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CCS with Alstom's Chilled Ammonia Process at AEP's Mountaineer Plant

Paper No. 167

Brian Sherrick
Project Manager
American Electric Power
1 Riverside Plaza
Columbus, OH 43215
USA
Tel: +1 614 716 1923
Fax: +1 614 716 2027
E-Mail: bdsherrick@aep.com

Mike Hammond
Project Engineer
American Electric Power
1 Riverside Plaza
Columbus, OH 43215
USA
Tel: +1 614 716 5931
Fax: +1 614 716 1779
E-Mail: mrhammond@aep.com

Gary Spitznogle
CO_2 Storage Technical Lead
American Electric Power
1 Riverside Plaza
Columbus, OH 43215
USA
Tel: +1 614 716 3671
Fax: +1 614 716 1779
E-Mail: gospitnogle@aep.com

David Muraskin
Alstom Power, Inc.
Technology Manager
Environmental Control Systems
1409 Centerpoint Blvd
Knoxville, TN 37932
USA
Tel: +1 865 694 5269
Fax: +1 865 694 5203
E-Mail: david.j.muraskin@power.alstom.com

Sean Black
Alstom Power, Inc.
Business Manager CAP Technology
Environmental Control Systems
1409 Centerpoint Blvd
Knoxville, TN 37932
USA
Tel: +1 865 694 4453
Fax: +1 865 694 5203
E-Mail: sean.black@power.alstom.com

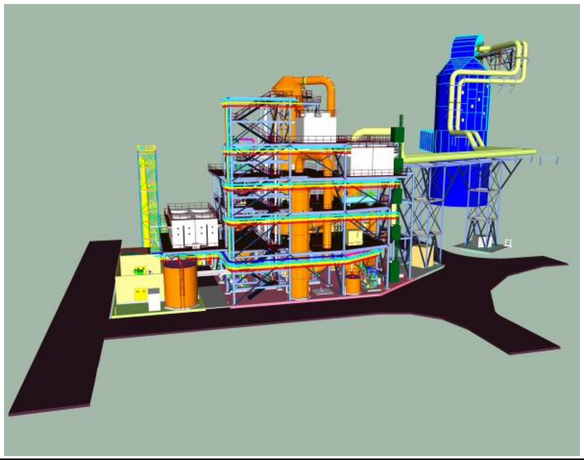
Matt Cage
Alstom Power, Inc.
Project Engineer
Environmental Control Systems
1409 Centerpoint Blvd
Knoxville, TN 37932
USA
Tel: +1 865 694 5269
Fax: +1 865 694 5203
E-Mail: matt.cage@power.alstom.com

Abstract:

Alstom and American Electric Power are jointly participating in the installation of a carbon dioxide (CO_2) capture Product Validation Facility at AEP's Mountaineer Power Plant. The CO_2 capture technology to be installed at Mountaineer is Alstom's Chilled Ammonia Process; AEP is also working with Battelle to develop a saline formation geologic storage system. The Product Validation Facility is approximately 20 megawatt electric (MWe) in size and involves the treatment of a slipstream of combustion flue gases from an existing coal-fired boiler. A flue gas slipstream will be taken from a location downstream of the Mountaineer's existing selective catalytic reduction (SCR) and wet flue gas desulfurization (WFGD) systems. The project is presently in the engineering design phase with scope that includes CO_2 capture, compression, and storage in two geologic reservoirs with injection wellheads located on the plant property. The following paper summarizes Alstom's Chilled Ammonia Process technology and describes the scope and objectives of the CO_2 Capture Product Validation Facility and Geologic Storage Project.

INTRODUCTION

Figure 1. PVF at AEP's Mountaineer Power Plant, New Haven, WV



American Electric Power's (AEP) Mountaineer Power Plant is a coal-fired power generation facility that is presently equipped with an air quality control system (AQCS) consisting of low NOx burners, SCR, and WFGD. Alstom and American Electric Power are jointly participating in the installation of a Carbon Capture and Storage (CCS) Product Validation Facility (PVF) at the Mountaineer site for capture and storage of approximately 100,000 metric tons of CO_2 annually. Validation of Alstom's Chilled Ammonia Process (CAP) CO_2 capture technology and CO_2 injection and storage in two geologic reservoirs beneath the site are key objectives of the project. AEP is working with Battelle to develop the geologic storage and monitoring, mitigation, and verification (MMV) systems.

