USE AND ELIMINATION OF METHANE IN COALMINE VENTILATION AIR

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ABSTRACT

The paper covers development work on a Fuel Ingested Gas Turbine (FIGT) system specifically designed to ingest methane-contaminated coalmine ventilation air mixed with coalmine seam drainage methane to create an inlet air flow containing about 1.6% methane. The special burner incorporated with the turbine is designed to efficiently burn this ultra lean fuel mixture to power the turbine at rated load. The system is covered by granted international patents.

Development stages have been

- Laboratory work on a single tube ultra-lean combustor (reactor).
- A pressurised 200 kW pilot plant simulating turbine conditions
- A demonstration 2.5 MW recuperated FIGT Solar Centaur 3000R turbine.

The demonstration stage has identified operational problems which are currently being resolved. It is also evident that conditions in most coalmines now differ from Australian practice in the early 1990s, in that the average gas-prone coalmine has the greater part of methane emissions as methane-contaminated ventilation air.

Attention is now focussed on modifications to enable fuel gas derived from low-cost coal and/or coal waste gasifiers to co-fire the turbines.

The latest AIDG/FIGT design can also deal with coalmine tailings and waste water problems and gain enhanced power output and efficiency from what are “old fashioned” and simple turbines. Turbines such as the Solar Centaur, GE Frame-3 and Frame-5 and some other proven designs are suited to AIDG/FIGT duty. The AIDG/FIGT system is also a possible low cost and minimum risk route to very high efficiency, low-cost and ultra-low emission coal-fired power or coal-based liquid fuels.

1.0 INTRODUCTION

DUT Pty Ltd is a process development company specialising in combustion, gasification, gas separation and related technologies.

In 1993 DUT developed the Fuel Ingested Gas Turbine (FIGT) concept. FIGT was developed primarily to deal with coalmine methane emissions and in particular methane contained in coalmine ventilation air. A typical methane content of coalmine ventilation air is 0.5-1.0% by volume.

The amount of methane emitted, world-wide, in coalmine ventilation air, based on [1] is assumed to be about 23 million tonnes per year.

2.0 THE FIGT SYSTEM

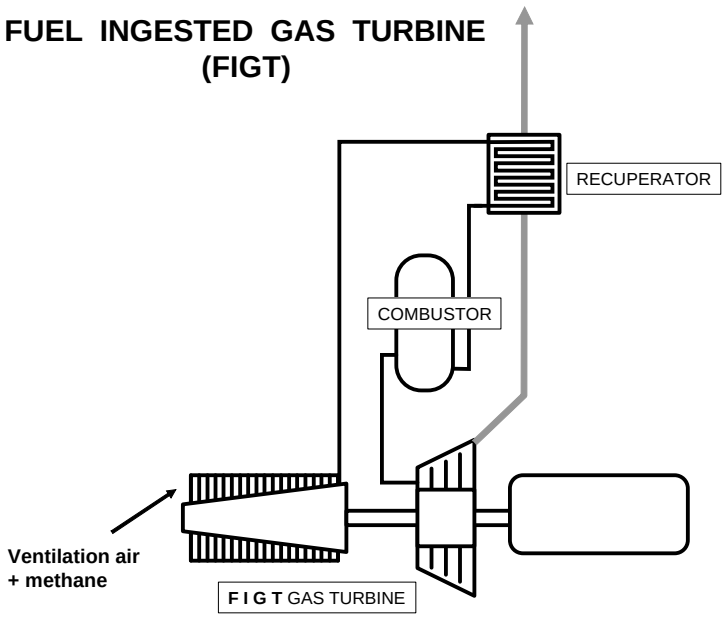
The patents covering the FIGT process, also known to as the Carburetted Gas Turbine (CGT) system, are owned by Isentropic Systems Ltd. CGT is licensed to Energy Developments Ltd (EDL) for commercial development.

The FIGT system is based on a special, patented ultra-lean burn combustor system. The combustor system was initially demonstrated by Isentropic in a single tube heat exchanger/reactor. Following this, Isentropic designed and EDL constructed a demonstration pressurised 200 kw (heat release) seven tube heat exchanger bundle and reactor/combustor at the EDL factory at Richlands in Queensland. The recuperator stage was simulated by an electrical heater, which was followed by addition and mixing of methane and the preheated mix being fed to the heat exchanger combustor system.

This unit achieved in excess of 99% combustion efficiency and, as expected, a very low NOX emission of less than 1 ppm.

