Florida Department of Environmental Protection

Marjory Stoneman Douglas Building
3900 Commonwealth Boulevard
Tallahassee, Florida 32399-3000

Rick Scott
Governor

Herschel Vinyard
Secretary

May 30, 2013

David Adomatis, CFA, Senior Analyst
Personal Property Section
Palm Beach County Property Appraiser's Office
301 North Olive Avenue
West Palm Beach, Florida 33401

Re: Florida Power & Light Company, West County Energy Center

Dear Mr. Adomatis:

In accordance with §193.621, Florida Statutes (F.S.), if it becomes necessary for a manufacturing or industrial plant or installation "to install or construct a facility in order to eliminate or reduce industrial air or water pollution, those facilities shall be deemed to have value, for purposes of assessment for ad valorem property taxes, no greater than their market value as salvage". Only those facilities specifically installed to eliminate or reduce air or water pollution are eligible for this type of assessment. Additionally, if a property appraiser is in doubt as to whether a taxpayer is entitled to an assessment under this section, the matter may be referred to the Department of Environmental Protection for a recommendation.

On April 15, 2011 the Siting Coordination Office (SCO) received a request from your office concerning the eligibility (pursuant to §193.621, F.S.) of pollution control devices associated with the operation of Units 1 and 2 at Florida Power & Light Company's (FPL's) West County Energy Center (WCEC) located in Palm Beach County. In response to that request, the SCO made a recommendation that the items on the equipment list submitted by FPL were eligible for assessment as pollution control devices with the exception of the inlet fogger system, noise abatement equipment, and the cooling tower system.

On May 3, 2013 the SCO received an email from you regarding a list of pollution control devices submitted by FPL associated with the operation of Units 1, 2 and 3 at the same facility. I have reviewed the material attached to your email and considered additional information. In my opinion, the items on the equipment list submitted by FPL (attached) are "primarily for the purpose of pollution control" and are eligible for assessment as pollution control devices pursuant to §193.621, F.S., with the following exceptions and clarifications.

1. Units 1, 2 and 3 Noise Abatement – Pollution is defined in §403.031, F.S., in part, as the presence of "noise" in the outdoor atmosphere. Upon further review, I consider noise abatement equipment that has been installed in order to meet specific regulatory requirements regarding such "noise pollution" is eligible for assessment as a pollution control device.
2. Units 1, 2 and 3 Afterburners (duct burners) – Duct burners are located in the heat recovery steam generator and are used to increase steam production in order to provide boosts in power. They are in fact additional <u>sources</u> of air pollution and help to produce additional electrical power. However, modern duct burners have been designed to minimize emissions of pollutants such as nitrogen oxides (NO_x), carbon monoxide, and particulate matter. If FPL can provide verification that Low NO_x duct burners are installed on the WCEC units, I recommend partial assessment at salvage value, perhaps 50%, for each of the burners.
3. Units 1, 2 and 3 Cooling Tower Components: Trays, Packing System, and Water Distribution System – Consistent with the recommendation of May 10, 2011, I do not consider a cooling tower's primary purpose to be that of pollution control. However:

a. Cooling towers are equipped with drift eliminators to minimize losses (water/particulate matter) due to drift. Therefore, I recommend that equipment demonstrated to be specifically part of the drift elimination system within the cooling towers be assessed as pollution control.

b. Although the internal water distribution systems are an integral part of the cooling towers, those systems can be designed to be equipped with a variety of high performance fills or packing to improve efficiency, and which also results in drift reduction. Therefore, I recommend partial assessment for the equipment demonstrated to be specifically part of the internal water distribution system (perhaps 25-50%).

4. Combustion Caps and Flow Sleeves (Unit 3) – Combustion caps and flow sleeves are used to direct air, including cooling air, to downstream components of the combustors. However, they are optimized to achieve efficient combustion and low NO_x emissions. I recommend partial assessment at salvage value, perhaps 50%.

If you have any questions regarding this recommendation, please contact Cindy Mulkey at (850) 717-9110 or me at (850) 717-9111.

Sincerely,

Bobby Bull, P.E.
Siting Coordination Office

GOVERNMENTAL CENTER - 5TH FLOOR
PERSONAL PROPERTY SECTION
301 NORTH OLIVE AVENUE
WEST PALM BEACH, FLORIDA 33401
(561) 355-2896 FAX (561) 355-2882
www.pbcgov.com/papa

GARY R. NIKOLITS, CFA
PALM BEACH COUNTY
PROPERTY APPRAISER

May 1, 2013

Cindy Mulkey
Department of Environmental Protection
3900 Commonwealth Blvd; MS48
Tallahassee, FL 32399-3000

RE: Request for Determination of Pollution Control

Ms. Mulkey,

We are requesting, pursuant to Florida Statute section 193.621(5), that the Dept. of Environmental Protection advise the Palm Beach County Property Appraiser of the validity of items listed in the attached DR-492. We ask for, and you provided your opinion on these same items in your letter dated May 10, 2011. Palm Beach County has been and is following your recommendations of 2011. Please let us know of any changes, (if any) that you would make based on the attached DR-492.

Please feel free to contact Florida Power & Light directly should you need additional information to make your determination. They are aware that we are making this request and understand that you may request additional information.

Thank you for your assistance in this matter, and if you need additional information from us, please do not hesitate to contact us at (561) 355-2896.

Sincerely yours,

GARY R. NIKOLITS, CFA
Palm Beach County Property Appraiser

David A Adomatis

David Adomatis, PPS, CFE, Senior Analyst
Personal Property Section
Palm Beach County, Florida
Property Appraiser's Office
Phone (561) 355-2685
Fax (561) 355-2882

DR-492 R. 3/83

RETURN OF POLLUTION CONTROL DEVICES
FOR AD VALOREM TAX PURPOSES - 2013
FLORIDA STATUTES CHAPTER 193.621

To the Property Appraiser: Honorable Gary Nikolits
Palm Beach County, Florida

Return is hereby made for the assessment of the following described property under Florida Statues as pollution control devices.

Description of Property

West County Energy Center Units 1, 2 & 3

Tangible Property: $161,816,339
Real Property: $ 3,585,114

Description of Facility

Please see the attached signed and sealed Registered Engineer's Certification and the Pollution Control Equipment and Facilities cost schedule.

Name and address of Owner:

Florida Power & Light Company
Atten: Property Tax Dept. – PSX
P. O. Box 14000
Juno Beach, FL 33408

The undersigned taxpayer hereby agrees to furnish such other reasonable information as the Appraiser may request in regards to the assessment requested herein.

Taxpayers Signature: **Christopher Cothran, Manager Property Tax**

This form must be filed with the county Property Appraiser before April 1st.

This is to certify that, to the best of my knowledge and belief, the facilities/systems at the **FPL West County Energy Center Units 1 & 2** listed below are "primarily" used as "pollution control facilities" as defined in Chapter 62-8.020 (1) and (3) Florida Administrative Code (F.A.C.), respectively. In addition, the definitions of "contaminant" and "pollution" contained in 403.031 Florida Statues (F.S.) are used to provide meaning of these terms in Chapter 62-8 F.A.C. The list provides the Facility/System, System Description and Pollution Control Functions.

FACILITY / SYSTEM	SYSTEM DESCRIPTION	POLLUTION CONTROL FUNCTION
Air Emission Control Systems	**Stack/H.R.S.G. Enclosures** • CEM-Computer / Microprocessor	System monitors various air emissions to help ensure compliance with State and Federal air emissions standards. The Continuous Emission Monitoring System (CEMS) is a requirement of State and Federal regulations and approvals.
	Water Injection System Water injection system equipment	System reduces NO_x emissions by introducing water in the combustion process.
	H.R.S.G. Enclosures • Emission Monitoring System • SCR Duct • SCR Superstructure • SCR Ammonia Injection System • SCR Catalyst • SCR Tank • Afterburners (duct burners)	Selective Catalytic Reduction (SCR) system that controls emissions of NO_x emissions by the reaction of ammonia and NO_x on the surface of a catalyst that occurs at a specific temperature range. Duct burners control of air emissions during combustion process that is required by State and Federal regulations.
Industrial Wastewater Treatment System	**Wastewater Treatment System** • Control/Instrumentation System • Foundation • Piping • Tank • Pump Complete	System captures and treats industrial waste streams, and storm water runoff from equipment and power block areas.
	Ponds (not cooling) • Pond • Piping, All • Water Monitoring Well	

FACILITY / SYSTEM	SYSTEM DESCRIPTION	POLLUTION CONTROL FUNCTION
Noise Abatement Equipment	**Industrial Gas Turbine** • Acoustical Enclosure **H.R.S.G. Pressure Parts** • Silencer / Muffler **Reheat Steam System** • Silencer / Muffler **Steam Turbine** • Acoustical Enclosure **Turbine Drain System** • Silencer / Muffler	Includes items such as silencers / mufflers and acoustical enclosures that provide noise abatement for the subject systems. The control of noise is a requirement of the Site Certification Conditions (PA 05-47B XX) that specifies the plant comply with Palm Beach Noise Ordinance (Unified Land Development Code, Article 5, Section 4. B.). (Note: Noise is "pollution" as defined in 403.013 F.S.)
Cooling Tower System	**Cooling Tower** • Water Distribution System • Trays, Packing Complete	Water distribution, and trays, packing complete together reduce the air emissions of particulate matter (drift) that is a specific requirement of FDEP Air Permit Nos. 0990646-001 & 002-AC; PSD-FL-354 & 396.
Fuel / Oil / Chemical Spill Containment / Prevention Systems	**Turbine Lube Oil Storage and Transfer** • Retaining Wall for Spills	Includes items such as storage tank containment dikes and tank liners that provide spill containment/ protection.