The Mountaineer PVF is designed to remove carbon dioxide from a slipstream of flue gas taken downstream of the existing WFGD system. The PVF is approximately 20 MWe in size and is a ten (10) times scale up of Alstom's CAP pilot plant facility at We Energies Pleasant Prairie Plant. The CCS Product Validation Facility at Mountaineer is presently (summer 2008) in the engineering, design and procurement phase with initial site preparation activities underway.

Plant Background

Figure 2. AEP's Mountaineer Power Generating Station, New Haven, WV

Located on the Ohio River near New Haven, West Virginia, the Mountaineer Plant complex consists of one 1,300 megawatt (MW) net super-critical coal-fired unit that began service in 1980. The plant was initially equipped with an electrostatic precipitator (ESP) and was later retrofitted with more advanced AQCS equipment including SCR, WFGD, and a sulfur trioxide (SO_3) Mitigation System. Mountaineer Plant is one of AEP's best operating plants having the distinction of 607 days of continuous operation in 1985-1987. AEP chose to demonstrate the CAP technology at Mountaineer due to the existing pollution control equipment on the Mountaineer unit and an existing 9,200-foot geologic characterization well dug on site.

Under direction of Battelle, with sponsorship from the U.S. Department of Energy (DOE), AEP, and several other entities, a characterization well was drilled on the site in 2003 with reservoir testing completed during 2004 as part of the Ohio River Valley project. Since that time, the data have been analyzed and a multi-phase flow model completed for the site. The results of the study indicate that the Rose Run Sandstone and Copper Ridge B Zone, located at 7,800 and 8,200 feet below ground surface, respectively, are acceptable reservoirs for geologic storage. CO_2 will be trapped in the reservoir layers due to the excellent containment conditions. In total, there are several thousand feet of very low-permeability caprock layers above the storage formations.

Project Overview

In September 2007, Alstom, Battelle and AEP started the CCS project with preliminary engineering, project planning, and permitting activities. Procurement of long lead time items started in December 2007 with the initial purchase order of the regenerator system followed by the purchase order for the CO_2 compressor system in February 2008. Preliminary site activities started in March 2008 with utility tie-ins during a scheduled Mountaineer unit outage. Detailed engineering started in April 2008, followed closely by relocation of ancillary facilities and site preparation starting in May 2008. Construction of the CAP and shallow drilling for the storage system is scheduled to start in July 2008 with mechanical completion scheduled for summer 2009 and system startup in third Quarter 2009.

AEP and Alstom are sharing the costs for the capture project. AEP is responsible for all costs associated with the storage system. The German company RWE is involved in the project, and AEP is in discussion with other organizations interested in participating in the project, including funding. While the estimated cost of the project is not publicly available, it is important to note that this is an experimental project with additional costs for testing, monitoring, and validation that may not be required for a commercial project. In addition, full heat integration with the power generation facility will not be implemented for the Mountaineer PVF. Finally, it is a relatively small project and neither the capture nor storage systems have been optimized with respect to both capital and operating costs. While it is not feasible to directly derive from the capital and operating costs of this project a reasonable assessment of the cost of commercial capture and storage systems, the results of the PVF will be used to develop and refine techno-economic studies for future commercial-scale projects.

Outreach and communication are important parts of the project. In addition to having dedicated personnel with experience in retrofit projects, the Mountaineer Plant has an excellent environmental record and a good relationship with the community. In order to maintain this relationship and gain support for this effort, the team developed an outreach plan at the beginning of the project. AEP initially held a series of internal informational meetings at its corporate office, Mountaineer Plant site, and operating companies followed by meetings and presentations with other key stakeholders including the West Virginia Department of Environmental Protection, other permitting agencies, public officials, local residents, and universities. AEP and Battelle completed the second round of Mountaineer Plant staff meetings in May 2008 and AEP conducted the first two public informational meetings in early June 2008 at local town hall meetings with community leaders. The project team plans to conduct future town hall meetings in preparation for the Underground Injection Control (UIC) permit public comment period.

Project Structure

AEP, Alstom, and Battelle are the three main entities involved in the Mountaineer CO_2 Capture and Storage Project. Alstom and AEP are developing the Mountaineer Product Validation Facility (CO_2 Capture Project) with Alstom as the project leader. Alstom is responsible for the CAP equipment. AEP is responsible for the utilities to and from the CAP and the compressed CO_2 discharge stream. Alstom has subcontracted the balance of plant engineering to Zachry Engineering Corporation, mechanical and structural steel work to APCom Power, and foundations to Bowen Engineering Corporation. AEP has subcontracted the utilities to and from the PVF to Professional Construction Services and Nitro Electric Company. AEP has contracted with Battelle to perform engineering, procurement, and construction services for the storage system (CO_2 Storage Project), and Enerteq Engineering Company for engineering and procurement services for the CO_2 transport system.

