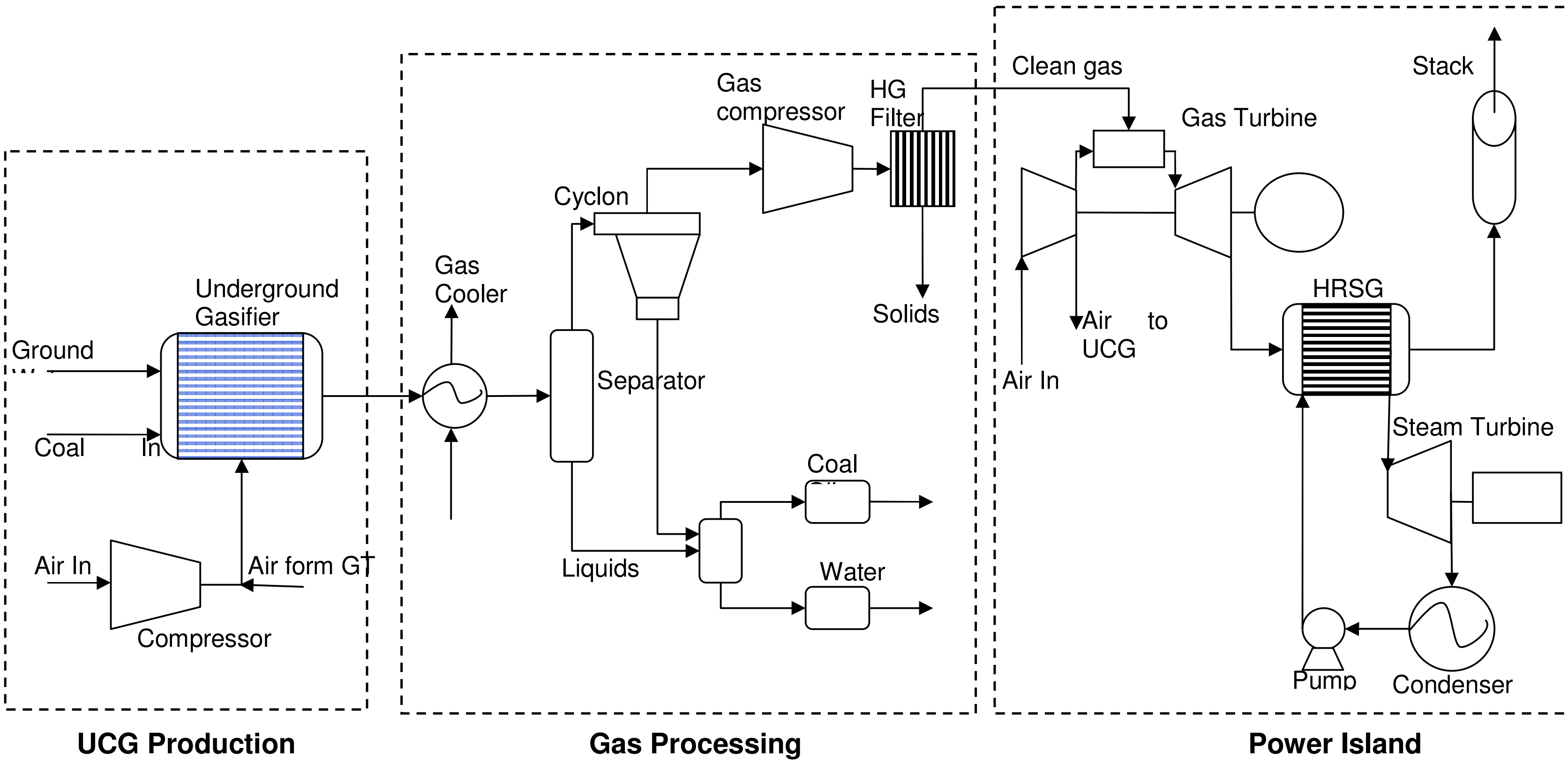

Figure 2.3 Layout of UCG-CCGT plant

When the front end engineering design (FEED) is initiated, the configuration for the CCGT power plant in the Amersfoort area will be determined. Previous FEED results for other projects have shown that for nine installed gas turbines, 3 x 2-on-1 (2 gas turbines per HRSG) and 1 x 3-on-1 (3 gas turbines per HRSG) configuration is optimum.