Kennard F. Kosky

Date: March 26, 2013

Kennard F. Kosky, P.E.
Florida Registration No. 14996
Golder Associates Inc.
6026 NW 1st Place
Gainesville, Florida 32607
Board of Professional Engineers Certificate of Authorization No: 1670

SEAL

This is to certify that, to the best of my knowledge and belief, the facilities/systems at the **FPL West County Energy Center Unit 3** listed below are "primarily" used as "pollution control facilities" as defined in Chapter 62-8.020 (1) and (3) Florida Administrative Code (F.A.C.), respectively. In addition, the definitions of "contaminant" and "pollution" contained in 403.031 Florida Statues (F.S.) are used to provide meaning of these terms in Chapter 62-8 F.A.C. The list provides the Facility/System, System Description and Pollution Control Functions.

<table>
<tr><th>FACILITY / SYSTEM</th><th>SYSTEM DESCRIPTION</th><th>POLLUTION CONTROL FUNCTION</th></tr>
<tr><td rowspan="5">Air Emission Control Systems</td><td>Stack
• CEM-Computer / Microprocessor</td><td>System monitors various air emissions to help ensure compliance with State and Federal air emissions standards. The Continuous Emission Monitoring System (CEMS) is a requirement of State and Federal regulations and approvals.</td></tr>
<tr><td>Demineralized Water System
• Foundation
• Pump,Complete
• Tank
• Water Treatment Systems</td><td>System reduces NO_x emissions by introducing water in the combustion process.</td></tr>
<tr><td>Industrial Gas Turbine
• Combustion Caps
• Flow Sleeves</td><td rowspan="3">Combustion liners assist with the combustion process to limit air emissions.
Selective Catalytic Reduction (SCR) system that controls emissions of NO_x emissions by the reaction of ammonia and NO_x on the surface of a catalyst that occurs at a specific temperature range.
Duct burners control of air emissions during combustion process that is required by State and Federal regulations.</td></tr>
<tr><td>H.R.S.G. Enclosures
• Emission Monitoring System
• SCR Duct
• SCR Superstructure
• SCR Ammonia Injection System
• SCR Catalyst
• SCR Tank
• Afterburners (duct burners)</td></tr>
<tr><td>Ponds (not cooling)
• Pond
• Piping, All
• Water Monitoring Well</td></tr>
</table>

FACILITY / SYSTEM	SYSTEM DESCRIPTION	POLLUTION CONTROL FUNCTION
Noise Abatement Equipment	**Industrial Gas Turbine** • Acoustical Enclosure **H.R.S.G. Pressure Parts** • Silencer / Muffler	Includes items such as silencers / mufflers and acoustical enclosures that provide noise abatement for the subject systems. The control of noise is a requirement of the Site Certification Conditions (PA 05-47B XX) that specifies the plant comply with Palm Beach Noise Ordinance (Unified Land Development Code, Article 5, Section 4. B.). (Note: Noise is "pollution" as defined in 403.013 F.S.)
Cooling Tower System	**Cooling Tower** • Water Distribution System • Trays, and Packing Complete	Water distribution, and trays, packing complete together control the air emissions of particulate matter (drift) and is a specific requirement of FDEP Air Permit Nos. 0990646-001 & 002-AC; PSD-FL-354 & 396.
Fuel / Oil / Chemical Spill Containment / Prevention Systems	**Turbine Lube Oil Storage and Transfer** • Retaining Wall for Spills	Includes items such as storage tank containment dikes and tank liners that provide spill containment/ protection.

Kennard F. Kosky

Kennard F. Kosky, P.E.
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6026 NW 1st Place
Gainesville, Florida 32607
Board of Professional Engineers Certificate of Authorization No: 1670