Scope of Work

The following is a high-level work breakdown structure for the project, including the primary party responsible for the work:

CO_2 Capture Project:

1. Flue gas handling (Alstom)
2. Utilities to and from the PVF (AEP)
3. Monitoring and control system (Alstom)
4. PVF island steel (Alstom)
5. Cooling and cleaning system (Alstom)
6. CO_2 absorption system (Alstom)
7. CO_2 regeneration system (Alstom)
8. CO_2 compression for CO_2 transportation (Alstom)
9. Handling of PVF bleed stream (AEP)

CO_2 Storage Project

1. CO_2 transport pipeline (AEP)
2. Pump to reach injection pressure (AEP)
3. Finish existing well for injection (Battelle)
4. Install second injection well (Battelle)
5. Install monitoring wells (Battelle)
6. Monitoring, mitigation, and verification (MMV) system (Battelle)

Obtaining the plant permits and legal approval along with communication and public outreach programs for the CO_2 Capture and Storage project are the responsibility of AEP.

Technology Overview

The Mountaineer carbon capture PVF will involve the treatment of a flue gas stream using Alstom's Chilled Ammonia Process. The flue gas is taken from a location downstream of an existing WFGD system. The PVF treats approximately 20 MWe of flue gas, or 1.5% of the total plant flue gas flow, and is designed to capture and store approximately 100,000 metric tons of carbon dioxide annually. The features of the Chilled Ammonia Process CO_2 technology include:

- Regeneration of reagent, resulting in low reagent consumption costs
- Ammonium sulfate byproduct stream that can be used commercially as fertilizer
- Lower energy consumption than other CO_2 removal technologies
- High-purity CO_2 product stream containing low moisture and ammonia at elevated pressure, resulting in reduced CO_2 compression costs
- The CAP technology is capable of receiving flue gas from typical AQCS equipment without additional flue gas treatment

The flue gas leaving the WFGD system is cooled and sent to the CO_2 absorber, where the CO_2 in the flue gas will react with ammonium carbonate to form ammonium bicarbonate (ABC). The flue gas slip stream, with most of the CO_2 removed, will be returned to the existing stack for discharge, and the PVF bleed stream will be sent to the plant waste water treatment system for processing. The rich ammonium bicarbonate (ABC) solution is sent to a regenerator column under pressure. Heat will be added in the regenerator to separate the CO_2 and return the ammonium carbonate (AC) solution to the CO_2 absorber for re-use. The CO_2 stream will be scrubbed to remove excess ammonia, then compressed and transported to the storage system. The storage system will further pump and then inject approximately 100,000 metric tons of CO_2 per year into one or both of two geologic reservoirs: the Rose Run Sandstone or Copper Ridge B Zone. There will be three monitoring wells and an extensive MMV program to monitor the injection and migration of the CO_2 within the reservoirs.

Process Chemistry

The overall chemical reactions associated with the carbon capture process are defined in Equations 1–4:

$$2NH_3(g) + H_2O(l) + CO_2(g) \Rightarrow (NH_4)_2CO_3(aq) \qquad (1)$$

$$NH_3(aq) + H_2O(l) + CO_2(g) \Rightarrow (NH_4)HCO_3(aq) \qquad (2)$$

$$(NH_4)_2CO_3(aq) + H_2O(l) + CO_2(g) \Rightarrow 2(NH_4)HCO_3(aq) \qquad (3)$$

$$(NH_4)HCO_3(s) \Rightarrow NH_3(aq) + H_2O\ (l) + CO_2(g) \qquad (4)$$

Equations 1-3 are exothermic reactions requiring removal of heat from the process in order to maintain the desired CO_2 absorption temperature. Equation 4 is an endothermic reaction that requires energy to produce the desired products.

Overall chemical reactions associated with removal of residual SO_2 in the flue gas in the cleaning and cooling stage of the CAP process are provided below in Equations 5 and 6.

$$SO_2(g) + 2NH_3(g) + H_2O(aq) \Rightarrow (NH_4)_2SO_3(aq) \qquad (5)$$

$$(NH_4)_2SO_3(aq) + 1/2O_2(g) \Rightarrow (NH_4)_2SO_4(aq) \qquad (6)$$

Other minor acid gases, including sulfur trioxide, hydrogen chloride, and hydrogen fluoride, are also removed in the CAP cleaning and cooling stage, but equations are not listed in this document.

