THE ALLAM CYCLE: CLEAN POWER FROM NATURAL GAS WITH INTEGRATED CARBON CAPTURE

The innovative Allam-Fetvedt cycle is a breakthrough that can use natural gas to generate power and contribute to a climate-friendly, net-zero future. It is a high-efficiency thermal power cycle that avoids CO2 emissions. Key to the process is oxy-fuel combustion. When natural gas, is fully combusted in pure oxygen, only water vapour and carbon dioxide (CO2) are produced. In comparison to the combustion of coal in air, the emissions from natural gas oxy-fuel combustion are much simpler to handle.

In air-fed power generation using coal-fired burners, flue gas treatment is highly complex. A typical coal fired power plant will have filtration or electrostatic precipitation equipment to knock down dust and ash particles. It will also be fitted with flue gas desulphurisation where lime is reacted with sulphur dioxide to form gypsum. Then there is likely to be a DeNOx process based on selective catalytic or non-catalytic reduction of oxides of nitrogen (NOx) emissions to inert nitrogen gas. Mercury removal on activated carbon filters may also be required.

In the case of oxy-fuel combustion of natural gas, the main products are carbon dioxide (CO2) and water vapour. These can be separated simply by cooling the flue gas to condense the water vapour. The resultant CO2 can be liquefied or compressed and the transported from the site for utilisation or sequestration without the need for additional mechanical compression energy to be expended.

This is in sharp contrast to post-combustion CO2 capture from conventional coal fired power generation, where the CO2 capture equipment operates at close to atmospheric pressure. The implication is that CO2 must be compressed or liquefied to be moved to a storage or utilisation location. The compression consumes power from within the process, resulting in a lower overall efficiency.

In the Allam-Fetvedt cycle, the burner feed gases are pre-heated by the exhaust gases. The equipment used for heat recovery is referred to as a printed circuit heat exchanger, or PCHE. This is a mature technology that has been used at scale in the oil gas sector for decades. Its compact nature has made it popular for offshore deployment on rigs where space is at a premium.

Conventional coal-fired power generation heats up steam, which is the working fluid within the power generation turbines. In conventional air-fed, gas-fired turbines, which are commonly fed with pipeline natural gas or revaporised LNG, the nitrogen-rich combustion gases themselves drive the generator. In the Allam-Fetvedt cycle, combustion gases are also used to spin the main turbine. However, in this case, a mixture of 97% CO2 and 3% water vapour flows through the turbine.

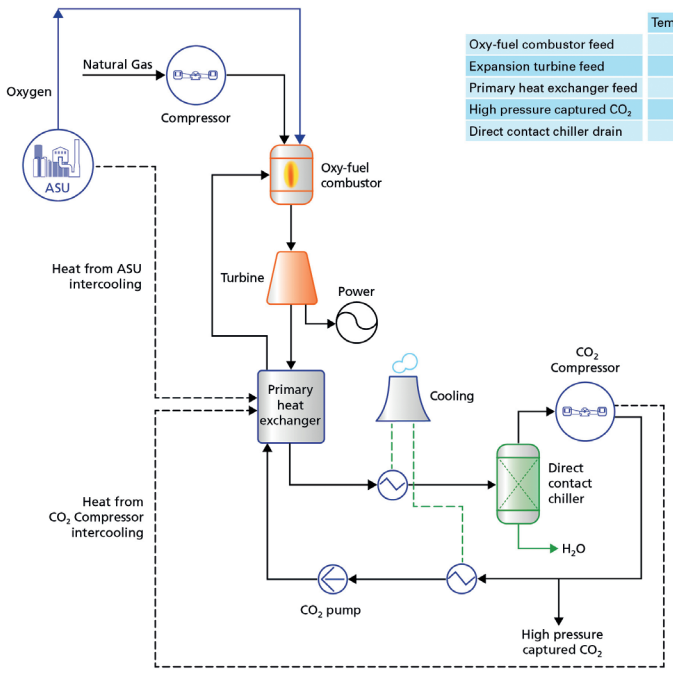
The turbine used at the NET Power Allam-Fetvedt cycle pilot plant in LaPorte, Texas, was developed by Toshiba. The operating temperature and pressure ensure that the CO2 is super-critical at the turbine inlet. And the presence of moisture means that carbonic acid formation is possible. Materials selection and coating technologies are the key to successful turbine production in this challenging operating environment.

Through multiple cases, it is evident that CO2 is gaining traction as a thermodynamic working fluid. The US DOE-funded STEP demonstration project that GE and GTI have contributed to uses a closed cycle with supercritical al CO2 as the working fluid. The Italian startup Energy Dome uses sub-critical CO2 in a closed cycle in their CO2 battery, a technology aligned to long duration energy storage. In the Allam-Fetvedt cycle CO2 is the main working fluid in a semi-closed, modified Brayton cycle.

Australia, the USA, Canada, and the Middle East are major and LNG exporters. The alignment of LNG trade from these producers to markets in Asia had stabilised in the first two decades of this millennium. However, as Russian pipeline gas supplies to Europe dwindled in 2022, large, industrialised nations such as Germany ramped up their LNG imports. The results were a shocking LNG price spike in Q2 and Q3 of 2022.

Use of indigenous fuels bagasse crop waste and coal reserves can mitigate the reliance on LNG imports. Gasification of these solid feedstocks to generate syngas to feed to the Allam-Fetvedt cycle can be a clean and cost-effective way to generate power. Since CO2 emissions from the gasifier and the Allam-Fetvedt cycle can readily be captured, these fuels can be used in a climate-friendly manner.

The Allam cycle for natural gas: oxy-fuel thermal power generation with integrated CO_2 capture



			Stream composition, referenced to combustor feed			
	Temperature °C	Pressure bar	CO_2 wt%	Natural gas wt%	Oxygen wt%	H_2O wt%
Oxy-fuel combustor feed	700	300	94	1,25	4,75	0
Expansion turbine feed	1150	300	97,25	0	0	2,75
Primary heat exchanger feed	720	30	97,25	0	0	2,75
High pressure captured CO_2	60	80	100	0	0	0
Direct contact chiller drain	20	30	0	0	0	100

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