2.3. Water and Cooling

The purpose of the main cooling system is to cool the steam that turns the turbines so that it can be pumped back to the boilers as water.. The proposed power station would implement either a direct or indirect dry cooling system. Dry cooling systems are used where there is insufficient water, or where the water is too expensive to be used in an evaporative system.

Dry cooling systems are the least used systems as they have a much higher capital cost, higher operating temperatures, and lower efficiency than wet cooling systems. In the dry cooling system, heat transfer is by air to finned tubes. The minimum temperature that can be theoretically provided is that of the dry air, which can be regularly over 30ºC and up to 40ºC on typical summer afternoons. Compare this to wet cooling towers, which cool towards the wet bulb temperature, which is typically 20ºC on summer afternoons. The steam condensing pressures and temperatures of a dry cooled unit are significantly higher than a wet cooled unit, due to the low transfer rates of dry cooling and operation at the dry bulb temperature.

There are two basic types of dry cooling systems:
1. The direct dry cooling system; and
2. The indirect dry cooling system.

- ***Direct dry cooling***

In the direct dry system, the turbine exhaust steam is piped directly to the air-cooled, finned tube, condenser. The finned tubes are usually arranged in the form of an 'A' frame or delta over a forced draught fan to reduce the land area. The steam trunk main has a large diameter and is as short as possible to reduce pressure losses, so that the cooling banks are usually as close as possible to the turbine. A schematic of a direct dry cooling system is illustrated in Figure 2.4.

In the direct system, steam from the last stage turbine blades is channelled directly into radiator- type heat exchangers adjacent to the turbine hall of the power station (there are no cooling towers.). The heat is conducted from the steam to the metal tubes of the exchanger. Air passing through the exchanger is supplied by a number of electrically driven fans. The air removes the heat, thus condensing the steam back into water which will be used once again to produce steam in the boiler.

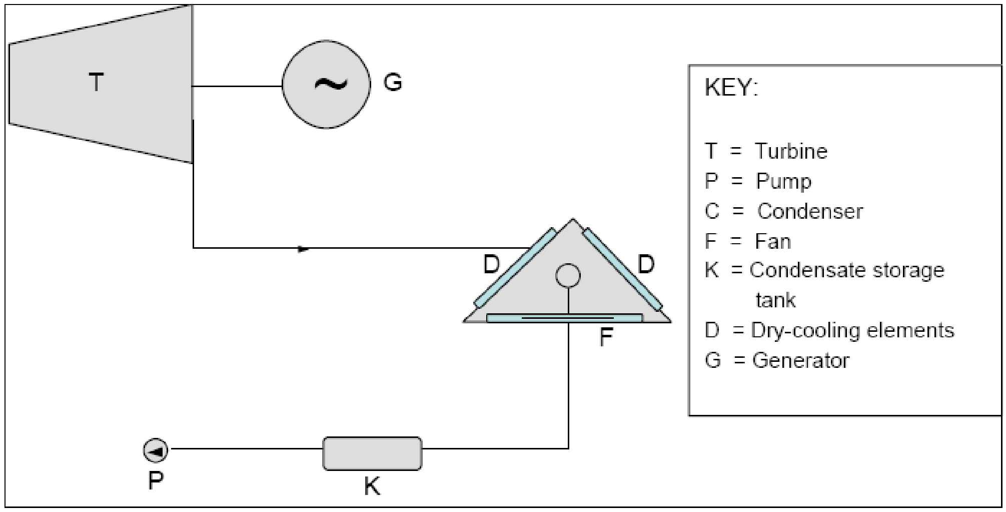

Figure 2.4 Showing a direct dry cooling system

- ***Indirect dry cooling***

Indirect dry cooling systems have a condenser and turbine exhaust system as for wet systems, with the circulating water being passed through finned tubes in a natural draught cooling tower. The water pipework allows the towers to be sited away from the station. A schematic of an indirect dry cooling system is illustrated in Figure 2.5.