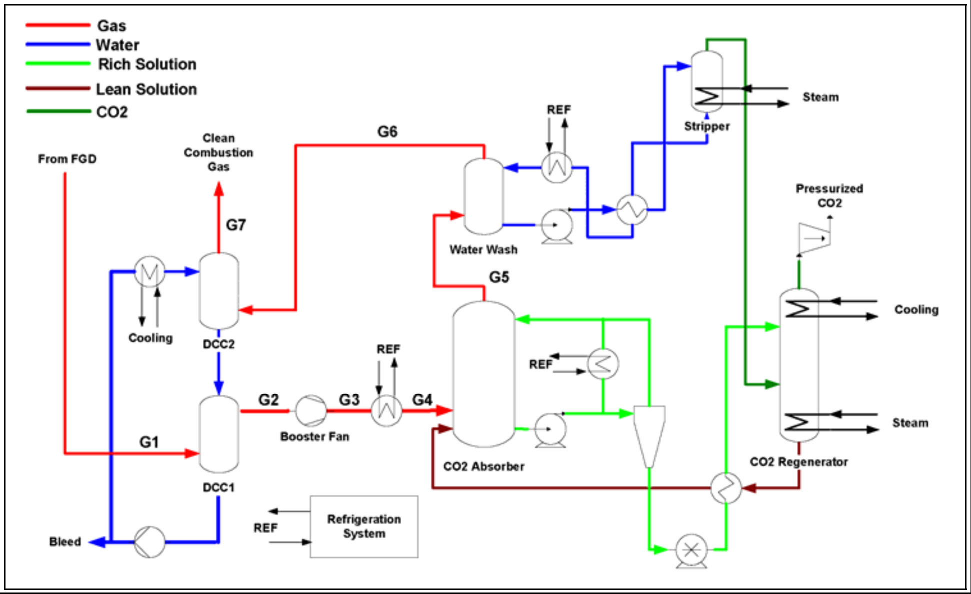
In the CAP, CO_2 is absorbed in an ammoniated solution at temperatures lower than the exit temperature from the flue gas desulfurization system. Therefore, cooling of the flue gas is a necessary step within the process, resulting in condensation of moisture from the flue gas. Gaseous ammonia (NH_3) is released from the ammoniated solution during absorption of CO_2. To minimize gaseous NH_3 emissions, CO_2 absorption is carried out at lower flue gas temperatures. Generally, a lower absorption temperature results in lower ammonia emissions from the CAP absorber and higher power consumption for the cooling process equipment. The formation of aqueous ammonium carbonate ($(NH_4)_2CO_3$) with the precipitation of ammonium bicarbonate ($(NH_4)HCO_3$) solids is conducted at a temperature that optimizes cooling energy demand, carbon dioxide removal efficiency, and ammonia vapor in the flue gas. The formation of ammonium bicarbonate solids is a reversible reaction. With the required amount of heat, the ammonium bicarbonate solids are dissolved with eventual evolution of ammonia, water, and carbon dioxide gases. A regeneration vessel that operates as a distillation column is used to produce the gaseous CO_2 product stream. The CO_2 product stream leaves the CAP regenerator vessel at a higher pressure than other CO_2 processes which results in fewer stages of downstream CO_2 compression equipment. The ammonia and water reaction products are stripped and condensed from the resulting gas stream for use as reagent and flue gas wash solvent, respectively.

The Chilled Ammonia Process equipment can be divided into the following systems:

1. Flue gas cooling and cleaning
2. CO_2 absorption
3. Water wash and CO_2/NH_3 stripping
4. High-pressure regeneration and compression

An overview of the Mountaineer PVF is illustrated in the following schematic (Figure 3) and is described in the following sections.

Figure 3. Chilled Ammonia Process – Process Flow Diagram



A booster fan diverts flue gas from a location downstream of the WFGD absorber to the PVF. The flue gas first enters the cooling and cleaning stages of the process. In the CAP, the purpose of cooling the flue gas is to:

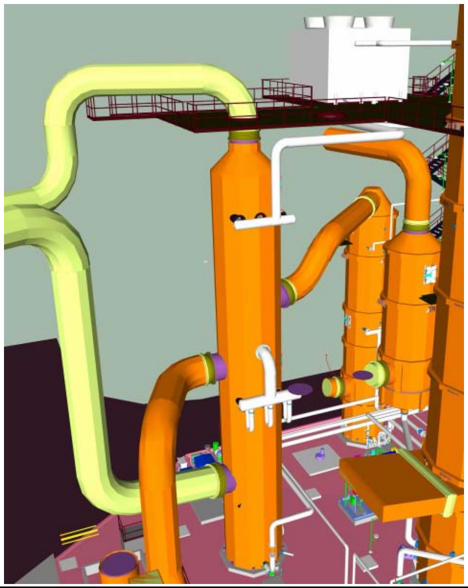
- Operate at a flue gas temperature that minimizes ammonia slip from the absorption process
- Operate at a temperature that enables the formation of ammonium bicarbonate solids, which significantly increase the CO_2 capacity of the rich solution sent to the regenerator
- Condense the moisture in the flue gas, which reduces the volumetric gas flow, increases the CO_2 concentration and reduces the size of CO_2 absorber vessels.

