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# Toms Creek Integrated Gasification Combined Cycle Demonstration Project

## Quarterly Report
## April 1 - June 30, 1993

**G. Feher**
**M. Schmid**

September 1993

Work Performed Under Contract No.: DE-FC21-93MC29444

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
TAMCO Power Partners
Williamsport, Pennsylvania

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# 1 SUMMARY

The Quarterly Technical Progress Report for the period ending June 30, 1993, summarizes the work done to date by Tampella Power Corporation and Enviropower, Inc. Enviropower Inc.'s efforts were concentrated on the Toms Creek PDS (Preliminary Design and Studies). Tampella Power Corporation's efforts were concentrated on site specific heat and material balances to provide the basis for evaluating alternate locations for the Project.

The Quarterly Technical Progress Report is presented in two parts:

1. Section 2.1

   PDS (Preliminary Design and Studies) work done by Enviropower, Inc. for the Toms Creek design. This is a continuation of the work presented in the first Quarterly Technical Progress Report.

2. Section 2.2

   Work done by Tampella Power Corporation for alternate designs for different site-specific cases.

# 2 GASIFIER ISLAND EQUIPMENT DESIGN

Enviropower, Inc. is nearing completion of the PDS (Preliminary Design and Studies). The status of the design of the equipment for the Gasifier Island, not covered in the previous Technical Progress Report, is given below.

## 2.1 Product Gas Cooler

The product gas cooler is a natural circulation type fire tube boiler. The gas cooler generates saturated steam by cooling the product gas to about 1,000 °F. The product gas must be cooled for the following reasons:

a) to match the operating temperature requirements of the external sulfur removal system;

b) to meet the temperature limitations of the gas turbine control valve.

The gas cooler is a heavy duty heat exchanger (steam generator), cooling high temperature, dust laden, corrosive gases at high pressure. Due to the harsh conditions, special construction materials and special design have to be utilized. In order to avoid high material temperatures and condensation of gaseous contaminants in the product gas, the gas cooler is designed to be an evaporator heat exchanger (boiler) without superheating or water heating.

The steam side of the gas cooler is integrated with the steam cycle of the plant. The gas cooler is connected by risers and downcomers to a steam drum. The steam drum is connected in parallel to the high pressure steam drum of the HRSG (heat recovery steam generator), i.e. the gas cooler feed water is preheated and the saturated steam generated in the gas cooler is superheated in the HRSG economizer and superheater, respectively.

The product gas contains contaminants including $H_2S$ and dust. The reducing atmosphere and the presence of $H_2S$ make the gas cooler conditions corrosive. To cope with high-temperature corrosion, special construction materials (alloys of chromium and nickel) and high corrosion allowances have to be specified. The dust in the product gas can plug heat exchanger tubes and cause erosion at tube bundle entrance, which have to be taken into consideration for the heat exchanger design. Tar formation does not pose a problem in this case of coal gasification because tars and other condensables decompose at the high temperature in the upper part of the gasifier. The high product gas temperature and steam pressure limit the gas cooler application to evaporation.

## 2.2 External Sulfur Removal System

The sulfur removal system comprises sulfur removal with a sorbent inside the gasifier, and a post-gasification sulfur removal from the product gas with a zinc oxide based sorbent as a polishing step. The post-gasification sulfur removal system consists of two reactors: a sulfider, where desulfurization takes place, and regenerator, where sulfided zinc sorbent is regenerated.

The function of the external sulfur removal system is to reduce the amount of sulfur in the gasifier product gas to levels which meet environmental emission standards. Further, by removing excess sulfur compounds before the gas turbine, the corrosion of gas turbine blades is minimized.

From the gasifier, the sulfur containing product gases flow through the product gas cooler to the sulfider. In the sulfider, still above 1,000 F, the sulfur compounds are removed according to the following reaction:

$$ZnO_{(s)} + H_2S_{(g)} \rightarrow ZnS_{(s)} + H_2O_{(g)}$$

The sulfided sorbent is continuously removed from the sulfider and is transferred to the regenerator reactor where ZnS reacts with oxygen - containing gas, according to the following reaction:

$$ZnS_{(s)} + 1.5\ O_{2\,(g)} \rightarrow ZnO_{(s)} + SO_{2\,(g)}$$

The regenerated sorbent is transferred back to the sulfider. The $SO_2$ - containing regenerator off-gas is transferred back to the gasifier, where the $SO_2$ is reduced to $H_2S$ and is captured by the gasifier sorbent. The sorbent is oxidized in the bottom of the gasifier. Thus, all the coal-based sulfur compounds are eventually removed from the gasification process in the form of calcium sulfate.