Date: March 26, 2013

SEAL

WEST COUNTY ENERGY CENTER

Plant Description	Retirement Unit	Property Group Description	Retirement Unit Description	Pollution Control Category	Property Type	Eligible %	Pollution Control tangible_prop_amnt	Pollution Control real_prop_amnt	Total Pollution Control Balance (H + I)	Tangible Prop Reserve Adj for TRI & Pollution Percentage (L x O x J)	Real Prop Reserve Adj for TRI & Pollution Percentage (M x 0 x J)	Total Reserve Adj for TRI & Pollution Percentage (P + Q)	Tangible Property Pollution Ctrl Net Book Adj for TRI (I - P)	Real Property Pollution Ctrl Net Book Adj for TRI (J - Q)	Pollution Ctrl Net Book Adj for TRI (K - R)
WestCountyEC U1	341.501.6020	501 : RAW WATER SUPPLY SYSTEM	501.6020 : CONTROL/INSTRUMENTATION	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.501.6022	501 : RAW WATER SUPPLY SYSTEM	501.6022 : FOUNDATION	Air Emission Control	REAL	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.501.6024	501 : RAW WATER SUPPLY SYSTEM	501.6024 : PIPING	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.501.6025	501 : RAW WATER SUPPLY SYSTEM	501.6025 : PUMP COMPLETE	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.501.6026	501 : RAW WATER SUPPLY SYSTEM	501.6026 : TANK	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.501.6030	501 : RAW WATER SUPPLY SYSTEM	501.6030 : RAW WATER WELL	Air Emission Control	REAL	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.502.6051	502 : WATER TREATMENT SYSTEM	502.6051 : WATER TREATMENT EQUIPMEN	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.502.6053	502 : WATER TREATMENT SYSTEM	502.6053 : PIPING	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.502.6054	502 : WATER TREATMENT SYSTEM	502.6054 : PUMP COMPLETE	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.502.6055	502 : WATER TREATMENT SYSTEM	502.6055 : TANK	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.502.6065	502 : WATER TREATMENT SYSTEM	502.6065 : FOUNDATION	Air Emission Control	REAL	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0143	142 : H.R.S.G. ENCLOSURES	142.0143 : AFTERBURNER	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0151	142 : H.R.S.G. ENCLOSURES	142.0151 : EMISSION MONITORING SYST	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0152	142 : H.R.S.G. ENCLOSURES	142.0152: CEMS-COMPUTER/MICROPR	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0158	142 : H.R.S.G. ENCLOSURES	142.0158 : SCR DUCT	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0159	142 : H.R.S.G. ENCLOSURES	142.0159 : SCR SUPERSTRUCTURE	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0160	142 : H.R.S.G. ENCLOSURES	142.0160 : SCR AMONIA INJEC SYSTEM	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0161	142 : H.R.S.G. ENCLOSURES	142.0161 : SCR CATALYST	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.142.0162	142 : H.R.S.G. ENCLOSURES	142.0162 : SCR TANK	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.145.0265	145 : INDUSTRIAL GAS TURBINE	145.0265 : COMBUSTOR LINER	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.145.0272	145 : INDUSTRIAL GAS TURBINE	145.0272 : COMBUSTOR CAPS	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.145.0274	145 : INDUSTRIAL GAS TURBINE	145.0274 : FLOW SLEEVES	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.434.4812	434 : STACK	434.4812 : CEM-COMPUTER/MICROPROCES	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.438.9496	438 : DEMINERALIZED WATER SYSTEM	438.9496 : CONTROL/INSTRUMENTATION	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.438.9498	438 : DEMINERALIZED WATER SYSTEM	438.9498 : FOUNDATION - Active	Air Emission Control	REAL	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.438.9502	438 : DEMINERALIZED WATER SYSTEM	438.9502 : PUMP COMPLETE	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.438.9508	438 : DEMINERALIZED WATER SYSTEM	438.9508 : TANK	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.832.9271	832 : WATER INJECTION SYSTEM	832.9271 : WATER INJECTION SYSTEM E	Air Emission Control	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U3	341.502.6065	502 : WATER TREATMENT SYSTEM	502.6065 : FOUNDATION	Air Emission Control	REAL	33.30%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U3	343.142.0143	142 : H.R.S.G. ENCLOSURES	142.0143 : AFTERBURNER	Air Emission Control	TANGIBLE	100.00%	$3	$0	$3	$0	$0	$0	$3	$0	$3
WestCountyEC U3	343.142.0151	142 : H.R.S.G. ENCLOSURES	142.0151 : EMISSION MONITORING SYST	Air Emission Control	TANGIBLE	100.00%	$16	$0	$16	$0	$0	$0	$16	$0	$16
WestCountyEC U3	343.142.0158	142 : H.R.S.G. ENCLOSURES	142.0158 : SCR DUCT	Air Emission Control	TANGIBLE	100.00%	$38	$0	$38	$0	$0	$0	$38	$0	$38
WestCountyEC U3	343.142.0159	142 : H.R.S.G. ENCLOSURES	142.0159 : SCR SUPERSTRUCTURE	Air Emission Control	TANGIBLE	100.00%	$9	$0	$9	$0	$0	$0	$9	$0	$9
WestCountyEC U3	343.142.0160	142 : H.R.S.G. ENCLOSURES	142.0160 : SCR AMONIA INJEC SYSTEM	Air Emission Control	TANGIBLE	100.00%	$192	$0	$192	$0	$0	$0	$192	$0	$192
WestCountyEC U3	343.142.0161	142 : H.R.S.G. ENCLOSURES	142.0161 : SCR CATALYST	Air Emission Control	TANGIBLE	100.00%	$9	$0	$9	$0	$0	$0	$9	$0	$9
WestCountyEC U3	343.142.0162	142 : H.R.S.G. ENCLOSURES	142.0162 : SCR TANK	Air Emission Control	TANGIBLE	100.00%	$18	$0	$18	$0	$0	$0	$18	$0	$18
WestCountyEC U3	343.145.0265	145 : INDUSTRIAL GAS TURBINE	145.0265 : COMBUSTOR LINER	Air Emission Control	TANGIBLE	100.00%	$50	$0	$50	$0	$0	$0	$50	$0	$50
WestCountyEC U3	343.145.0272	145 : INDUSTRIAL GAS TURBINE	145.0272 : COMBUSTOR CAPS	Air Emission Control	TANGIBLE	100.00%	$68	$0	$68	$0	$0	$0	$68	$0	$68
WestCountyEC U3	343.145.0274	145 : INDUSTRIAL GAS TURBINE	145.0274 : FLOW SLEEVES	Air Emission Control	TANGIBLE	100.00%	$38	$0	$38	$0	$0	$0	$38	$0	$38
WestCountyEC U3	343.434.4812	434 : STACK	434.4812 : CEM-COMPUTER/MICROPROCES	Air Emission Control	TANGIBLE	100.00%	$83	$0	$83	$0	$0	$0	$83	$0	$83
WestCountyEC U3	343.438.9496	438 : DEMINERALIZED WATER SYSTEM	438.9496 : CONTROL/INSTRUMENTATION	Air Emission Control	TANGIBLE	33.30%	$0	$0	$0	$73	$0	$73	($73)	$0	($73)
WestCountyEC U3	343.438.9498	438 : DEMINERALIZED WATER SYSTEM	438.9498 : FOUNDATION - Active	Air Emission Control	REAL	33.30%	$0	$2	$2	$0	$0	$0	$0	$2	$2
WestCountyEC U3	343.438.9502	438 : DEMINERALIZED WATER SYSTEM	438.9502 : PUMP COMPLETE	Air Emission Control	TANGIBLE	33.30%	$1	$0	$1	$0	$0	$0	$1	$0	$1
WestCountyEC U3	343.438.9508	438 : DEMINERALIZED WATER SYSTEM	438.9508 : TANK	Air Emission Control	TANGIBLE	33.30%	$18	$0	$18	$0	$0	$0	$18	$0	$18
WestCountyEC U3	343.832.9271	832 : WATER INJECTION SYSTEM	832.9271 : WATER INJECTION SYSTEM E	Air Emission Control	TANGIBLE	100.00%	$1	$0	$1	$0	$0	$0	$1	$0	$1
WestCountyEC U1	343.142.0143	142 : H.R.S.G. ENCLOSURES	142.0143 : AFTERBURNER	Air Emission Control	TANGIBLE	100.00%	$92,777	$0	$92,777	$89	$0	$89	$92,687	$0	$92,687
WestCountyEC U2	343.142.0143	142 : H.R.S.G. ENCLOSURES	142.0143 : AFTERBURNER	Air Emission Control	TANGIBLE	100.00%	$34,512	$0	$34,512	$782	$0	$782	$33,729	$0	$33,729
WestCountyEC U1	343.142.0151	142 : H.R.S.G. ENCLOSURES	142.0151 : EMISSION MONITORING SYST	Air Emission Control	TANGIBLE	100.00%	$543,898	$0	$543,898	$524	$0	$524	$543,374	$0	$543,374
WestCountyEC U2	343.142.0151	142 : H.R.S.G. ENCLOSURES	142.0151 : EMISSION MONITORING SYST	Air Emission Control	TANGIBLE	100.00%	$202,322	$0	$202,322	$4,585	$0	$4,585	$197,737	$0	$197,737