In the process of cooling the flue gas, other benefits are realized, including:

- Residual pollutants are condensed from the flue gas making CAP operation less susceptible to variance in boiler combustion and FGD operation, and
- Clean combustion gas temperature leaving the CAP (from DCC2: refer to Figure 3) is increased prior to entering the flue gas to the existing chimney.

The flue gas enters a direct contact cooling tower vessel (DCC1) to reduce the temperature of the flue gas and to remove residual acid gases. The DCC vessel is illustrated in Figure 4; support steel and other ductwork are hidden for clarity.

Figure 4. Direct Contact Cooler



The flue gas design basis for the project is provided in Table 1. The direct contact cooler is a conventional packed tower with liquid recirculation through a cooling tower that uses ambient air to lower the recirculation liquid temperature. Flue gas enters the DCC1 inlet at the bottom and flows upward through the packing. Cool water is sprayed at the top of the packing and flows downward, counter to the flue gas flow. As the gas flows upward through DCC1, it is forced into contact with the water. Direct cooling of the saturated flue gas results in the condensation of most of the water in the flue gas stream. In addition, the residual acid gases and particulate present in the flue gas leaving the WFGD system, including SO_2, SO_3, hydrogen chloride, and hydrogen fluoride gas, are removed from the flue gas in DCC1. As such, the CAP technology can accommodate acid gases present in flue gases downstream of typical wet and dry FGD systems without the need for additional SO_2 control technology.

Table 1

Mountaineer PVF CO_2 Capture Design Basis		
Parameter	**Unit**	**Value**
Flue Gas Temperature	°F	129
Flue Gas Pressure	In H_2O	-1.5 to 1.0
Flue Gas Flow Rate	scfm	50,584
Flue Gas Flow Rate	scfmd	43,007
Total Mass Rate	lb/hr	240,336
Particulate	lb/hr	3.8
CO_2	lb/hr	39,472
CO_2 Concentration	Vol%	10.61
SO_2	lb/hr	28.5
SO_3	lb/hr	26.9
H_2O	lb/hr	22,874
N_2	lb/hr	163,087
O_2	lb/hr	14,904
NOx	lb/mmbtu	0.47
NH_3 Concentration	ppmv	2

A bleed stream containing primarily dissolved ammonium sulfate is purged from the DCC1 tower for disposal or possible commercial use as fertilizer.

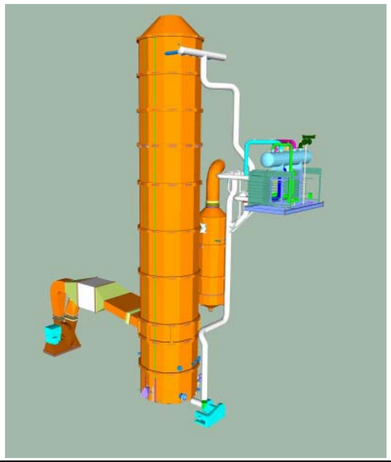
The flue gas leaves DCC1 and is directed through flue gas cooling coils to further reduce the flue gas temperature prior to entering the CO_2 absorbers. The flue gas cooling is accomplished with the use of a mechanical chiller system. Additional moisture is condensed from the flue gas in the cooling coils and is collected for use within the process or discharged from the CAP for use as WFGD make-up water. The quality of the condensed water from the cooling coils is suitable for use as make-up without further treatment.

CO_2 Absorption

Carbon dioxide absorption occurs in the absorber system (ABS 1 & 2) using an ammonium carbonate/bicarbonate scrubbing liquor. As the flue gas flows upwards through the column, it is contacted with the scrubbing slurry solution containing dissolved ammonium carbonate and ammonium bicarbonate suspended solids that flow in a countercurrent direction to the flue gas, and the CO_2 is absorbed.

