Natural Resources Canada / Ressources naturelles Canada

CETC CANMET ENERGY TECHNOLOGY CENTRE

CLEAN POWER GENERATION

NON THERMAL PLASMA

CLEAN ENERGY TECHNOLOGIES

MULTI-POLLUTANT CONTROL

Background

Coal Combustion Emissions

Burning coal to generate electricity produces a number of pollutant species that are considered harmful to people, animals, and the environment in general [1], [2], [3], [4]. Pollutants of significant concern are oxides of nitrogen and sulphur (NO_x and SO_2, respectively), mercury (Hg), and particulate matter (PM). The harmful effects of these species are well documented, and these emissions are the subject of numerous and ever-stringent legislations in many parts of the world.

Current Pollutant Reduction Technologies

Current technologies such as baghouses, wet scrubbers, and electrostatic precipitators are typically designed to control emissions of a single pollutant species. Controlling multiple pollutants with conventional technologies can require the installation of a suite of different devices. The capital and operating costs of retrofitting or upgrading non-compliant facilities are major concerns for electricity producers and consumers.

Non-thermal Plasma Pollutant Control

Non-thermal plasma technology can be used to control multiple pollutants of interest, namely SO_2, NO_x, and Hg. Currently, most of the plasma technology being developed employs wire-cylinder discharge geometry and an ammonia (NH_3) reagent introduced into the flue gases. The reduction of SO_2, NO_x, and Hg pollutant species can be over 90%, and the electrical consumption of the technology can be as high as 3% of the power plant's production capacity [5].

Plasma Corona Radical Shower (PCRS) is a newer technology which employs a different geometric configuration in the reaction chamber, along with better control of the NH_3 injection. In this process, ammonia is fed into the reaction chamber through hollow electrodes, resulting in higher NH_3 concentrations within the plasma corona.

Research facilities in CETC Bells Corners Complex, ON, with facility building (Bldg. 7) circled

Initial testing of PCRS shows promise of improved plasma performance with substantially reduced electricity consumption (<1% of production) [5].

Our Goal

CETC aims to develop the lab-scale PCRS technology into robust and economically optimized industrial solutions for controlling SO_2, NO_x, and Hg emissions.

Our focus is to obtain the most relevant data possible to address practical concerns of industrial users. We have built a fully-customized test facility to simulate industrial flue conditions as realistically as possible at an economical scale (coal combus-

Canada

CETC – OTTAWA
CANMET Energy Technology Centre
Natural Resources Canada
1 Haanel Drive, Ottawa, Ontario K1A 1M1
Telephone: 1 (613) 996-8693 **Fax:** 1 (613) 995-9584

tion producing flue gas at a rate of 53 m^3/h). Our tests will investigate the effects of various parameters on the efficiency of PCRS technology, including:

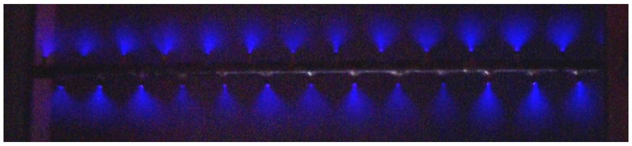
- Number and position of electrodes
- Excitation profile: AC, DC, or AC/DC - superimposed voltages, frequency, waveform, peak voltage
- Type, concentration, and amount of reagent(s)
- Flue gas flow rate, pressure, temperature, and humidity
- Presence and amount of additional contaminants
- Coal type

CETC-Ottawa Non-Thermal Plasma Facility

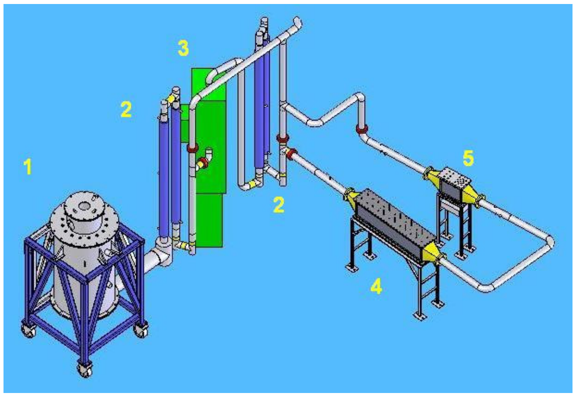
The facility includes the following components:

- Gravimetric pulverized coal feeder
- Coal combustion furnace operating at 100,000 Btu/h
- Water jacket heat exchangers
- Baghouse
- Plasma Corona Radical Shower (PCRS)
- High-efficiency electrostatic precipitator (ESP)
- Induced draft fan
- Automated firing and monitoring control system
- Gas and particulate matter analyzers

Three truly unique pieces of technology lie at the core of this system: the custom-designed pulverized coal furnace, the PCRS reactor, and the high-efficiency ESP.