The indirect system also uses a cooling tower and water. However, the principle of operation is similar to that used in a car radiator. Heat is conducted from the water through A- frame bundles of cooling elements arranged in concentric rings inside the tower. The cooling water flows through these elements, cools down as the cold air passes over them and returns to the condenser. This is referred to as a closed system as there is no loss of water due to evaporation.

A variation on this type of indirect system is the system that uses a direct contact condenser in place of the traditional tube type condenser. In the spray condenser, the water from the cooling cycle mixes with the boiler water. The maintenance of the water quality to suit all circuits is critical to the successful operation of the system.

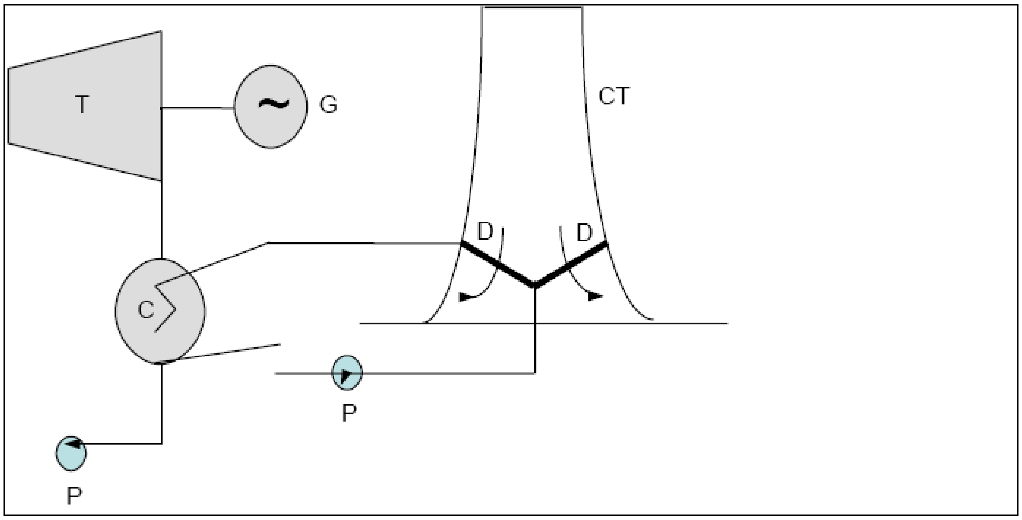

Figure 2.5 Showing an indirect dry cooling system

The relative humidity at the site and the availability of water will dictate the method of cooling to be employed. The FEED will address the issue of water availability and cooling method. As a guide, in regions of water scarcity, air cooled condensers (ACC) are generally adopted over wet cooling towers due to the huge difference in relative water consumption.

2.4. Storage Tanks

The proposed development includes the installation of a number of storage tanks within the boundary of the study site. The number and volumes of tanks required would be informed by further technical planning as well as the current environmental investigation. At this stage, it is anticipated that storage tanks may typically be required for the following liquids:

- Ignition gas (typically propane)
- Diesel;
- Demineralised water;
- Neutralised water;
- Acid; and
- Caustic soda.

2.5. Other Infrastructure

Other infrastructure for the proposed project include:

- Weather and communication mast of up to 60 meters in height and air quality monitoring station;
- high voltage yard;

- a gas pipeline from the adjacent gas cleaning plant to the CCGT power plant;
- a water supply pipeline from the Rietpoort Balancing Dam (for construction and operational water supply);
- electricity supply for construction;
- a water treatment plant as well as ancillary works such as other associated infrastructure;
- sewage treatment plant;
- storage facility for hazardous materials;
- storage facility for waste; and
- borrow pits.

2.5.1. Access Roads

Appropriate access roads (temporary and permanent) will be constructed to link the proposed power station with the nearby existing roads network. The final routing of the road network for both the construction and operational phases will be dependent on the final site selected for the CCGT power plant. These routes will be identified in the form of access roads corridors from which alignments may be designed. The corridors will cater for temporary (to be used during construction) and permanent (to be used during operation) access and site roads. All the corridors will be studied in detail in the EIA phase of the process. The impacts of the proposed power station on the local traffic conditions will be studied through a traffic specialist study.

2.5.2. Construction Village

A construction village of not more than 1 ha will be required to house workers during the construction phase. The exact positioning of this structure is not decided at this stage. However, impacts associated with the construction village will be studied at the EIA phase.