Lean (low CO_2 concentration) ammonium carbonate solution from the regenerator (REG) is returned to the absorber. A small amount of fresh ammonium carbonate reagent is added to replenish ammonia losses from the CAP system and is used to control the ratio of ammonia to CO_2 in the flue gas.

Figure 5 CO_2 Absorber



The CO_2 absorber (Figure 5) system design is optimized using an Alstom proprietary design that minimizes the packing volume while maintaining the ability to form ammonium bicarbonate solids and minimize the ammonia slip from the absorber. The absorption of CO_2 and reaction with ammonia is an exothermic reaction. As such, heat exchangers remove heat from the process and control the temperature at the desired set point. The cooling medium for these heat exchangers comes from a mechanical chiller.

Water Wash and CO_2/NH_3 Stripping

The flue gas exits the CO_2 absorption system and enters a water wash system to further reduce the ammonia vapor from the flue gas. The water wash system (water wash) is a packed column that utilizes water to absorb ammonia from the flue gas (Figure 6). The temperature of the flue gas is maintained using heat exchangers and a mechanical chilling system. The ammoniated water is sent to a stripper column (CO_2/NH_3 Stripper, Figure 7) where the ammonia is stripped and returned to the process as reagent. The clean water from the CO_2/NH_3 stripper is re-used within the water wash column to remove additional ammonia. Energy for the CO_2/NH_3 stripping column is provided by steam from the power generation facility.

Figure 6 Water Wash Column

The flue gas exits the water wash column and enters the direct contact cooler (DCC2) for removal of residual ammonia, using a proprietary design before entering the chimney as clean combustion gas.

Chiller System

The Chilled Ammonia Process includes a mechanical chiller system to remove heat from the following process streams:

- The flue gas downstream of the direct contact cooler # 1 (DCC1) to further reduce the flue gas moisture and to lower the flue gas temperature
- The absorber (ABS 1 & 2) recirculation streams to remove the heat of reaction generated by the absorption of carbon dioxide with ammonia
- The water wash recirculation stream to reduce the amount of ammonia vapor in the flue gas

Both chiller system compressors are screw type. The heat transferred from the process streams to the chiller system refrigerant is dissipated from the system using evaporative condensers.

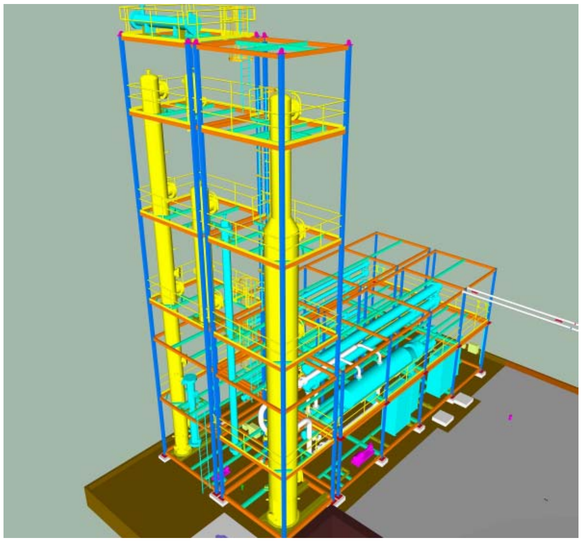
The chiller system refrigerant was selected based upon its efficiency and compatibility with the mechanical chiller compressor system. Ammonia is the most efficient refrigerant for the chiller system as it results in the lowest energy consumption. It can be efficiently used with screw-type chiller compressors. However, site restrictions prohibit the use of ammonia as a refrigerant for the chiller system, so the team selected hydrofluorocarbon (R410A), even though hydrofluorocarbon (difluoromethane and pentafluoroethane) is slightly less efficient than ammonia.

Regenerator

The CO_2-rich solution in the absorber (ABS 1 & 2) contains ammonium bicarbonate solids in an aqueous carbonate/bicarbonate solution. The solution is pumped through a hydrocyclone, where the solids content is increased, before being sent to the regenerator (REG). The solution is pumped by the regenerator feed pump through a series of heat exchangers, where heat is recovered against the lean solution from regenerator bottoms and the CO_2/NH_3 stripper reboiler condensate.

The regenerator vessel is a stripper column that contains a mass transfer device. The feed to the regenerator is

Figure 7 Regenerator and CO_2/NH_3 Stripping Column



introduced at several stages. Flashed CO_2 in the feed proceeds up the column to the overhead. Rich solution, containing CO_2, is flashed by heat introduced in the regenerator reboiler. The regenerator reboiler is designed to maintain the temperature of regenerator bottoms as needed to evolve CO_2 at a pressure resulting in fewer compression stages than other CO_2 removal technologies. As the rich solution falls through the lower regenerator bed, CO_2 is separated and rises to the regenerator overhead, and the solution becomes leaner as it reaches the bottom of the column. The lean solution is then returned to the CO_2 absorber for re-use.

