Panel Session Overview

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Panel Presentation

Tuesday, May 15, 2007 @ 2:30 – 5:00 PM

CO2 Compression Opportunities in Fossil Fueled Power Plants
Session Chairs: Richard Dennis and Manfred Klein

Panel Abstract

With increasing concerns regarding CO2 concentrations in the earth's atmosphere options for CO2 capture are of interest. Large-scale stationary power systems offer opportunities to separate and capture large volumes of CO2 that would normally be exhausted to the atmosphere. Effectively capturing and delivering this CO2 for geological sequestration requires the compression of large volumes of gas with significant parasitic power consumption. For example, in a coal fueled integrated gasification combined cycle (IGCC) power plant the CO2 compression penalty can represent about 4 % of the gross power. When 90 % CO2 capture is implemented in a precombustion decarbonization IGCC and CO2 is compressed to 2,200 psia, the auxiliary power load increases by about 40 %, compared to the non-capture case. Over 50 % of this increase is due to CO2 compression. Reducing this power requirement will improve overall plant efficiency and encourage CO2 sequestration at both existing and future power plants. To facilitate this opportunity for CO2 capture, and ultimately sequestration, the compression of large volumes of CO2 is required. This panel will present and discuss existing state-of-the-art techniques for the compression and delivery of large volumes of CO2, advanced concepts for CO2 compression and delivery, and integration opportunities for CO2 compression in large-scale fossil fuel power systems.

Panelists

1) An Assessment of CO2 Compression Options for Near Zero Emission IGCC;
Ashok Rao, UC Irvine

Carbon dioxide is one of the most prevalent greenhouse gases in the atmosphere. Anthropogenic emissions of CO2 result primarily from combustion of fossil fuels, and as a result world energy use has emerged at the center of the climate change debate. Due to the projected increases in fossil fuel usage world-wide, emissions of CO2 to the atmosphere are expected to increase by about 35% by 2015 and by about 75% by 2030 over the 2003 level. Because of the emphasis being given to CO2 capture and sequestration in power plants, optimization of the CO2 compression unit is critical in order to increase the overall plant thermal efficiency while lowering the capital and operating costs. As a first step in this analysis, a thermodynamic assessment of various options for pressurizing the captured CO_2 to sequestration pressures in coal fired power plants (IGCC as well as boilers) are discussed. Options considered include “isothermal” compression, adiabatic compression with various options for recovery of the low temperature heat contained in the compressed stream, and compression to supercritical pressure followed by pumping of the supercritical fluid to the sequestration pressure.

2) CO_2 Compression: Design and Operating Experience at the Sleipner Gas Field; Harald Underbakke, Statoil

Statoil has operated a 13 megawatt CO_2 injection compressor for 10 years on the Sleipner gas/condensate field in the North Sea. The compressor is a gas turbine driven 4 process stage centrifugal compressor taking suction from atmospheric pressure and delivering at around 70 bar to an injection well for underground storage. The injected volume is around 1 million tons of CO_2 per year. The CO_2 is taken from a CO_2 separation plant extracting CO_2 from the produced gas in order to meet the pipeline gas specification. The compression system, however, is similar to a system compressing CO_2 from power plant exhaust gas separation.

The presentation would focus on the system design, compressor selection, operating experience and considerations for reducing the power consumption. Special attention to phase changes, safety, startup and interaction between the compressor and the injection well.

3) High Efficiency/Low Cost CO_2 Compressor for Carbon Capture & Storage; Shawn Lawlor, Ramgen Power Systems

Ramgen Power Systems, Inc. is developing a family of high performance CO_2 compressors that combine many of the aspects of shock compression systems commonly used in supersonic flight inlets, with turbo-machinery design practices employed in conventional axial and centrifugal compressor design. The result is a high efficiency compressor that is capable of single stage pressure ratios of 10-12:1, far exceeding capabilities in existing axial or centrifugal compressor designs. A variety of design configurations for land-based compressors utilizing this system have been explored. Two proof-of-concept rotor performance test rigs have been designed and tested to demonstrate the basic operational characteristics of the technology as an air compressor. The demonstration units were designed to process ~1.4 kg/s and ~1.2 kg/s and produce pressure ratios across the supersonic rotors of ~2.4:1 and ~8:1 respectively. Based on the results of these efforts, development of a high pressure ratio CO_2 compressor to support Carbon Capture & Storage has been initiated, with the active support of the DOE. The basic theory of operation of this new family of compressors will be reviewed along with the performance characteristics and conceptual design features of the proposed CO_2 compressor systems. Shock wave compression technology has the potential to develop very high compression ratio per stage and very high efficiency, simultaneously. This capability allows Ramgen to configure a 2-stage CO_2 compressor for a pressure ratio of 100:1, while conventional technology will typically require 8-stages of compression. The input power to Ramgen’s 2-stage compressor will be comparable to the 8-stage conventional approaches, but the individual compressor stage discharge temperature will be 450-500°F vs. the conventional 8-stage 200°F, allowing for cost effective heat recovery of 80% of the input Btu. The benefits of this technology are: fewer stages, higher efficiency, lower part count and therefore lower capital and maintenance costs, and smaller size for comparable mass flow and pressure ratio. The all-in capital cost is expected to 1/3 of the conventional approaches. In addition, development of Ramgen's compression technology is cross-cutting and capable of delivering benefits to many of the technical areas of concern in zero-emission clean coal facilities.