WestCountyEC U1	343.142.0152	142 : H.R.S.G. ENCLOSURES	142.0152: CEMS-COMPUTER/MICROPR	Air Emission Control	TANGIBLE	100.00%	$970,156	$0	$970,156	$935	$0	$935	$969,221	$0	$969,221
WestCountyEC U1	343.142.0158	142 : H.R.S.G. ENCLOSURES	142.0158 : SCR DUCT	Air Emission Control	TANGIBLE	100.00%	$1,313,092	$0	$1,313,092	$1,265	$0	$1,265	$1,311,827	$0	$1,311,827
WestCountyEC U2	343.142.0158	142 : H.R.S.G. ENCLOSURES	142.0158 : SCR DUCT	Air Emission Control	TANGIBLE	100.00%	$488,451	$0	$488,451	$11,069	$0	$11,069	$477,382	$0	$477,382
WestCountyEC U1	343.142.0159	142 : H.R.S.G. ENCLOSURES	142.0159 : SCR SUPERSTRUCTURE	Air Emission Control	TANGIBLE	100.00%	$1,226,913	$0	$1,226,913	$1,182	$0	$1,182	$1,225,731	$0	$1,225,731
WestCountyEC U2	343.142.0159	142 : H.R.S.G. ENCLOSURES	142.0159 : SCR SUPERSTRUCTURE	Air Emission Control	TANGIBLE	100.00%	$108,186	$0	$108,186	$2,452	$0	$2,452	$105,734	$0	$105,734
WestCountyEC U1	343.142.0160	142 : H.R.S.G. ENCLOSURES	142.0160 : SCR AMONIA INJEC SYSTEM	Air Emission Control	TANGIBLE	100.00%	$1,226,913	$0	$1,226,913	$1,182	$0	$1,182	$1,225,731	$0	$1,225,731
WestCountyEC U2	343.142.0160	142 : H.R.S.G. ENCLOSURES	142.0160 : SCR AMONIA INJEC SYSTEM	Air Emission Control	TANGIBLE	100.00%	$2,485,191	$0	$2,485,191	$56,318	$0	$56,318	$2,428,873	$0	$2,428,873
WestCountyEC U1	343.142.0161	142 : H.R.S.G. ENCLOSURES	142.0161 : SCR CATALYST	Air Emission Control	TANGIBLE	100.00%	$1,226,913	$0	$1,226,913	$1,182	$0	$1,182	$1,225,731	$0	$1,225,731
WestCountyEC U2	343.142.0161	142 : H.R.S.G. ENCLOSURES	142.0161 : SCR CATALYST	Air Emission Control	TANGIBLE	100.00%	$108,186	$0	$108,186	$2,452	$0	$2,452	$105,734	$0	$105,734
WestCountyEC U1	343.142.0162	142 : H.R.S.G. ENCLOSURES	142.0162 : SCR TANK	Air Emission Control	TANGIBLE	100.00%	$108,659	$0	$108,659	$105	$0	$105	$108,554	$0	$108,554
WestCountyEC U2	343.142.0162	142 : H.R.S.G. ENCLOSURES	142.0162 : SCR TANK	Air Emission Control	TANGIBLE	100.00%	$233,453	$0	$233,453	$5,290	$0	$5,290	$228,162	$0	$228,162
WestCountyEC U1	343.434.4812	434 : STACK	434.4812 : CEM-COMPUTER/MICROPROCES	Air Emission Control	TANGIBLE	100.00%	$2,549,319	$0	$2,549,319	$2,456	$0	$2,456	$2,546,863	$0	$2,546,863
WestCountyEC U2	343.434.4812	434 : STACK	434.4812 : CEM-COMPUTER/MICROPROCES	Air Emission Control	TANGIBLE	100.00%	$3,018,135	$0	$3,018,135	$68,396	$0	$68,396	$2,949,739	$0	$2,949,739
WestCountyEC U1	343.832.9271	832 : WATER INJECTION SYSTEM	832.9271 : WATER INJECTION SYSTEM E	Air Emission Control	TANGIBLE	100.00%	$14,975	$0	$14,975	$14	$0	$14	$14,961	$0	$14,961
WestCountyEC U2	343.832.9271	832 : WATER INJECTION SYSTEM	832.9271 : WATER INJECTION SYSTEM E	Air Emission Control	TANGIBLE	100.00%	$28,088	$0	$28,088	$637	$0	$637	$27,452	$0	$27,452
WestCountyEC U3	343.142.0143	142 : H.R.S.G. ENCLOSURES	142.0143 : AFTERBURNER	Air Emission Control	TANGIBLE	100.00%	$146,313	$0	$146,313	$3,330	$0	$3,330	$142,984	$0	$142,984
WestCountyEC U3	343.142.0151	142 : H.R.S.G. ENCLOSURES	142.0151 : EMISSION MONITORING SYST	Air Emission Control	TANGIBLE	100.00%	$857,754	$0	$857,754	$19,520	$0	$19,520	$838,235	$0	$838,235
WestCountyEC U3	343.142.0158	142 : H.R.S.G. ENCLOSURES	142.0158 : SCR DUCT	Air Emission Control	TANGIBLE	100.00%	$2,070,813	$0	$2,070,813	$47,125	$0	$47,125	$2,023,688	$0	$2,023,688
WestCountyEC U3	343.142.0159	142 : H.R.S.G. ENCLOSURES	142.0159 : SCR SUPERSTRUCTURE	Air Emission Control	TANGIBLE	100.00%	$458,658	$0	$458,658	$10,438	$0	$10,438	$448,220	$0	$448,220
WestCountyEC U3	343.142.0160	142 : H.R.S.G. ENCLOSURES	142.0160 : SCR AMONIA INJEC SYSTEM	Air Emission Control	TANGIBLE	100.00%	$10,536,092	$0	$10,536,092	$239,766	$0	$239,766	$10,296,327	$0	$10,296,327
WestCountyEC U3	343.142.0161	142 : H.R.S.G. ENCLOSURES	142.0161 : SCR CATALYST	Air Emission Control	TANGIBLE	100.00%	$458,658	$0	$458,658	$10,438	$0	$10,438	$448,220	$0	$448,220
WestCountyEC U3	343.142.0162	142 : H.R.S.G. ENCLOSURES	142.0162 : SCR TANK	Air Emission Control	TANGIBLE	100.00%	$989,735	$0	$989,735	$22,523	$0	$22,523	$967,212	$0	$967,212
WestCountyEC U3	343.434.4812	434 : STACK	434.4812 : CEM-COMPUTER/MICROPROCES	Air Emission Control	TANGIBLE	100.00%	$4,508,610	$0	$4,508,610	$102,601	$0	$102,601	$4,406,010	$0	$4,406,010
WestCountyEC U3	343.832.9271	832 : WATER INJECTION SYSTEM	832.9271 : WATER INJECTION SYSTEM E	Air Emission Control	TANGIBLE	100.00%	$41,960	$0	$41,960	$955	$0	$955	$41,005	$0	$41,005
				Air Emission Control Total			$36,049,275	$3	$36,049,278	$617,681	$0	$617,681	$35,431,594	$3	$35,431,597
WestCountyEC U1	343.376.3694	376 : COOLING TOWER	376.3694 : FOUNDATION	Cooling Ponds	REAL	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.376.3704	376 : COOLING TOWER	376.3704 : TRAYS, PACKING COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.376.3705	376 : COOLING TOWER	376.3705 : WATER DISTRIBUTION SYSTE	Cooling Ponds	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.378.3750	378 : COOLING TOWER MAKE-UP SYSTEM	378.3750 : CONTROL/INSTRUMENTATION	Cooling Ponds	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.378.3754	378 : COOLING TOWER MAKE-UP SYSTEM	378.3754 : PIPING	Cooling Ponds	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.378.3755	378 : COOLING TOWER MAKE-UP SYSTEM	378.3755 : PUMP COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U3	343.378.3754	378 : COOLING TOWER MAKE-UP SYSTEM	378.3754 : PIPING	Cooling Ponds	TANGIBLE	100.00%	$176,763	$0	$176,763	$4,023	$0	$4,023	$172,740	$0	$172,740
WestCountyEC U3	343.376.3694	376 : COOLING TOWER	376.3694 : FOUNDATION	Cooling Ponds	REAL	100.00%	$0	$164	$164	$0	$0	$0	$0	$164	$164
WestCountyEC U3	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	$13	$0	$13	$0	$0	$0	$13	$0	$13
WestCountyEC U3	343.376.3704	376 : COOLING TOWER	376.3704 : TRAYS, PACKING COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$93	$0	$93	$0	$0	$0	$93	$0	$93
WestCountyEC U3	343.376.3705	376 : COOLING TOWER	376.3705 : WATER DISTRIBUTION SYSTE	Cooling Ponds	TANGIBLE	100.00%	$838	$0	$838	$0	$0	$0	$838	$0	$838
WestCountyEC U3	343.378.3750	378 : COOLING TOWER MAKE-UP SYSTEM	378.3750 : CONTROL/INSTRUMENTATION	Cooling Ponds	TANGIBLE	100.00%	$3	$0	$3	$0	$0	$0	$3	$0	$3
WestCountyEC U3	343.378.3754	378 : COOLING TOWER MAKE-UP SYSTEM	378.3754 : PIPING	Cooling Ponds	TANGIBLE	100.00%	$58	$0	$58	$0	$0	$0	$58	$0	$58
WestCountyEC U3	343.378.3755	378 : COOLING TOWER MAKE-UP SYSTEM	378.3755 : PUMP COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$10	$0	$10	$0	$0	$0	$10	$0	$10
WestCountyEC U1	343.376.3694	376 : COOLING TOWER	376.3694 : FOUNDATION	Cooling Ponds	REAL	100.00%	$0	$5,097,069	$5,097,069	$0	$4,911	$4,911	$0	$5,092,158	$5,092,158
WestCountyEC U2	343.376.3694	376 : COOLING TOWER	376.3694 : FOUNDATION	Cooling Ponds	REAL	100.00%	$0	$6,034,411	$6,034,411	$0	$136,749	$136,749	$0	$5,897,662	$5,897,662
WestCountyEC Comm	343.376.3699	376 : COOLING TOWER	376.3699 : GEARBOX	Cooling Ponds	TANGIBLE	100.00%	$55,492	$0	$55,492	($18)	$0	($18)	$55,510	$0	$55,510
WestCountyEC U1	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	($11,981)	$0	($11,981)	($92)	$0	($92)	($11,889)	$0	($11,889)
WestCountyEC U1	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	$319,388	$0	$319,388	$308	$0	$308	$319,081	$0	$319,081

