PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Innovations for Existing Plants

01/2009

Transport Membrane Condenser for Water and Energy Recovery from Power Plant Flue Gas
ProMIS/Project No.: NT0005350

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Background

One area of the U.S. Department of Energy's (DOE) Innovations for Existing Plants (IEP) Program's research is being performed to develop advanced technologies to reuse power plant cooling water and associated waste heat and to investigate methods to recover water from power plant flue gas. Considering the quantity of water withdrawn and consumed by power plants, any recovery or reuse of this water can significantly reduce the plant's water requirements.

Coal occurs naturally with water present (3-60 weight %), and the combustion process releases additional water as hydrogen in the coal reacts with oxygen. The amount of water that can be recovered from flue gas is sufficient to substantially reduce the need for off-plant sources of water. At the present time, there is no practiced method of extracting the water found in the power plant stack gas.

Description

The focus of this project is to develop a membrane separation technology to recover water vapor from power plant flue gas based on modifications to Gas Technology Institute's (GTI) patented Transport Membrane Condenser (TMC) technique originally developed for industrial gas-fired boilers. In the new process, a small part of the recovered water vapor will be directly added to the coal-fired power plant boiler feed water loop to replace expensive fresh makeup water and at the same time improve power plant energy efficiency. The major part of recovered water will be available for plant use such as cooling tower water makeup or flue-gas desulfurization (FGD). With the large amount of cooling water stream available

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Gas Technology Institute

Media & Process Technology, Inc.

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for power plant application, up to 90 percent of the water vapor in the power plant flue gas can be cost-effectively recovered, especially from flue gas from high-moisture content coals. It is particularly advantageous when applied to power plants that use FGDs because of the increased moisture level in the stack gases. The TMC approach can also be used to recover water from the exhaust stream from drying high-moisture coals. There will be three phases for the project. The objectives for Phase 1 are to evaluate the membrane and to develop the two-stage TMC design concept; the objective for Phase 2 is to design, build, and test the pilot-scale TMC at GTI's laboratory; and the objectives for Phase 3 are to test the pilot-scale TMC on a power plant slipstream and to develop a scale-up design and commercialization plan.

Figure 1 shows a conceptual layout for a TMC water recovery unit in a typical power generation boiler steam turbine loop. GTI proposes a two-stage TMC unit to maximize its function for recovering both water and heat; therefore, two separate cooling water streams will be used. On the water side, the first stage TMC inlet water will be obtained from steam condensate from the condenser. Its outlet water with recovered water vapor and associated latent heat from flue gas will go to the deaerator for boiler water makeup. The second stage TMC inlet water will be from part of the condenser cooling water stream. This outlet water will go back to the cooling water stream with extra recovered water from the flue gas. On the flue gas side, the TMC is situated between the FGD unit and the stack.