Zinc titanate-based sorbents were selected for development and testing for the external sulfur removal step. Extensive research and development work has narrowed the choice to zinc ferrite and zinc titanate sorbents. With a low steam content product gas (such as U-Gas with dry coal feed), the use of zinc ferrite is ruled out.

The external sulfur removal system includes the following process components:

- sorbent feeding system
- sulfider reactor
- regenerator reactor
- sorbent conveying lines and vessel between sulfider and regenerator
- sorbent discharge system
- regenerator off-gas handling system

## 2.3 Flare System

The purpose of the flare is to combust gasifier gases during start-up, shut-down, or under relief conditions in a safe, environmentally sound manner.

The design of the flare depends on the quality and composition of the waste gas. Heat radiation, noise levels, smoke formation and atmospheric dispersion are the main design considerations of the flare equipment.

The flare system chosen for Toms Creek is an air-assisted elevated flare, which is located on the top of the gasifier building. The flare system can be divided into two sections:

- Valve system, including connection piping to the product gas line and control valves;
- Flare, including flare tip combustor, spiral venturi seal, ignition and control panel.

The flare system is operated at the start-up and shutdown of the gasifier and in case of emergency shutdown or upset conditions. In these instances, the product gas is directed from the gas turbine fuel gas line to the flare by the control valve system. The product gas is at a high pressure and a high temperature when flare operation can occur. The pressure of the gas will be reduced by a pressure control valves to near atmospheric level. The hot gas enters the combustor and is ignited by the pilot flame.

At start-up, product gas is flared until minimum load of the gasifier is achieved, and the product gas is then directed to the gas turbine. During normal shutdowns, the gasifier through-put is reduced first to minimum. The product gas is then switched from the gas turbine to the flare. At emergency shutdown, fuel and air feeds are stopped to the gasifier and a controlled pressure let down occurs through the flare.

## 2.4 Auxiliary Systems

The Gasifier Island operations require numerous auxiliary systems as follows:

### 2.4.1 Start-up and Support Fuels

- Natural gas is used to heat-up the gasifier island system, the external sulfur removal system, and support flare operations.
- Metallurgical coke is used to heat-up the gasification system, start gasification, and maintain fluidized bed operations.

### 2.4.2 Water

Water consumers include cooling water and boiler feed water make-up. Water is consumed by the steam used in the gasifier and the regenerator, as well as through steam and cooling water losses and their blow-downs.

2.4.3 Steam

Steam consumers include the gasifier, the regenerator, filter purges, and transport systems.

2.4.4 Air

Air is used for instrumentation, sealing, and pressurizing for lock-hoppers.

2.4.5 Inert Gas

Inert gas is used for purging, instrumentation, the sampling and measuring systems, filter ash transport, external sulfur removal system, pressurization, and emergency shutdowns.

2.4.6 Electrical Power

The main power users are the booster compressor, motors in the solids feeding system, motors in the solids removal systems, motors in the coal handling system, ejector booster compressor, and the cooling water pumps.

2.5 Preliminary Design Studies Review

The PDS (Preliminary Design and Studies) document prepared by Enviropower, Inc. for the Toms Creek design is being reviewed and will be discussed in detail with Enviropower.

## 3. PROJECT RELOCATION

Since the Power Purchase Agreement could not be reached from the Toms Creek site, the Clean Coal 4 project must be relocated to another location.

3.1 Technical Presentation

Technical presentations have been made and updated to focus on issues of specific interest for different sites. Site specific heat and material balances were prepared, which incorporated local coal and sorbent analyses and specific power plant steam cycle data.

### 3.2 Project Economics

Spread sheets were prepared showing pro-forma cash flow analyses for several candidate sites. The proprietary analyses were site specific, and were based on the heat and material balances which were calculated for each case.

## 4 IGCC Plant Size

The Toms Creek IGCC plant was based on a nominal 55 MW(e) power generation design. A re-evaluation of plant performance and economics using recently announced larger sized gas turbines has begun.