The CO_2 exits the top of the regeneration column and flows to a receiver at the top of the regenerator to condense residual moisture and ammonia. At these conditions, there is a significant difference in the vapor pressure between CO_2 and ammonia and water. Because of this difference, a very low concentration of water vapor and ammonia are present in the regenerator overhead. The CO_2 product stream enters the CO_2 compressor, which compresses the stream to a pressure of 1500 psia (103 bar).

The CO_2 compressor is a two-stage, reciprocating type with intercooler and aftercooler to produce the desired pressure and temperature for CO_2 handling prior to storage. The CO_2 compressor is designed with CO_2 stream bypass to the chimney if required. The CO_2 compressor is fabricated of carbon steel construction with stainless steel inlet scrubber, intercooler and aftercooler.

CO_2 Handling & Storage

Taking control of the supercritical CO_2 at the outlet of Alstom's compressor is one of the key interface points between AEP and Alstom. AEP will install the connection at Alstom's compressor outlet; it will likely be a 3- or 4-inch carbon steel pipe. Carbon steel is an acceptable material for the transport system due to the low moisture content ($\leq$ 600 ppm) and low ammonia levels ($\leq$ 50 ppm) in the CO_2 product stream. Moisture or ammonia concentrations above these values could lead to corrosion or erosion issues over time requiring specialized materials of construction and frequent maintenance. The supercritical CO_2 will be transported via pipeline approximately 1,800 feet to the injection wells. A pump will then increase the CO_2 pressure to approximately 2,000–2,800 psi for injection into one or both of two injection wells. The project team evaluated having one compressor that would achieve injection pressure versus a compressor and pump or two compressors. In the end, the team selected a compressor and pump system to give maximum flexibility to inject the CO_2 into two different reservoirs at the same time with varying pressures.

The key objective of the storage project is validating CO_2 injection and storage in the geologic reservoirs. Geologic formations need to be both porous and permeable in order to serve as storage reservoirs. In general, sandstone formations make excellent geologic storage reservoirs, whereas dolomite, shale, and limestone formations are excellent caprock for geologic storage. At Mountaineer, the CO_2 will be injected into one or both of two reservoirs: the Rose Run Sandstone, approximately 7,800 ft below ground; and the Copper Ridge B-Zone, approximately 8,200 ft below ground. At the Mountaineer site, the Rose Run Sandstone, an interbedded sandstone and dolomite layer, has approximately

114 ft gross thickness with porosity (8–13%) and permeability (up to 70 mD), and the Copper Ridge B-Zone consists of several thin but high permeability zones within a 250 ft thick interval of dense dolomite. The reservoir properties have been evaluated using both laboratory and field tests and published in peer-reviewed literature. *(Battelle)* However, these reservoirs would not be acceptable storage zones without caprock above these layers to contain the CO_2.

The Rose Run Sandstone and Copper Ridge B Zone are well contained vertically with excellent caprock consisting of thick layers of dense and impermeable dolomite, shale, and limestone formations. The primary confining layer above the Rose Run Sandstone is the Beekmantown Dolomite, which is approximately 550 feet thick at a depth of 7,160 to 7,710 feet below ground. The Ohio River Valley Project core samples from this interval showed very low porosity and permeability. The primary confining layer above the Copper Ridge B Zone is the upper Copper Ridge Dolomite which is approximately 310 feet thick at a depth of 7,840 to 8,150 feet below ground. Additionally, there are several thousand feet of dolomites, shales, and limestone formations above these layers that provide very substantial secondary layers of containment for the captured CO_2 *(Battelle).*

Data collected from the storage efforts of this project will be compared with modeling results and predicted CO_2 behavior. Battelle's modeling simulations based on the seismic survey, well logging, and core and reservoir testing data from the existing well, AEP-1, will be validated and tuned based on this real-world information. This project offers a rare opportunity for authenticating a large pool of data collected during characterization. Following the active injection period, the CO_2 placed below ground will continue to be monitored for migration and permanence. The duration and extensiveness of this monitoring program is still under development.