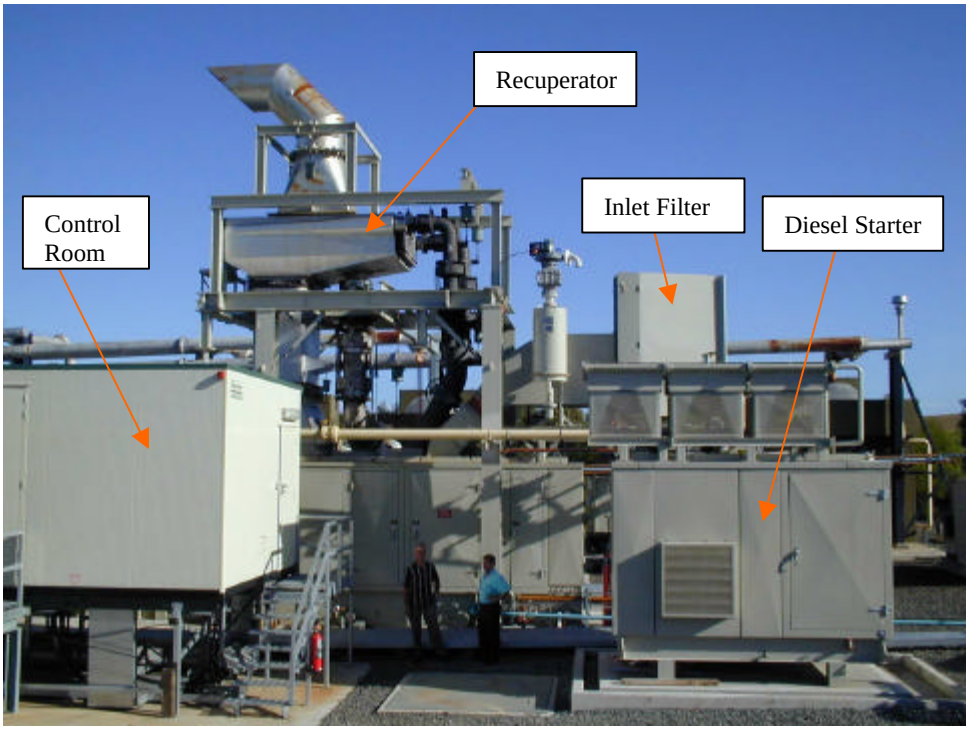
The FIGT system is also based on the use of “old fashioned” recuperated gas turbines such as the GE Frame-1, Frame-3 and Frame-5 turbines and also the Solar Turbines Centaur 3000R turbine. These turbines are in general service (probably about 300 units) driving gas compressors and generating electricity.

A simple flowsheet of the FIGT system is shown below.