Above: plasma corona being generated during PCRS commissioning (image rotated 90° clockwise). Below: the PCRS facility in building 7, with the coal furnace in foreground.



System schematic featuring 1) coal furnace, 2) heat exchangers, 3) baghouse, 4) PCRS, and 5) ESP.

The furnace allows for testing industrial fuels at a laboratory scale, thereby providing operational and experimental flexibility. The size of the facility makes it financially amenable to further customization, and testing modified components or even entirely different devices, either separately from or in tandem with the existing configurations.

The plasma generating zone is designed to be configurable such that any number of electrodes can be positioned in a variety of ways with regard to the inlet, outlet, ground plate, or other electrodes.

Downstream of the PCRS is a custom-designed, high-efficiency electrostatic precipitator (ESP) which will be capable of very high particulate removal rates for capturing solid products of ammonium solts formed from pollutants and ammoia under plasma action. The ESP also has configurable electrode geometry.

Scope of Work

The PCRS test facility will be primarily used in the investigation of the effects of variations in the following parameters:

- Fuel characteristics
- Furnace operating parameters
- Emissions Measurement (PM, SO_2, NO_x, Hg)
- Flue gas properties and composition
- PCRS operating parameters (reagent concentrations, voltage levels and profiles, electrode geometry, rapping sequences)

In the course of this project we have developed more efficient electrodes with star-shaped discharge elements. Preliminary result showed that over 98% of SO_2 could be removed from the flue gas.

Pollutant Control Configuration		ESP	PAC + ESP	SCR + ESP	SCR + ESP + FGD	SCR + PAC + ESP + FGD	PCRS + ESP
Eastern Bituminous Coal, 165 MW_e (gross), 156 MW_e (net)							
Capital cost	$MM US	10.4	12.45	24.5	68.5	70.1	33.9
Annual cost	$MM US/y	3.5	6.3	7.3	20.7	22.9	5.6
Power consumption	kW	663	684	1624	4994	5015	1588
Power consumption	% gross	0.40	0.41	0.98	3.02	3.04	0.96
Species Removal							
$PM_{2.5}$	%	96.0	90.3	96.0	98.0	97.2	?
PM	%	99.2	97.8	99.2	99.95	99.9	99.9
NO_x	%	0	0	80	80	80	80
SO_2	%	0	0	0	80-99	80-99	95
Hg	%	76	90	76	90	95	90
Lignite Coal, 297.8 MW_e (gross), 271.8 MW_e (net)							
Capital cost	$MM US	18.2	19.9	38.5	98.5	98.5	51.0
Annual cost	$MM US/y	6.3	8.6	12.1	30.9	33.2	9.4
Power consumption	kW	1049	1103	2917	9160	9214	2513
Power consumption	% gross	0.35	0.37	0.98	3.08	3.09	0.84
Species Removal							
$PM_{2.5}$	%	96.0	86.3	96.0	98.0	93.2	?
PM	%	99.2	96.9	99.2	99.95	99.8	99.9
NO_x	%	0	0	80	80	80	80
SO_2	%	0	0	0	80-99	80-99	95
Hg	%	53	83	53	63	90	90
Western Subbituminous Coal, 410 MW_e (gross), 381 MW_e (net)							
Capital cost	$MM US	25.5	27.5	59.8	119	119	65.7
Annual cost	$MM US/y	10.2	13.4	22.6	40.6	43.8	14.4
Power consumption	kW	1201	1270	3558	11858	11927	3658
Power consumption	% gross	0.29	0.31	0.87	2.89	2.91	0.89
Species Removal							
$PM_{2.5}$	%	96.0	84.1	96.0	98.0	76.4	?
PM	%	99.2	96.3	99.2	99.95	99.3	99.9
NO_x	%	0	0	80	80	80	80
SO_2	%	0	0	0	80-99	80-99	95
Hg	%	42	69	42	50	75	90

ESP = electrostatic precipitator, PAC = powdered activated carbon injection, SCR = selective catalytic reduction, FGD = flue gas desulphurization, PCRS = plasma corona radical shower; capital cost is the total owner's cost and the annual cost includes operating and maintenance costs as well as financing.

The table above compares various pollutant control configurations at three Canadian electrical utilities. PCRS combined with an ESP is the most cost-effective and power saving technology in removing pollutants from flue gas to comparable levels. The O & M data in the above, when appropriately scaled, agree with the results reported in the figure below.