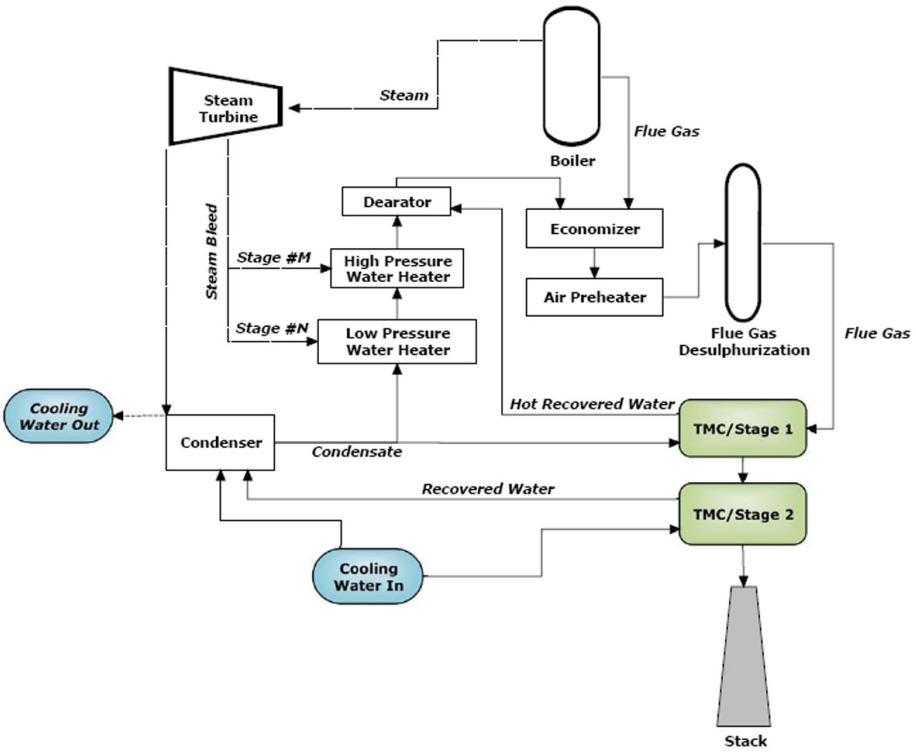

Figure 1: Power Plant Flue Gas Water Recovery with a Two-Stage TMC

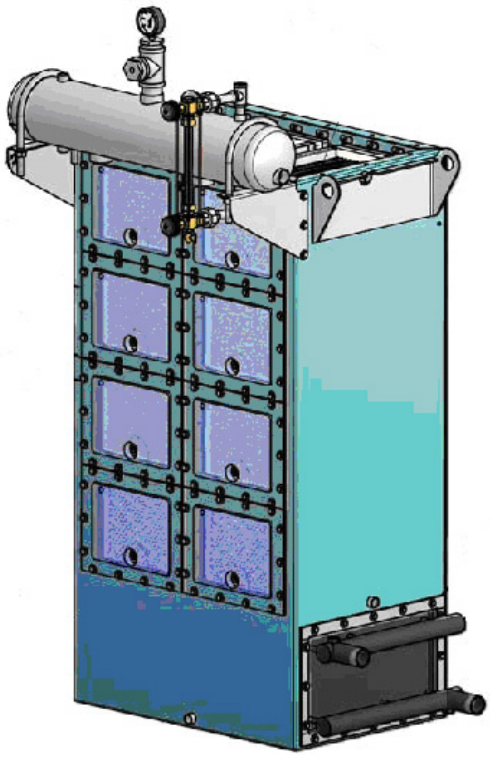

Figure 2: Image of a TMC Currently Used for Industrial Gas-Fired Boiler Flue Gas Water/Heat Recovery

Primary Project Goal

The goal of this project is to develop an effective flue gas water vapor recovery system for use in power production facilities to reduce high quality freshwater withdrawal and consumption.

Objectives

- Develop, model, and evaluate the two-stage TMC water recovery concept by using analytical and numerical methods, resulting in a design basis for power plant application.
- Optimize the currently available ceramic membrane performance for flue gas water recovery application.

PERIOD OF PERFORMANCE

10/01/08 to 03/31/11

COST

Total Project Value
$1,438,116

DOE/Non-DOE Share
$1,148,141 / $289,975

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- Design and fabricate the pilot-scale test system for TMC technology applied to flue gas from coal-fired power plants.
- Test the TMC water transport and heat recovery performance at different flue gas conditions corresponding to flue gas properties in different coal-fired power plants with both wet and dry FGD units.
- Develop scaling algorithms for application of the TMC technology to a typical range of coal-fired power plant sizing.
- Develop a path for commercial deployment of the TMC system.

Benefits

The main benefit of this research is the progress towards allowing power-generation facilities to utilize water vapor in flue gas streams to supplement facility water usage.

Planned Activities

The following includes the activities proposed to develop the technology for effectively recovering water and energy from power plant flue gas:

- Develop a new two-stage TMC design for optimum water and heat recovery from power plant flue gas. TMC/stage 1 focused on partial water recovery and maximum heat recovery, and TMC/stage 2 focused on maximum water recovery. Membrane specifications (e.g., membrane pore size) will vary between the two stages in order to achieve their different functions. An optimal combination needs to be determined. Membrane fouling was not an issue in previous TMC application because of the unique feature of TMC water vapor transportation and separation.
- Build and test a pilot-scale TMC unit to evaluate its overall performance on flue gas from an existing 3-million-Btu/h industrial boiler at GTI that can fire both natural gas and oil. After the performance is proved, it will be tested at an Alliant Energy power plant with a slip stream of flue gas from a coal-fired boiler.
- Develop a scale-up design for application of the TMC technology to coal-fired power plants based on the test results and inputs from Alliant Energy.
- Develop a robust technology transfer/commercialization plan to bring the TMC-based water and energy recovery technology to the power generation market in a timely fashion.