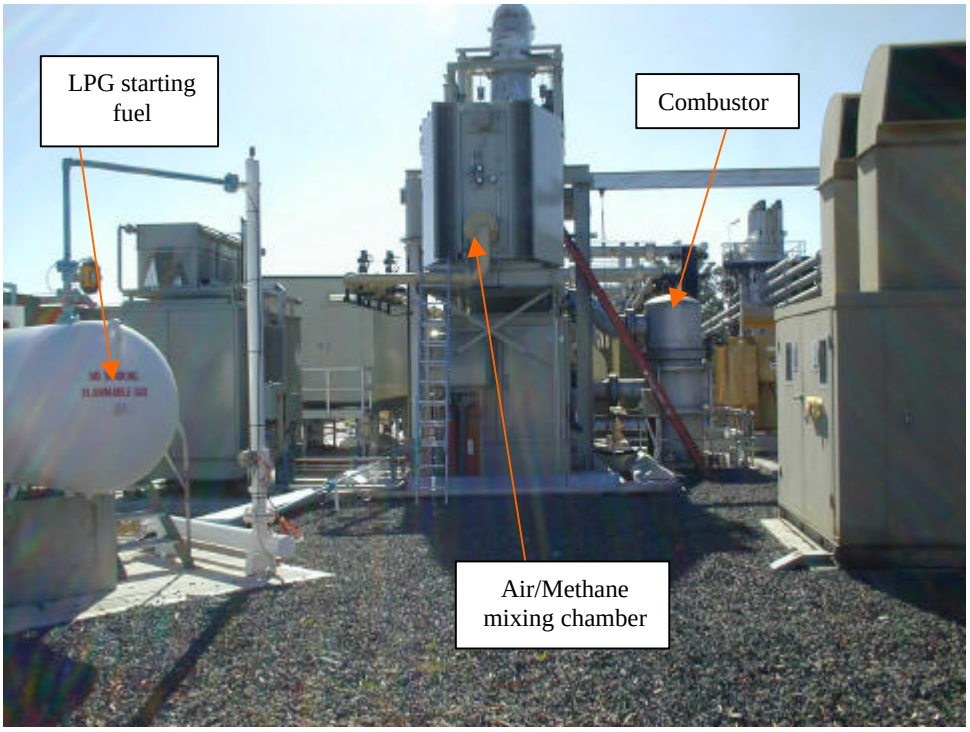


With a GE Frame-1, 3 or 5 unit or a Centaur 3000R unit a FIGT system can ingest its total fuel demand as a 1.6% methane in air mix entering the turbine i.e. a mixture of coalmine ventilation air plus methane from other sources such as coalmine coal seam drainage could fuel a FIGT unit at rated load.

The Centaur 3000R turbine, fitted with a FIGT combustor, which is located at EDL's site at BHP's Appin mine in NSW is shown below.



Appin Installation - Side View



Appin Installation - End View

2.1 CHANGES IN THE TARGET FIGT MARKET

In the early 1990s a typical, modern deep Australian coalmine probably produced and vented as much methane from coalseam drainage operations as there was methane in the ventilation air. Since that time coalseam drainage gas from underground mines has largely been absorbed by gas engines generating power and significant greenhouse credits from effective use of the previously vented methane. Australia now has a situation similar to other major coalmining areas in that the dominant intractable methane emission from coalmining is predominantly linked with methane in ventilation air emissions.

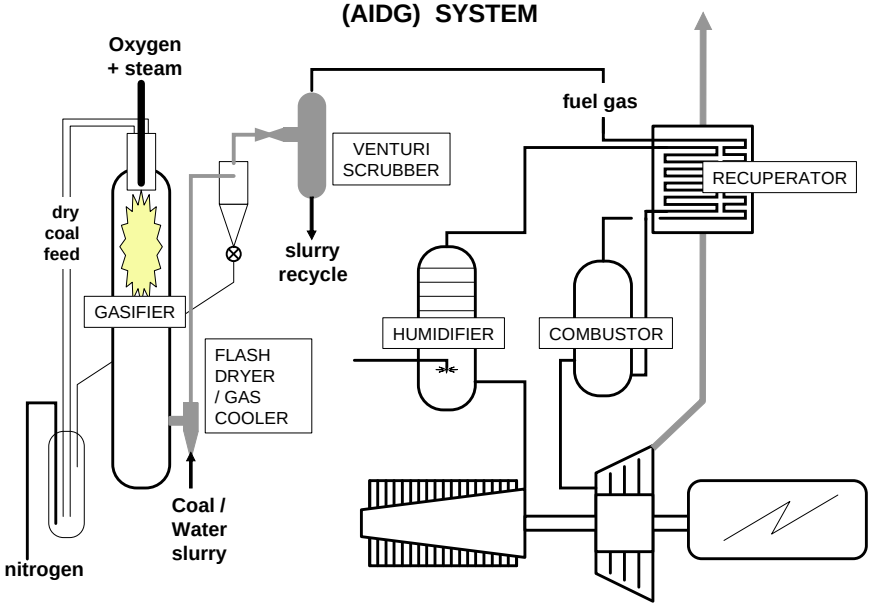
For FIGT to play its intended role as an optimum means to use and eliminate methane in coalmine ventilation air as a significant and major source of greenhouse gas emissions, the FIGT system requires an additional, preferably low-cost alternate fuel source for its operation.

3.0 THE AIDG SYSTEM

In 1992 DUT was co-inventor of the State Electricity Corporation of Victoria (SECV) / Herman Research Laboratory Integrated Drying and Gasification Combined Cycle (IDGCC) process. IDGCC was designed for generation of power from high water content brown coal.

Following a DUT/SECV patent ownership agreement, DUT separately pursued development and patenting of the simpler and more efficient AIDG cycle for both black and brown coal as shown below.

ADVANCED INTEGRATED DRYING AND GASIFICATION (AIDG) SYSTEM



The AIDG system has the potential, with modern humidified gas turbines having firing temperatures of about 1,300^{o}C, to generate power from coal/water slurries at efficiencies up to about 55%.

The AIDG process, in addition to generating low-cost, low-emission power enables coal to be delivered at low transport cost as coal-water slurry without the penalty of subsequent drying, as required for coal slurry transport for conventional generation systems.