Non-thermal Plasma Consortium

CETC is forming a consortium with industry, government, and academic partners to ensure that the resultant technology develops in a way that is optimized for industrial applications and maximum environmental benefit. Consortium members will have input into the testing process and design in order to address individual application issues. In this way, the consortium will enable members to share and benefit from considerable expertise across sectors. The consortium members will also have unlimited license to use the technology for their own purposes.

References

[1] EPA. 2005. Air trends: sulfur dioxide. http://www.epa.gov/air/airtrends/sulfur.html

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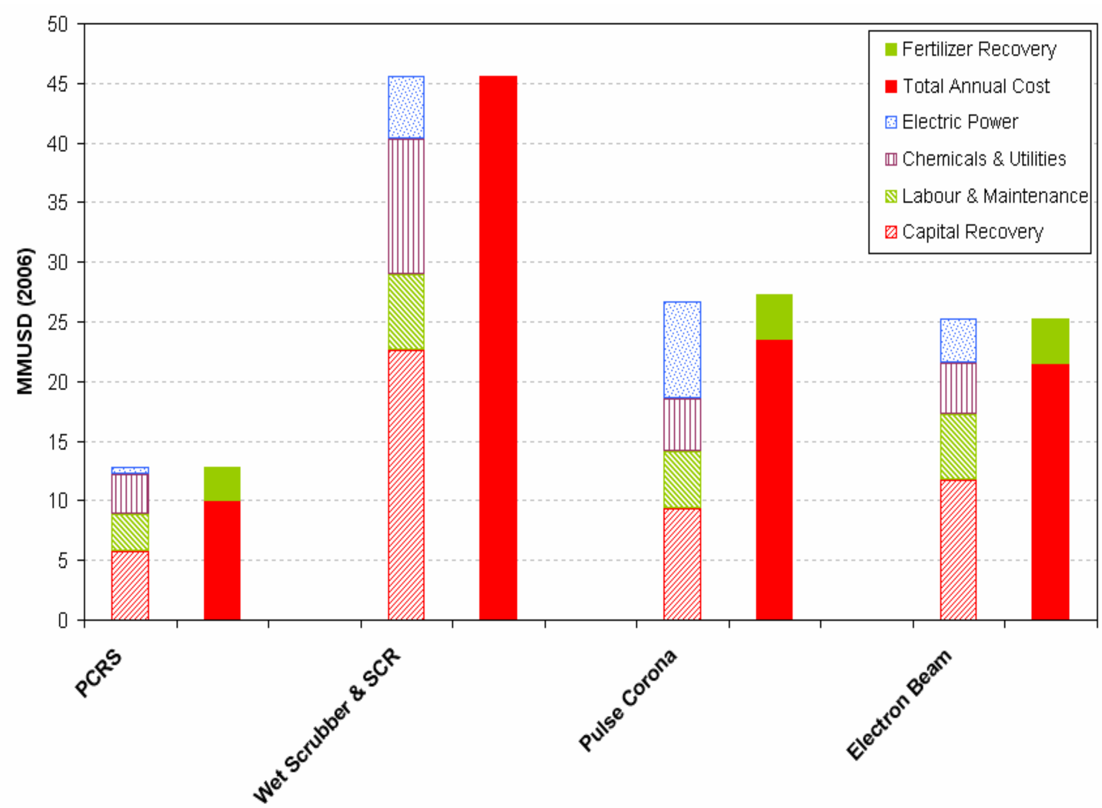
[3] EPA. 1997. Mercury study report to congress. Volume ii: an inventory of anthropogenic mercury emissions in the United States. http://www.epa.gov/ttn/oarpg/t3/reports/volume2.pdf

[4] EPA. 1997. Mercury study report to congress. Volume v: health effects of mercury and mercury compounds. http://www.epa.gov/ttn/oarpg/t3/reports/volume2.pdf

[5] Chang, J. & Kim, S.J. 1998. SUENTP code simulations of scaleup and economic evaluation of non-thermal plasma technology for exhaust gas emission control of coal fired power plants. Proceedings ICESP VII, Sep. 25-28, 1998, Kyongju, Korea.



Annual costs of different multi-pollutant control technologies for a typical 500 MW_e coal-fired power station. Plasma corona radical shower (PCRS) is the technology under investigation. Pulse corona and electron beam are two other types of non-thermal plasma technology.

Source: adapted from Chang & Kim [5] and converted to 2006 dollars.

For Further Information Please Contact:

Quan Zhuang
Research Scientist
(613) 947-0977
gzhuang@nrcan.gc.ca

CANMET Energy Technology Centre – Ottawa
Natural Resources Canada
1 Haanel Drive
Ottawa, Ontario, K1A 1M1
Canada

cetc.nrcan.gc.ca