Permitting this first-of-a-kind CO_2 storage project with the appropriate West Virginia agencies is another key task for the storage project. The list of known or anticipated permits for the project includes:

- Underground Injection Control (UIC) – WV DEP
- Well work permits for drilling deep wells– WV DEP
- NPDES permit modification – WV DEP
- Storm Water Construction Permit – WV DEP
- Public Lands Permit – WV DNR
- Corps permit notification – Corps of Engineers
- Periodic seismic survey – Local/county engineer

The two most significant permits for the storage project are the well work permits needed to drill the monitoring and injection wells and the Underground Injection Control (UIC) Permit needed to operate the CO_2 injection wells. Well work permits are needed in West Virginia for deep wells that are used for geologic characterization or other non-producing deep wells. AEP submitted the monitoring well work permit applications in March 2008 and received them in June 2008. AEP submitted the injection well work permit applications in July 2008 and expects to receive them by the end of August 2008.

The UIC Permit for this project is a Class V experimental well permit. It is important to note that the permitting activities for this project were undertaken prior to establishment of a new permitting classification for CO_2 injection. AEP filed the project UIC permit application on February 8, 2008 and expects to receive the permit in September 2008. The Department of Energy (DOE)-sponsored Ohio River Valley Project provided most of the information needed for this permit. The UIC permit also includes modeling data from Battelle's proprietary $STOMPCO_2$ model, including a map showing the 3,490 ft radius CO_2 saturation area ("Area of Review"), which was based on several conservative assumptions.

For geologic storage of CO_2, there are several questions and concerns that need to be addressed before programs are implemented on a commercial scale basis, such as:

- Who owns the rights to the pore space in the geologic reservoirs thousands of feet under ground? How can those rights be aggregated to support commercial storage projects?
- Are there valuable minerals in these reservoirs, and does CO_2 storage affect the value of those mineral rights?
- Are uniform federal standards needed to govern storage requirements in order to facilitate the use of interstate formations?
- What are the consequences if the CO_2 leaks out of the formations? What remedial standards should apply and how will leakage impact any greenhouse gas programs used to address climate change?
- What are the risks and liability complications for situations when CO_2 from one source combines underground with CO_2 from other source(s)?

For the Mountaineer CO_2 storage project, AEP owns most of the property and mineral rights within the Area of Review. AEP is researching mineral rights issues for the property not owned by AEP and is working with West Virginia to craft language that addresses corrective action during the term of the UIC permit. Questions regarding third party liability and insurance coverage are also still being reviewed.

Alstom's Chilled Ammonia Process Operating Experience

Alstom has conducted bench scale testing of the Chilled Ammonia Process at the SRI International test facility and at Alstom's Research Laboratory in Vaxjo, Sweden. Data collected from the bench-scale regenerator operating at SRI International has shown CO_2 product stream quality of greater than 99.9%, with ammonia emissions below 10 ppm and water emissions well below 1,000 ppm. A field pilot plant has been installed at We Energy's Pleasant Prairie Power Plant ("P4"). As of

Figure 8 Field Pilot at We Energy's Pleasant Prairie Power Plant

early July, the field pilot had completed over 100 hours of operation and is currently operating in 4-5 by 24-hour continuous shifts. Parametric testing is scheduled to commence in July 2008 and the pilot will proceed into 7 by 24 hour operations starting in September 2008.

SUMMARY

Alstom and American Electric Power are jointly participating in the installation of a CO_2 capture Product Validation Facility at AEP's Mountaineer Power Plant. The CO_2 capture Product Validation Facility is designed to capture and store 100,000 metric tons of CO_2 annually. The CO_2 capture technology to be installed at Mountaineer is Alstom's Chilled Ammonia Process. The project targets include:

- Energy consumption that is lower than amine-based, CO_2 capture technologies
- Ammonium sulfate byproduct stream with a potential commercial value
- Inlet flue gas conditions that are tolerant of acid gases at levels consistent with outlet conditions of modern FGD systems
- Regenerable reagent requiring low reagent make-up

Operating data from the CAP field pilot plant at the We Energies Power generation facility is expected by the end of 2008.

The CO_2 storage portion of the project involves validation of CO_2 injection and storage in the geologic reservoirs located beneath the site. At Mountaineer Plant, the CO_2 will be injected into one or both of two reservoirs: the Rose Run Sandstone at approximately 7,800 ft below ground, and the Copper Ridge B-Zone at approximately 8,200 ft below ground. These formations are representative of geologic reservoirs in the Midwest and should be good indicators of the feasibility of CO_2 geologic storage in the region.

Acknowledgements

1. Battelle, *Section XVI Support Material – Class 5X27 Underground Injection Control Permit Application for Geologic Carbon Dioxide Storage Demonstration for the AEP Mountaineer Plant New Haven, West Virginia, February 2008.*