WEST COUNTY ENERGY CENTER

Plant Description	Retirement Unit	Property Group Description	Retirement Unit Description	Pollution Control Category	Property Type	Eligible %	Pollution Control tangible_prop_amnt	Pollution Control real_prop_amnt	Total Pollution Control Balance (H + I)	Tangible Prop Reserve Adj for TRI & Pollution Percentage (L x O x J)	Real Prop Reserve Adj for TRI & Pollution Percentage (M x O x J)	Total Reserve Adj for TRI & Pollution Percentage (P + Q)	Tangible Property Pollution Ctrl Net Book Adj for TRI (I - P)	Real Property Pollution Ctrl Net Book Adj for TRI (J - Q)	Pollution Ctrl Net Book Adj for TRI (K - R)
WestCountyEC U2	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	($29,087)	$0	($29,087)	($2,443)	$0	($2,443)	($26,643)	$0	($26,643)
WestCountyEC U2	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	$469,219	$0	$469,219	$10,633	$0	$10,633	$458,586	$0	$458,586
WestCountyEC U1	343.376.3704	376 : COOLING TOWER	376.3704 : TRAYS, PACKING COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$2,885,241	$0	$2,885,241	$2,780	$0	$2,780	$2,882,461	$0	$2,882,461
WestCountyEC U2	343.376.3704	376 : COOLING TOWER	376.3704 : TRAYS, PACKING COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$3,415,832	$0	$3,415,832	$77,408	$0	$77,408	$3,338,424	$0	$3,338,424
WestCountyEC U1	343.376.3705	376 : COOLING TOWER	376.3705 : WATER DISTRIBUTION SYSTE	Cooling Ponds	TANGIBLE	100.00%	$25,967,173	$0	$25,967,173	$25,019	$0	$25,019	$25,942,153	$0	$25,942,153
WestCountyEC U2	343.376.3705	376 : COOLING TOWER	376.3705 : WATER DISTRIBUTION SYSTE	Cooling Ponds	TANGIBLE	100.00%	$30,684,325	$0	$30,684,325	$695,355	$0	$695,355	$29,988,970	$0	$29,988,970
WestCountyEC U1	343.378.3750	378 : COOLING TOWER MAKE-UP SYSTEM	378.3750 : CONTROL/INSTRUMENTATION	Cooling Ponds	TANGIBLE	100.00%	$83,237	$0	$83,237	$80	$0	$80	$83,157	$0	$83,157
WestCountyEC U2	343.378.3750	378 : COOLING TOWER MAKE-UP SYSTEM	378.3750 : CONTROL/INSTRUMENTATION	Cooling Ponds	TANGIBLE	100.00%	$106,010	$0	$106,010	$2,402	$0	$2,402	$103,608	$0	$103,608
WestCountyEC U1	343.378.3754	378 : COOLING TOWER MAKE-UP SYSTEM	378.3754 : PIPING	Cooling Ponds	TANGIBLE	100.00%	$1,786,961	$0	$1,786,961	$1,722	$0	$1,722	$1,785,239	$0	$1,785,239
WestCountyEC U2	343.378.3754	378 : COOLING TOWER MAKE-UP SYSTEM	378.3754 : PIPING	Cooling Ponds	TANGIBLE	100.00%	$2,115,736	$0	$2,115,736	$47,946	$0	$47,946	$2,067,790	$0	$2,067,790
WestCountyEC U1	343.378.3755	378 : COOLING TOWER MAKE-UP SYSTEM	378.3755 : PUMP COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$315,034	$0	$315,034	$304	$0	$304	$314,731	$0	$314,731
WestCountyEC U2	343.378.3755	378 : COOLING TOWER MAKE-UP SYSTEM	378.3755 : PUMP COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$372,968	$0	$372,968	$8,452	$0	$8,452	$364,516	$0	$364,516
WestCountyEC U3	343.376.3694	376 : COOLING TOWER	376.3694 : FOUNDATION	Cooling Ponds	REAL	100.00%	$0	$9,014,444	$9,014,444	$0	$205,138	$205,138	$0	$8,809,306	$8,809,306
WestCountyEC U3	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	$25,683	$0	$25,683	$584	$0	$584	$25,099	$0	$25,099
WestCountyEC U3	343.376.3702	376 : COOLING TOWER	376.3702 : SUPERSTRUCTURE	Cooling Ponds	TANGIBLE	100.00%	$700,938	$0	$700,938	$15,951	$0	$15,951	$684,987	$0	$684,987
WestCountyEC U3	343.376.3704	376 : COOLING TOWER	376.3704 : TRAYS, PACKING COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$5,102,707	$0	$5,102,707	$116,120	$0	$116,120	$4,986,588	$0	$4,986,588
WestCountyEC U3	343.376.3705	376 : COOLING TOWER	376.3705 : WATER DISTRIBUTION SYSTE	Cooling Ponds	TANGIBLE	100.00%	$45,837,471	$0	$45,837,471	$1,043,106	$0	$1,043,106	$44,794,365	$0	$44,794,365
WestCountyEC U3	343.378.3750	378 : COOLING TOWER MAKE-UP SYSTEM	378.3750 : CONTROL/INSTRUMENTATION	Cooling Ponds	TANGIBLE	100.00%	$158,363	$0	$158,363	$3,604	$0	$3,604	$154,759	$0	$154,759
WestCountyEC U3	343.378.3754	378 : COOLING TOWER MAKE-UP SYSTEM	378.3754 : PIPING	Cooling Ponds	TANGIBLE	100.00%	$3,160,571	$0	$3,160,571	$71,924	$0	$71,924	$3,088,647	$0	$3,088,647
WestCountyEC U3	343.378.3755	378 : COOLING TOWER MAKE-UP SYSTEM	378.3755 : PUMP COMPLETE	Cooling Ponds	TANGIBLE	100.00%	$557,155	$0	$557,155	$12,679	$0	$12,679	$544,476	$0	$544,476
				Cooling Ponds Total			$124,256,215	$20,146,088	$144,402,303	$2,137,847	$346,799	$2,484,645	$122,118,368	$19,799,290	$141,917,658
WestCountyEC U1	343.472.5697	472 : TURBINE LUBE OIL STORAGE & TR	472.5697 : RETAINING WALL	Fuel Oil or Chemical Spills	REAL	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U3	343.472.5697	472 : TURBINE LUBE OIL STORAGE & TR	472.5697 : RETAINING WALL	Fuel Oil or Chemical Spills	REAL	100.00%	$0	$12	$12	$0	$251	$251	$0	($239)	($239)
WestCountyEC U1	343.472.5697	472 : TURBINE LUBE OIL STORAGE & TR	472.5697 : RETAINING WALL	Fuel Oil or Chemical Spills	REAL	100.00%	$0	$379,742	$379,742	$0	$366	$366	$0	$379,376	$379,376
WestCountyEC U2	343.472.5697	472 : TURBINE LUBE OIL STORAGE & TR	472.5697 : RETAINING WALL	Fuel Oil or Chemical Spills	REAL	100.00%	$0	$449,575	$449,575	$0	$10,188	$10,188	$0	$439,387	$439,387
WestCountyEC U3	343.472.5697	472 : TURBINE LUBE OIL STORAGE & TR	472.5697 : RETAINING WALL	Fuel Oil or Chemical Spills	REAL	100.00%	$0	$671,594	$671,594	$0	$15,283	$15,283	$0	$656,310	$656,310
				Fuel Oil or Chemical Spills Total			$0	$1,500,922	$1,500,922	$0	$26,088	$26,088	$0	$1,474,835	$1,474,835
WestCountyEC Comm	341.301.1954	301 : A BUILDING	301.1954 : CONDENSER/COMPRESSOR	No Basis	REAL	0.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.386.6166	386 : AA BUILDING	386.6166 : SUPERSTRUCTURE	No Basis	REAL	0.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.386.6168	386 : AA BUILDING	386.6168 : ROOF	No Basis	REAL	0.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.386.6188	386 : AA BUILDING	386.6188 : SUBSTRUCTURE/FOUNDATION	No Basis	REAL	0.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U3	341.350.3110	350 : MISCELLANEOUS BUILDINGS-PRODU	350.3110 : BUILDING/SHELTER, COMPLE	No Basis	REAL	0.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
				No Basis Total			$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.143.0194	143 : H.R.S.G. PRESSURE PARTS	143.0194 : SILENCER/MUFFLER	Noise Abatement Equipment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	343.145.0264	145 : INDUSTRIAL GAS TURBINE	145.0264 : ACOUSTICAL ENCLOSURE	Noise Abatement Equipment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U3	343.143.0194	143 : H.R.S.G. PRESSURE PARTS	143.0194 : SILENCER/MUFFLER	Noise Abatement Equipment	TANGIBLE	100.00%	$10	$0	$10	$0	$0	$0	$10	$0	$10
WestCountyEC U3	343.145.0264	145 : INDUSTRIAL GAS TURBINE	145.0264 : ACOUSTICAL ENCLOSURE	Noise Abatement Equipment	TANGIBLE	100.00%	$16	$0	$16	$0	$0	$0	$16	$0	$16
WestCountyEC U1	343.143.0194	143 : H.R.S.G. PRESSURE PARTS	143.0194 : SILENCER/MUFFLER	Noise Abatement Equipment	TANGIBLE	100.00%	$293,899	$0	$293,899	$283	$0	$283	$293,616	$0	$293,616
WestCountyEC U2	343.143.0194	143 : H.R.S.G. PRESSURE PARTS	143.0194 : SILENCER/MUFFLER	Noise Abatement Equipment	TANGIBLE	100.00%	$109,326	$0	$109,326	$2,478	$0	$2,478	$106,849	$0	$106,849
WestCountyEC U1	343.145.0264	145 : INDUSTRIAL GAS TURBINE	145.0264 : ACOUSTICAL ENCLOSURE	Noise Abatement Equipment	TANGIBLE	100.00%	$788,124	$0	$788,124	$759	$0	$759	$787,365	$0	$787,365
WestCountyEC U2	343.145.0264	145 : INDUSTRIAL GAS TURBINE	145.0264 : ACOUSTICAL ENCLOSURE	Noise Abatement Equipment	TANGIBLE	100.00%	$1,005,891	$0	$1,005,891	$22,795	$0	$22,795	$983,096	$0	$983,096
WestCountyEC U3	343.143.0194	143 : H.R.S.G. PRESSURE PARTS	143.0194 : SILENCER/MUFFLER	Noise Abatement Equipment	TANGIBLE	100.00%	$550,507	$0	$550,507	$12,528	$0	$12,528	$537,979	$0	$537,979
WestCountyEC U3	343.145.0264	145 : INDUSTRIAL GAS TURBINE	145.0264 : ACOUSTICAL ENCLOSURE	Noise Abatement Equipment	TANGIBLE	100.00%	$851,327	$0	$851,327	$19,373	$0	$19,373	$831,953	$0	$831,953
				Noise Abatement Equipment Total			$3,599,100	$0	$3,599,100	$58,216	$0	$58,216	$3,540,884	$0	$3,540,884
WestCountyEC U1	342.234.0862	234 : WASTE OIL STORAGE SYSTEM	234.0862 : PUMP COMPLETE	Waste Oil Storage System	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
				Waste Oil Storage System Total			$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC Comm	341.504.6091	504 : WASTE WATER TREATMENT SYSTEM	504.6091 : PUMP COMPLETE	Waste Water Treatment	TANGIBLE	100.00%	$21,957	$0	$21,957	$204	$0	$204	$21,753	$0	$21,753
WestCountyEC U1	341.210.1191	210 : PONDS (NOT COOLING)	210.1191 : PIPING, ALL	Waste Water Treatment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.210.1193	210 : PONDS (NOT COOLING)	210.1193 : WATER MONITORING WELL	Waste Water Treatment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.210.1201	210 : PONDS (NOT COOLING)	210.1201 : POND	Waste Water Treatment	REAL	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.504.6086	504 : WASTE WATER TREATMENT SYSTEM	504.6086 : CONTROL/INSTRUMENTATION	Waste Water Treatment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.504.6088	504 : WASTE WATER TREATMENT SYSTEM	504.6088 : FOUNDATION	Waste Water Treatment	REAL	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.504.6090	504 : WASTE WATER TREATMENT SYSTEM	504.6090 : PIPING	Waste Water Treatment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.504.6091	504 : WASTE WATER TREATMENT SYSTEM	504.6091 : PUMP COMPLETE	Waste Water Treatment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.504.6092	504 : WASTE WATER TREATMENT SYSTEM	504.6092 : TANK	Waste Water Treatment	TANGIBLE	100.00%	$0	$0	$0	$0	$0	$0	$0	$0	$0
WestCountyEC U1	341.210.1191	210 : PONDS (NOT COOLING)	210.1191 : PIPING, ALL	Waste Water Treatment	TANGIBLE	100.00%	$34,753	$0	$34,753	$2,263	$0	$2,263	$32,490	$0	$32,490
WestCountyEC U1	341.210.1193	210 : PONDS (NOT COOLING)	210.1193 : WATER MONITORING WELL	Waste Water Treatment	TANGIBLE	100.00%	$2,995,602	$0	$2,995,602	$195,073	$0	$195,073	$2,800,529	$0	$2,800,529
WestCountyEC U1	341.210.1201	210 : PONDS (NOT COOLING)	210.1201 : POND	Waste Water Treatment	REAL	100.00%	$0	$1,222,999	$1,222,999	$0	$79,641	$79,641	$0	$1,143,358	$1,143,358
WestCountyEC U1	341.504.6086	504 : WASTE WATER TREATMENT SYSTEM	504.6086 : CONTROL/INSTRUMENTATION	Waste Water Treatment	TANGIBLE	100.00%	$130,267	$0	$130,267	$8,483	$0	$8,483	$121,784	$0	$121,784
WestCountyEC U1	341.504.6088	504 : WASTE WATER TREATMENT SYSTEM	504.6088 : FOUNDATION	Waste Water Treatment	REAL	100.00%	$0	$861,189	$861,189	$0	$56,080	$56,080	$0	$805,109	$805,109
WestCountyEC U1	341.504.6090	504 : WASTE WATER TREATMENT SYSTEM	504.6090 : PIPING	Waste Water Treatment	TANGIBLE	100.00%	$3,236,324	$0	$3,236,324	$210,749	$0	$210,749	$3,025,575	$0	$3,025,575
WestCountyEC U1	341.504.6091	504 : WASTE WATER TREATMENT SYSTEM	504.6091 : PUMP COMPLETE	Waste Water Treatment	TANGIBLE	100.00%	($68,561)	$0	($68,561)	($4,465)	$0	($4,465)	($64,096)	$0	($64,096)
WestCountyEC U1	341.504.6091	504 : WASTE WATER TREATMENT SYSTEM	504.6091 : PUMP COMPLETE	Waste Water Treatment	TANGIBLE	100.00%	$889,338	$0	$889,338	$57,913	$0	$57,913	$831,424	$0	$831,424
WestCountyEC U1	341.504.6092	504 : WASTE WATER TREATMENT SYSTEM	504.6092 : TANK	Waste Water Treatment	TANGIBLE	100.00%	$1,034,604	$0	$1,034,604	$67,373	$0	$67,373	$967,231	$0	$967,231
				Waste Water Treatment Total			$8,274,284	$2,084,188	$10,358,473	$537,594	$135,722	$673,316	$7,736,690	$1,948,466	$9,685,157
				Grand Total			$172,178,875	$23,731,202	$195,910,077	$3,351,338	$508,608	$3,859,946	$168,827,537	$23,222,594	$192,050,131
				LESS: DISALLOWED PORTIONS OF COOLING PONDS			$10,362,536	$20,146,088	$30,508,624	$178,058	$346,799	$524,857	$10,184,478	$19,799,290	$29,983,767
				POLLUTION CONTROL REPORTED ON DR-405			$161,816,339	$3,585,114	$165,401,453	$3,173,280	$161,810	$3,335,090	$158,643,059	$3,423,304	$162,066,363

ZEECO BURNER DIVISION

Low NOx Duct Burners
DB Series

22151 EAST 91ST STREET · BROKEN ARROW OK 74014 USA · 918-258-8551 · SALES@ZEECO.COM · ZEECO.COM

INTRODUCTION:

The DB series addresses many of the problems normally associated with duct burner type applications. Zeeco uses a "zone analysis type approach" to determine the duct burner inlet conditions in different sections of grid layout. Then by adjusting the amount of open area in the duct burner wing section in the particular zones, the emissions and flame heat pattern can be better predicted and controlled. A summary of the DB advantages are listed as follows:

1. Reduces the effects of uneven TEG/ airflow.

2. Produces less NOx emissons.

3. Produces less CO emissions.

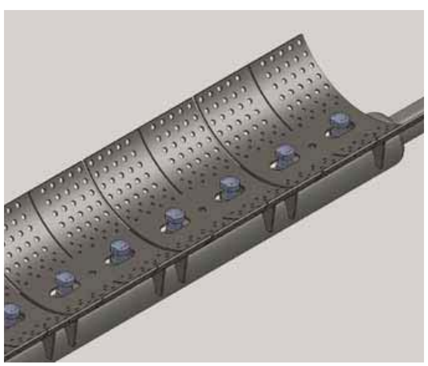
4. Produces less UHC emissions.