4) Novel Concepts for the Compression of Large Volumes of Carbon Dioxide; Jeff Moore, SwRI

In the effort to reduce the release of CO2 greenhouse gases to the atmosphere, sequestration of CO2 from Integrated Gasification Combined Cycle (IGCC) and Oxy-Fuel power plants is being pursued. This approach, however, requires significant compression power to boost the pressure to typical pipeline levels. The penalty can be as high as 8% to 12% on a typical IGCC plant. The goal of this research is to reduce this penalty through novel compression concepts and integration with existing IGCC processes. The primary objective of this study is to boost the pressure of CO2 to pipeline pressures with the minimal amount of energy required. Fundamental thermodynamics will be studied to explore pressure rise in both liquid and gaseous states. For gaseous compression, the project seeks to develop novel methods to compress CO2 while removing the heat of compression internal to the compressor. The high-pressure ratio required results in significant heat of compression. Since less energy is required to boost the pressure of a cool gas, both upstream and interstage cooling is desirable. While isothermal compression has been utilized in some services, it has not been optimized for the IGCC environment. This project will determine the optimum compressor configuration and develop technology for internal heat removal. Other concepts that liquefy the CO2 and boost pressure through cryogenic pumping will be explored as well. Preliminary analysis indicates up to a 35% reduction in power is possible with the concepts being considered.

5) Impact of Gas Phase Impurities on CO2 Compression; Paolo Chiesa, Politecnico di Milano

This talk will focus on the issues associated with the compression of impure CO2 (i.e. mixtures of CO2 and other gases). Power plant technologies that produce CO2 stream will be discussed and the various levels of impurities in these streams. Energy penalties related to these impurities and the problems of gas solubility in liquid CO2 at high pressure and high content of impurities will be discussed. Open literature studies about phase equilibrium at different conditions and ongoing research about this subject. Methods to separate incondensable gases in cryogenic devices will be introduced.

6) Field Experience with the Large Scale Compression of CO2; Pierre L. Bovon, MAN

TURBO Inc.

Recovery and injection of CO_2 is not a new concept. It is common in the Southern US, particularly on the Gulf Coast. The standard approach to compression has been to use high-speed reciprocating compressors. The familiarity of the operators with these machines and their suppliers, their flexibility with regards to pressure ratio and capacity and their quick availability (short-delivery) have rendered them popular for such a service. API 618 slow-speed reciprocating units have occasionally been looked at, since by design, they tend to be more reliable. They are available in larger sizes, but they do get physically very bulky; require specialized slow-speed drivers, and massive concrete foundations. With the new markets associated with clean coal power plants or IGCC, the capacities far exceed that of reciprocating compressors, and definitely fall in the range of turbomachines. These machines offer superior efficiency, oil free compression with fewer leakages, and are far less maintenance intensive. These high-power, high-flow machines are cost-effective to acquire and maintain. While less common in CO_2 service than reciprocating machines, sufficient experience exists to demonstrate that these new applications fall well within the range of proven designs, without the need to scale-up past what has been previously done in similar service. Single centrifugal CO_2 units with pressure ratios of 200 or more are possible. As a manufacturer of both designs of centrifugals available (in-line or integrally-geared), we recognize the respective merits of both, and are prepared to discuss these merits. The aim of the presentation is to demonstrate that by stepping into the field of turbomachines for CO_2 compression, we will not only find successfully running references, but gain, amongst others, from increased safety, higher efficiency, and improved capital and operating costs.

7) Field Experience with the Large Scale Compression of CO_2; Harry Miller, Dresser-Rand

This presentation will review the current Dresser-Rand centrifugal and reciprocating compressor technology and experience with CO_2 compression applications. It will also address some of the challenges and difficulties associated with the compression of CO_2, and will discuss some potential areas for technology development that would improve the efficiency of CO_2 compression.