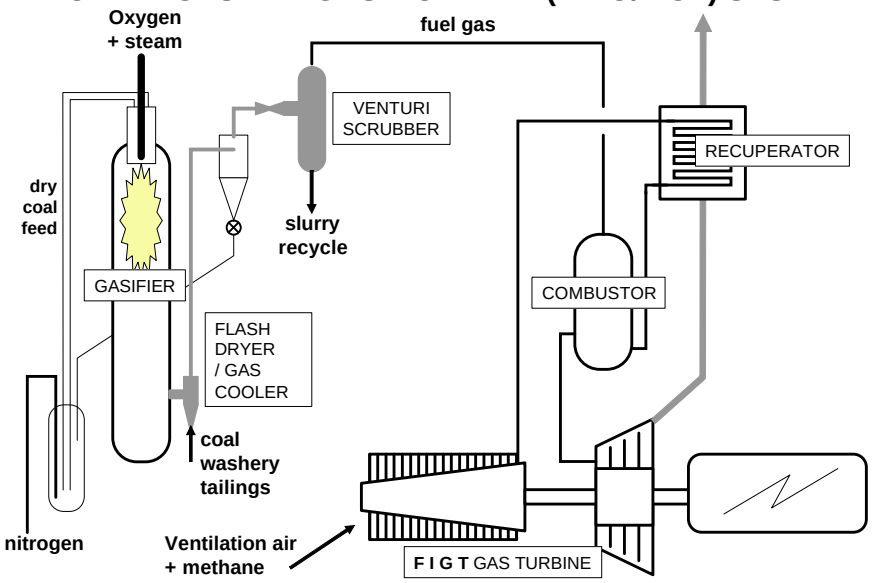
AIDG units with oxygen-blown gasifiers produce high quality pressurised gas from which excess CO2 and sulphur impurities can be easily removed for sequestration and the production of ultra-low emission coal-based power and or clean coal-based liquid fuels.

4.0 THE AIDG/FIGT PROCESS

It is now proposed to use the AIDG process, in simplified form, in low (about 35%) efficiency gas turbines i.e. the same type that can be modified for FIGT operation. The AIDG/FIGT system enables coalmining waste to provide low cost supplementary fuel for the FIGT component.

A flow diagram of the AIDG/FIGT system is shown below.

ADVANCED INTEGRATED DRYING AND GASIFICATION / FUEL INGESTED GAS TURBINE (AIDG/FIGT) SYSTEM



In Australia, and many other coalmining regions, a major loss of energy and a major source of environmental problems are coal wastes produced by coal washing for the production of commercial grades of reduced ash coal.

In a typical Australian coal washery about 25% (by weight) and 12% (coal content) of as-mined coal is discarded during washing with about half the coal loss being in washery tailings. Coal in tailings waste is typically a good quality coal (say up to 40% ash) as fine particles (less than 500 micron) suspended in water.

Because of the very small particle sizes, tailings slurries tend to be very stable suspensions which are difficult to de-water, by normal thickening techniques, to less than 40-50% water content.

Tailings dams are anaerobic and leakage of contaminated water into streams and aquifers can be a major problem, in addition, containment failures have resulted in major deaths and ecological disasters.

Coal washery tailings are a major, intractable, environmental problem for many coalmines and have little or no value as conventional fuel but are ideal for AIDG applications.

AIDG/FIGT can eliminate methane emissions and coal tailings waste production from many coalmines.

The FIGT and AIDG systems are covered by extensive, world-wide granted patents. The AIDG/FIGT system and other improvements to FIGT, AIDG and AIDG/FIGT, black and brown coal applications, are covered by provisional patent applications. DUT is involved in on-going process development in this field.

4.1 AIDG/FIGT EMISSIONS ECONOMICS AND MARKET

AIDG/FIGT system greenhouse gas emissions, based on methane contaminated coalmine ventilation air providing 40% of the FIGT unit fuel, with the remaining fuel being supplied by AIDG gasified coal tailings, would be -1.6 tonnes of CO_2/MWhr. In Australia where average electricity generation GHG emissions are 0.9 tonnes of CO_2/MWhr, AIDG/FIGT would provide a reduction in emission levels of 2.5 tonnes of CO_2 per MWhr of AIDG/FIGT-based power.

Current capital cost estimate for a 60 MW AIDG/FIGT system based on three 20 MW recuperated gas turbines and a single AIDG tailings gasifier is about $(A)100 million. With prevailing Australian base load power values and without emissions credits such a unit would be marginally economic.