5. Produces less Particulate emissions.

6. Provides a more even heat distribution.

The Zeeco Series DB Duct Burner is designed to be compatible with all turbine configurations and heat recovery systems. These reliable burners are available for gas only, oil only, or combination gas and oil firing. Gas burners consist of one or more linear runner type assemblies. Burner runners can be mounted either vertically or horizontally. Oil is fired transversely in a self-contained system. All fuel firing assemblies are mounted inside an insulated ductwork section.

This paper will describe in more detail the DB series design philosophy and advantages.



DESIGN FEATURES

Flame Length

Zeeco duct burners produce an evenly distributed flame pattern. The DB series burners can be designed for a wide range of fuels and heat release duties per linear foot of length. However, for most applications the flame lengths are in the 4 to 6 feet range depending upon the conditions.

Gas Firing

Gas assemblies are constructed with specially designed gas tips and flame holders to provide uniform heat release cross the duct and minimize emissions of NOx, CO, and Unburned Hydrocarbons. All materials of construction are high alloy metal for long life and superior performance.

Turndown

The Zeeco Series DB duct burner will achieve standard turndown ratios greater than 10:1 for gas. Higher turndowns can be achieved in certain applications.

Ignition

Zeeco duct burners are designed for ignition with the Zeeco AR/GS forced draft pilot. In addition, a Flame Front Generator (FFG) or a Zeeco S.E.T. high-energy electric igniter can also be used for ignition. Systems can be designed with either one pilot runner to light all runners or with individual pilots on each runner.

Maintenance

Zeeco duct burners are designed for minimal maintenance. Gas runners and oil guns can be easily removed from the ducting for cleaning or repair.

Fuels

Zeeco duct burners operate on a wide range of fuels including: natural gas, unsaturated hydrocarbons, plant gas, hydrogen, low Btu gases, propane, butane, pentane and LPG mixtures.

Construction

Zeeco duct burners are built for durability, reliability and low maintenance. Each burner is constructed of materials which resist warpage and fuel coking when exposed to direct flames and radiation.

DUCT BURNER CONTROL SYSTEMS

Zeeco can provide a duct burner management system to meet any safety and operational requirements necessary.

All control systems are designed to interface with existing plant computer control systems. Systems are either relay or PLC based and can be designed to meet IRI, NFPA-85, FM, CSA or other special requirements.

CFD FLOW ANALYSIS

CFD Analysis can be used for many different reasons for duct burner applications:

1. Flow Distribution of TEG or Air before duct burner runners

2. Temperature distribution after duct burner runners.

In addition, a more in depth use of CFD modeling is the "zone analysis type approach" that is used to first determine the inlet conditions to the duct burner in each section of a grid layout of the duct. The flow into each section of the grid is determined by modeling. Based upon the results of the modeling in each section of the grid, the open area in the duct burner wing design can be adjusted for the flow conditions for the particular zone of the grid.

The benefits of the zone analysis type approach are as follows:

1. Lower thermal NOx production

2. Lower CO production

3. Lower UHC production

4. Lower VOC production

5. Lower Particulate production

6. Better exit temperature profile

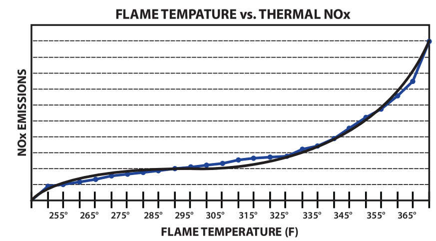
NOx EMISSIONS

Thermal NOx

For gaseous fuels with no fuel bound nitrogen, thermal NOx is the primary mechanism of NOx production. Thermal NOx is produced when the flame temperature reaches a high enough level to "break" the covalent N_2 bond apart and the "free" nitrogen atoms bond with oxygen to form NOx.

Methane & Air with Excess Air

$$2CH_4 + 4(XA)O_2 + 15(XR)N_2 \longrightarrow 2CO_2 + 4H_2O + (XA)15N_2 + (XR)O_2$$



Combustion air is comprised of 21% O_2 and 79% N_2. Combustion occurs when the O_2 reacts and is combined with the fuel (typically hydrocarbon). However, the temperature of combustion is normally not great enough to break all of the N_2 bonds, so most of the nitrogen in the air stream passes through the combustion process and remains as diatomic nitrogen (N_2) in the combustion products. Some of the N_2 does reach high enough temperatures in the high intensity regions of the flame to break apart and form "free" nitrogen. Once the covalent nitrogen bond is broken, the "free" nitrogen is available to bond with other atoms. The free nitrogen, or nitrogen radicals, will react with any other atoms or molecules suitable for reaction. Of the prospects in the products of combustion, free nitrogen will most likely react with other free nitrogen to form N_2. However, if another free nitrogen atom is not available, the free nitrogen and oxygen atoms will react to form NOx. As the flame temperature increases, the stability of the N_2 covalent bond decreases allowing the formation of more and more free nitrogen and subsequently increased thermal NOx. Burner designers can reduce NOx emissions by reducing the peak flame temperature which in turn reduces the formation of free nitrogen available to form NOx.

The varied requirements of refining and petrochemical processes require the use of numerous types and configurations of burners. The method utilized to lower NOx emissions can differ from application to application. However, thermal NOx reduction is generally achieved by delaying the rate of combustion. Since the combustion process is a reaction between oxygen and a fuel, the objective of delayed combustion is to reduce the rate at which the fuel and oxygen mix together and burn. The faster the oxygen and the fuel gas mix together, the faster the rate of combustion and the higher the peak flame temperature.

The table above plots Adiabatic Flame Temperature vs. Thermal NOx. As you can see, NOx emissions increase as the adiabatic flame temperature increases. Slowing the combustion reaction allows the flame temperature to be reduced, and as the flame temperature is reduced, so are the thermal NOx emissions.

ZONE ANALYSIS

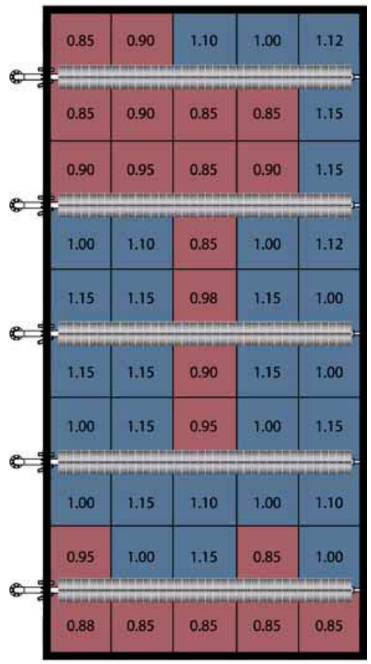
Zeeco uses a "zone analysis type approach" to determine the duct burner inlet conditions in different sections of grid layout. Then by adjusting the amount of open area in the duct burner wing section in the particular zones, the emissions and flame heat pattern can be better predicted and controlled. A summary of the DB advantages are listed as follows:

1. *Reduces the effects of uneven TEG/ airflow.*
2. *Produces less NOx emissons.*
3. *Produces less CO emissions.*
4. *Produces less UHC emissions.*
5. *Produces less Particulate emissions.*
6. *Provides a more even heat distribution.*

The "zone analysis type approach" is used to first determine the inlet conditions to the duct burner in each section of a grid layout of the duct. The flow into each section of the grid is determined by CFD modeling. Based upon the results of the modeling in each section of the grid, the open area in the duct burner wing design can be adjusted for the flow conditions for the particular zone of the grid.

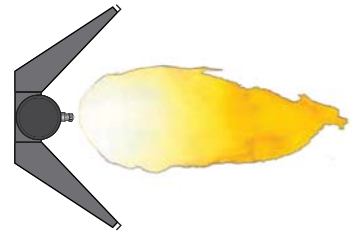
Zone analysis is very important to the successful design of a duct burner system since variances in the flow in different sections of the duct can cause changes in flame length and emissions.

Since NOx production can increase significantly with increased temperature and CO, Particulate, VOC & UHC can increase even more significantly with decreased temperature, it is very important for emissions to have the temperature exiting each of the zones within a range so the emissions can be controlled. Emissions can be controlled by adjusting the amount of open area in the duct burner wing section in the particular zones based upon the flow in each section to create more uniform emissions and flame characteristics.



Above is an example of flow distribution zones in a duct burner section with plus or minus 15% flow. If the duct was provided with uniform distribution all of the sections would be listed as 1.00. Sections which are listed as 0.85 have 15% less flow than the average and sections with 1.15 have 15% more than the average. The areas shown in red have less than average flow and the areas shown in blue have average flow or greater. In general, the red sections will produce greater NOx emissions and longer flames. The blue sections will produce shorter lames and increased CO, UHC, VOC and particulate emissions. Since our wings are manufactured in house, we can change the amount of open area in problem sections and drillings to tailor the duct system for each application.

TEG THAT DOES NOT TAKE PLACE IN COMBUSTION PROCESS



Since only the flow approximately 1 foot (305 mm) on each side of the wing takes part in the combustion process, it is very important to look at each job with a Zone Analysis type approach.

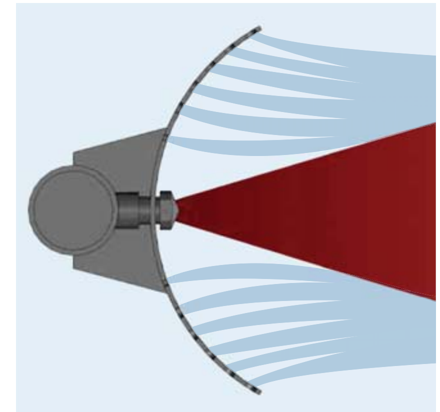
A) For applications with low excess oxygen in the TEG stream, the width of the wing can increase and the open area in the wing increased to increase the peak flame temperature.

B) For applications with high excess oxygen, the width of the wing can be decreased and the open area of the wing reduced to decrease the peak flame temperature.

DB LOW NOx EMISSIONS

Stringent environmental regulations have prompted the development of low emission duct burners for use in turbine exhaust systems. Zeeco, Inc. has addressed this critical environmental issue by redesigning their duct burner element to greatly reduce the NOx, CO and Unburned Hydrocarbons that may be produced. The DB-LN Low Emissions duct burners uses the basic "Free-Jet" mixing concept to combine the inert products of combustion with the fuel gas before combustion occurs to form new fuel composition that produces less thermal NOx emissions. The DB-LN design meets NOx emissions of 0.06 #/MM Btu (LHV) and 0.04# CO emissions for most typical applications.

The DB-LN Duct Burner design is specially designed for each application to allow for the correct flow of TEG/combustion air flow into the primary combustion zone to achieve both low CO and low NOx emissions.



The gas (shown in red) is ejected into the wing area of the duct burner and mixes with the TEG / combustion air flow via "free-jet' mixing method to produce very low emissions. The amount of TEG / combustion air flow into the primary combustion zone is controlled on each job by the amount of open area in the wing.

For applications with very low oxygen content in the TEG steam, more TEG / air mixture is allowed into the duct burner wing to ensure proper mixing for low NOx and especially low CO. For applications with higher oxygen content in the TEG stream, less of the TEG / air mixture is allowed into the duct burner wing section in order to achieve low CO and especially low NOx emissions.

Carbon Monoxide (CO)

Carbon monoxide is the result of incomplete combustion. Almost every combustion process produces trace amounts of CO. To minimize the production of CO, most combustion processes take place with more air than is required for stoichiometric combustion and the temperature of combustion should be above the minimum temperature of combustion of a specific fuel. In general, the higher the temperature, the production of CO is increasingly reduced if burned with sufficient combustion air. Because carbon monoxide is a toxic gas, it is strictly regulated.

Carbon Dioxide (CO2)

Carbon dioxide is a colorless, odorless gas that is produced by natural sources and as a product of combustion. Increasing CO2 concentrations in the atmosphere are believed to contribute to the greenhouse warming effect.

Particulate matter as defined here is a product of incomplete combustion. Particulate matter is most often produced when firing heavy fuel oils or when liquids are present in a fuel gas stream. The US Environmental Protection Agency defines particulate matter as follows:

<u>EPA 40 CFR Part 51.100 Definitions:</u>
(oo) *Particulate matter* means any airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 micrometers.

(pp) *Particulate matter emissions* means all finely divided solid or liquid material, other than uncombined water, emitted to the ambient air as measured by applicable reference methods or an equivalent or alternative method, specified in this chapter, or by a test method specified in an approved State implementation plan.

(qq) *PM*10 means particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers as measured by a reference method based on appendix J of part 50 of this chapter and designated in accordance with part 53 of this chapter or by an equivalent method designated in accordance with part 53 of this chapter.

(rr) *PM*10 emissions means finely divided solid or liquid material, with an aerodynamic diameter less than or equal to a nominal 10 micrometers emitted to the ambient air as measured by an applicable reference method, or an equivalent or alternative method, specified in this chapter or by a test method specified in an approved State implementation plan.

(ss) *Total suspended* particulate means particulate matter as measured by the method described in appendix B of part 50 of this chapter.

To minimize the production of Particulates, most combustion processes take place with more air than is required for stoichiometric combustion and the temperature of combustion should be above the minimum temperature of combustion of a specific fuel. In general, the higher the temperature, the production of Particulates is increasingly reduced if burned with sufficient combustion air.

Unburned Hydrocarbons (UHCs) and Volatile Organic Compounds (VOCs)

Unburned hydrocarbons and volatile organic compounds include a variety of low molecular weight hydrocarbons produced as a result of incomplete combustion. Their release contributes to smog and ozone depletion.

To minimize the production of UHC & VOC, most combustion processes take place with more air than is required for stoichiometric combustion and the temperature of combustion should be above the minimum temperature of combustion of a specific fuel. In general, the higher the temperature, the production of UHC & VOC is increasingly reduced if burned with sufficient combustion air.

Sulfur Oxides (SOx)

Sulfur oxides are a family of gases that can react with NOx and other chemicals in the air to form acid rain. Oxides of sulfur are produced during the combustion process when fuel sources containing sulfur compounds are burned. Because SOx formation is dependent on the amount of sulfur in the fuel and the equilibrium conditions inside the furnace, it is not a function of the burner design. As a result, SOx levels are not guaranteed by the burner manufacturer.

SUMMARY

Zeeco equipment is designed to provide the best performance for the best value for your applications. To learn more about Zeeco products and services, you may contact the following locations:

Head Quarters:
Zeeco, Inc.
22151 East 91st Street
Broken Arrow, Oklahoma 74014
United States of America
Phone: 918-258-8551
Fax: 918-251-5519
sales@zeeco.com
www.zeeco.com

Additional Offices:
Zeeco – Houston, Texas
Zeeco – Korea
Zeeco – Europe

Zeeco Test facility located at Broken Arrow Oklahoma.

Duct Burner Test Rig at Zeeco. The simulated TEG is cooled by a running the TEG through a boiler to control the TEG inlet temperature to the duct runner at the correct temperature.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEDERAL ENERGY MANAGEMENT PROGRAM

Cooling Towers: Understanding Key Components of Cooling Towers and How to Improve Water Efficiency

Source: Paul Johnston-Knight

Introduction

Federal laws and regulations require Federal agencies to reduce water use and improve water efficiency. Namely, Executive Order 13514 *Federal Leadership in Environmental, Energy, and Economic Performance*, requires an annual two percent reduction of water use intensity (water use per square foot of building space) for agency potable water consumption as well as a two percent reduction of water use for industrial, landscaping, and agricultural applications. Cooling towers can be a significant source of water use for both of these categories of water use at Federal facilities. To realize potential savings it is essential for Federal agencies understand the key components of cooling towers and how to improve water efficiency of the system as a part of a comprehensive approach to water management.

In this Fact Sheet:

Overview

Cooling towers are an integral component of many refrigeration systems, providing comfort or process cooling across a broad range of applications. They are the point in the system where heat is dissipated to the atmosphere through the evaporative process, and are common in industries such as oil refining, chemical processing, power plants, steel mills, and many different manufacturing processes where process cooling is required. They are also commonly used to provide comfort cooling for large commercial buildings including airports, office buildings, conference centers, hospitals, and hotels.

Cooling tower structures vary greatly in size and design, but they all function to provide the same thing: liberation of waste heat extracted from a process or building system through evaporation of water. In technical terms, cooling towers are engineered and designed based on a specified cooling load, expressed in refrigeration tons.[1] The cooling load is determined by the amount of heat that needs to be extracted from a given process or peak comfort cooling demand. The cooling tower must be adequately sized to reject this same amount of heat to the atmosphere.

Cooling towers are used to reject heat through the natural process of evaporation. Warm recirculating water is sent to the cooling tower where a portion of the water is evaporated into the air passing through the tower. As the water evaporates, the air absorbs heat, which lowers the temperature of the remaining water. This process provides significant cooling to the remaining water stream that collects in the tower basin where it can be pumped back into the system to extract more process or building heat, thereby allowing much of the water to be used repeatedly to meet the cooling demand.

The amount of heat that can be rejected from the water to the air is directly tied to the relative humidity of the air. Air with a lower relative humidity has a greater ability to absorb water through evaporation than air with a higher relative humidity, simply because there is less water in the air. As an example, consider cooling towers in two different locations– one in Atlanta, Georgia, and another in Albuquerque, New Mexico. The ambient air temperature at these two locations may be similar, but the relative humidity in Albuquerque on average will be much lower than that of Atlanta's. Therefore, the cooling tower in Albuquerque will be able to extract more process or building heat and will run at a cooler temperature because the dry desert air has a greater capacity to absorb the warm water.

Cooling towers can be split into two distinct categories: open circuit (direct contact) and closed circuit (indirect) systems. In open circuit systems the recirculating water returns to the tower after

(1) One ton of refrigeration is equal to 12,000 Btu/hour.

continued >

gathering heat and is distributed across the tower where the water is in direct contact with the atmosphere as it recirculates across the tower structure. Closed circuit systems differ in that the return fluid (often water, or sometimes water mixed with glycol) circulates through the tower structure in a coil, while cooling tower water recirculates only in the tower structure itself (see Figure 1). In this case, the return fluid is not exposed directly to the air.

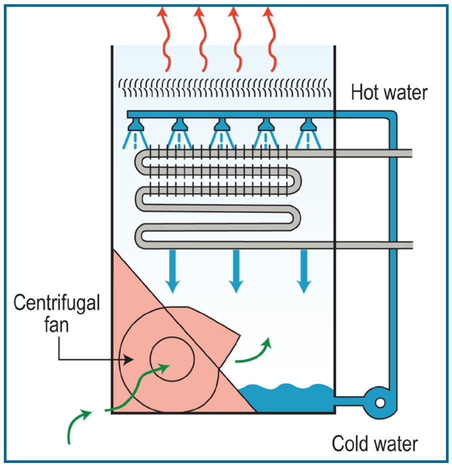


Figure 1. Example of a Closed Circuit Cooling Tower.

Structure

Cooling towers are the primary component used to exhaust heat in open recirculating cooling systems. They are designed to maximize air and water contact to provide as much evaporation as possible. This is accomplished by maximizing the surface area of the water as it flows over and down through the tower structure. Figure 2 illustrates the different components of a cooling tower structure.