Large-scale production of AIDG/FIGT systems, and power prices approaching $(US)30/MWhr makes the system economic in its own right with emission credits being an added and very major bonus.

In Queensland and NSW, the Australian coal exporting states, about 12 million tonnes of coal are dumped as tailings slurry and there is sufficient methane vented from coalmines to support about 1,000 MW of AIDG/FIGT negative emission power. The remaining tailings could support the base load production of about 4,500 MW of high efficiency black coal washery tailings waste-based AIDG power generation.

A similar bituminous coal waste and methane emission pattern exists in many other coal producing regions.

The world-wide fugitive emissions from coal mines and the potential world-wide market for AIDG/FIGT systems, as described, is as follows-

World-wide Potential Market for AIDG/FIGT

based on coalmine ventilation air emissions

	methane emissions millions tonnes per year
Australia	**0.8**
China	**10.0**
US	**6.0**
Russia	**2.5**
South Africa	**0.5**
Germany	**0.8**
India	**0.3**
Poland	**1.0**
UK	**0.4**
Czek	**0.2**
France	**0.1**
Japan	**0.1**
Turkey	**0.1**
TOTAL	**22.8**

POWER EQUIVALENT

25,000 MW

with 33% Efficient AIDG/FIGT gas turbines and ventilation air supplying 40% of turbine fuel

For the above AIDG/FIGT market 15,000 MW would have to be generated from coal-derived (or another source of) gas. For coal or coal waste to provide the supplementary fuel 350 gasifiers with an average throughput of 400 tonne of coal/day, would be required.

Potential emission credits from the combustion and use of the above emissions would be about 500 million tonnes of CO_2 per year.

5.0 WHAT CAN FOLLOWS AIDG/FIGT?

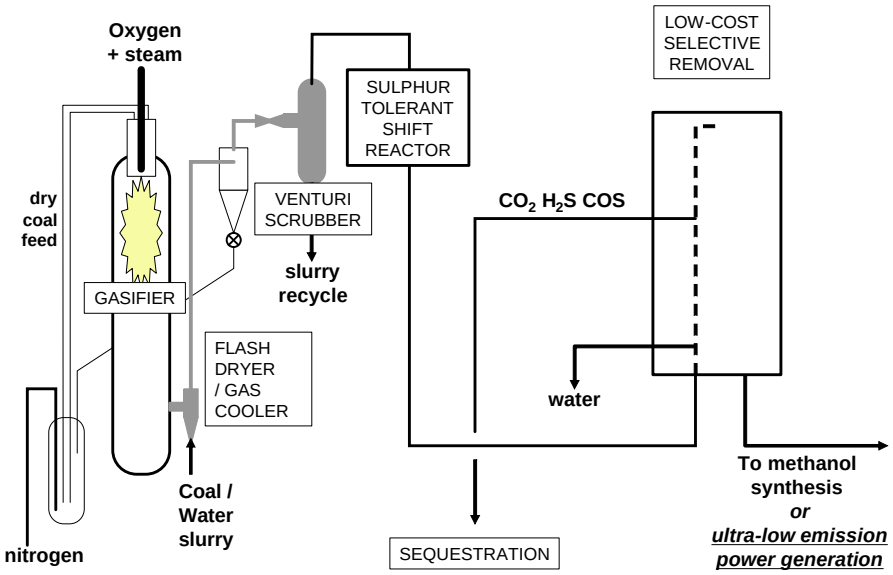
AIDG/FIGT in addition to enabling cost-effective use and elimination of coalmine methane emissions also demonstrates the key technologies required for oxygen-based AIDG systems and future clean-coal technologies.

Oxygen-based AIDG produces a high pressure synthesis-type gas which can have its hydrogen content increased by “shift reaction” enabling ready removal of impurities such as H_2S, COS, NH_3 & HCN.

It is possible to simply remove a mixture of CO_2, H_2S and COS as a gas or liquid stream for sequestration with the residual gas being suitable for ultra-low greenhouse gas emission power generation or clean coal-based liquid fuel production.

DUT is actively engaged in collaborative development of systems for the above operations, based on past DUT work on innovative gas processing and CO_2 removal systems.

A possible, simplified flowsheet for ultra-low emission coal-based power or clean coal-based liquids production is shown below.



[1] D J Williams “Fugitive Emissions from Coal Mining” The Australian Academy of Technological Sciences and Engineering. http://www.atse.org.au/publications/irc-reports/paper-china_november_1999p3.htm