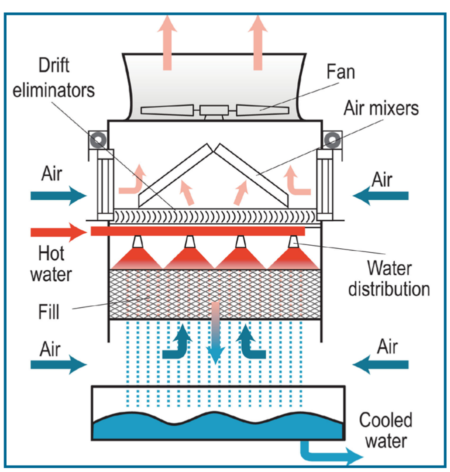


Figure 2. Overview of Cooling Tower Structure Components.

First, the water is distributed evenly across the top of the cooling tower structure. Tower distribution decks can be a series of spray nozzles oriented up or down (like a landscaping sprinkler system) to uniformly distribute the water over the tower structure. In some cases, the distribution deck may just be a series of holes through which the water falls onto the tower structure. Regardless the distribution deck must uniformly apportion the recirculating water across the tower structure. Broken nozzles or plugged orifices will impede uniform distribution across the tower structure, negatively impacting the overall heat exchange capacity of the system.

As the water falls from the distribution deck, the surface area is further expanded in the fill section. Older tower systems may feature splash bars made of plastic, fiberglass, or wood that serve to break the falling water into tiny droplets. In recent years, many different forms of labyrinth-like packing or film fill have been incorporated. The closely packed nature of film fill causes the water to travel through this portion of the tower in thin streams, improving thermal efficiency and the evaporation rate, thereby increasing heat rejection (see Figure 3).

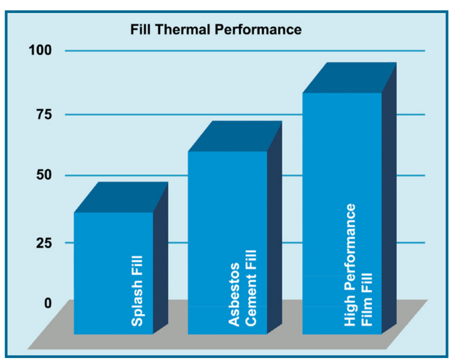


Figure 3. Relative Thermal Performance of Different Types of Fill.

There are several variations of film fill geometries commercially available, and though they do greatly increase the heat rejection rate over splash-type fills, they are also much more susceptible to fouling, scaling, and microbiological growth (these are discussed in greater detail in the System Concerns section). Development of any of these problems greatly reduces the cooling efficiency and in severe cases can collapse portions of the tower fill or tower structure. To avoid this, film fill should be inspected routinely to ensure it is clean and free of debris, scale, and biological activity.

To minimize losses due to drift and help direct airflow into the tower, louvers and drift eliminators are commonly used. Louvers are most often seen along the sides of the tower structure, while drift eliminators reside in the top section of the tower to capture entrained water droplets that may otherwise leave through the stack. Damaged or incorrectly oriented louvers along with damaged drift eliminators will lead to excessive losses due to drift from the tower structure. Therefore, louvers and drift eliminator sections should be routinely inspected and repaired to ensure optimal water usage.

After the water passes through the fill it cascades down to a collection basin at the base of the tower structure. From the basin the cold water can be pumped back into the system to extract process or comfort cooling needs and begin the cycle all over again.

By design, cooling towers consume large volumes of water through the evaporation process to maintain comfort cooling or process cooling needs, although they use significantly less water than similar capacity once-through cooling systems. Because the evaporative loss is water containing little to no dissolved solids, the water remaining in the cooling tower becomes concentrated with dissolved solids, which can lead to scaling and corrosive conditions. To combat these problems, water with high total dissolved solid content must be drained from the system via "blowdown." The associated losses caused by blowdown, evaporation, drift, and system leaks must be accounted for by system make-up requirements. Figure 4 illustrates these water system flow locations in generic terms.

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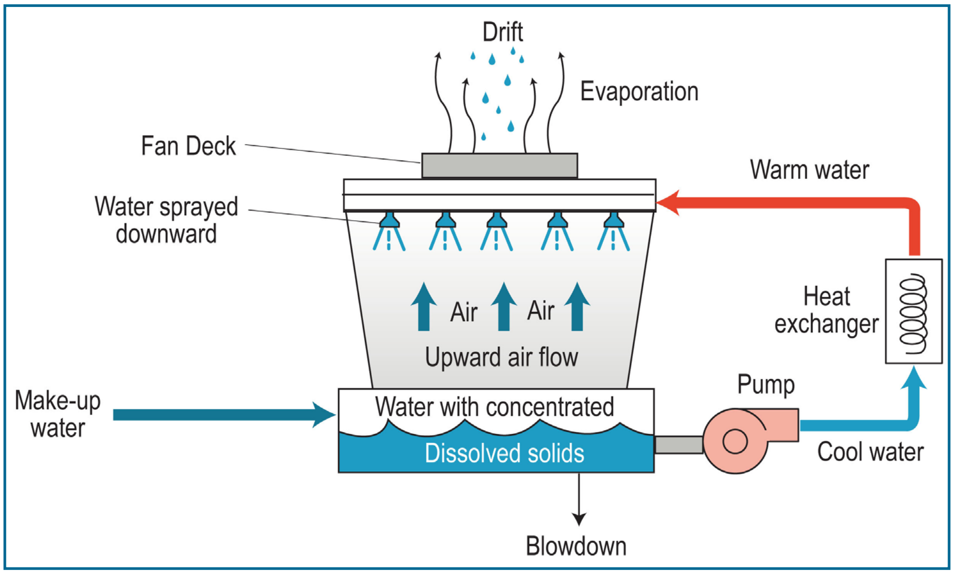

Figure 4. Illustration of Water Flow Across a Cooling Tower.

Basic Cooling Tower Terms

Blowdown – Water discharged to remove high mineral content system water, impurities, and sediment.

Cycles of Concentration – Technical term used to describe the mass flow relationship between the amount of system feed water and the amount of blowdown sent down the drain. Also referred to as concentration ratio, cycles of concentration correlates to the effective use of water in your system to provide heating or cooling needs. High cycles of concentration are directly related to low levels of water loss from your system.

Dissolved Solids – The amount of dissolved minerals present in the water.

Drift – Droplets of water entrained in the air leaving the top of the tower, or blown from the side of the tower by crosswinds.

Make-up – Water supply needed to replace all losses due to evaporation, leaks, or discharge in cooling systems.

Types of Towers

Cooling Towers – Cooling towers are classified by the direction of air flow (counter-flow or cross-flow) and the type of draft (mechanical or natural).

Mechanical Draft Towers – Mechanical draft towers have air forced through the structure by a fan. The air flow can be pushed through by fans located at the base of the tower (referred to as forced draft), or pulled through by fans located at the top of the tower (referred to as induced draft). Induced draft towers tend to be larger than forced draft units.

Natural Draft Towers – Natural draft towers are designed to move air up through the structure naturally without the use of fans. They use the natural law of differing densities between the ambient air and warm air in the tower. The warm air will rise within the chimney structure because of its lower density drawing cool ambient air in the bottom portion. Often times these towers are very tall to induce adequate air flow, and have a unique shape giving them the name "hyperbolic" towers (see Figure 5).

Figure 5. Hyperbolic Cooling Towers (Source: Victor Vizu).

Cross-Flow Towers – Cross-flow cooling towers are structured so that air flows horizontally across the falling water (see Figure 6). This design provides less resistance for the air flow, thereby reducing the fan horsepower required to meet the cooling demand. These towers usually feature gravity-fed water distribution decks that are either open and uncovered, or that are covered to limit algae growth and debris from getting into the distribution deck. Gravity-fed distribution decks have evenly spaced openings that the water drops through to be spread across the tower fill.

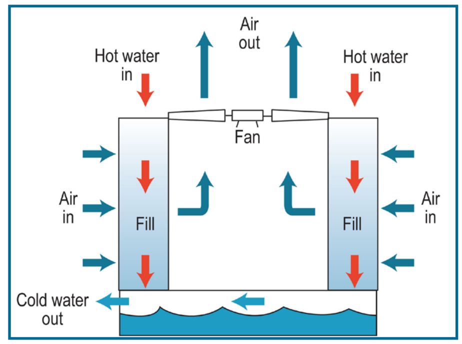

Figure 6. Example Cross-flow Cooling Tower.

Counter-flow Towers – Counter-flow cooling towers have upward air flow that directly opposes the downward flow of the water providing very good thermal efficiency because the coolest air contacts the coolest water (in the bottom section of the tower structure).

Important Properties of Water

A primary consideration for the operation of the cooling tower system is the water quality of the make-up source. Differing sources present differing challenges. Surface water sources include lakes, rivers, and streams, while groundwater sources consist of wells or aquifers. Depending on the location, surface water sources will have seasonal variations and can carry high levels of suspended silt and debris that cause fouling if not removed by pre-filtration systems. Groundwater sources don't have the seasonal variations that surface water sources have, but depending on the geology of the region, they can have high levels of dissolved minerals that contribute to scale formation or corrosion in the

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cooling system. Recently, water reuse has become popular and many cooling systems are being supplied reclaimed effluent or discharge water from other processes. While water reuse is a wise resource option, consideration should be made regarding the quality of the water and how that will impact the efficient operation of the cooling system, and the system's ability to meet the required cooling demand.

Whether the source water is surface, ground, or reuse, in nature there are a few basic water quality considerations that should be understood.

pH – pH is a measurement of how acidic or how alkaline a substance is on a scale of 0 to 14. A pH of 7.0 is neutral (the concentration of hydrogen ions is equal to the concentration of hydroxide ions), while measurements below 7.0 indicate acidic conditions, and measurements above 7.0 indicate basic or alkaline conditions. The pH scale is logarithmic (each incremental change corresponds to a ten-fold change in the concentration of hydrogen ions), so a pH of 4.0 is ten times more acidic than a pH of 5.0 and one hundred times more acidic than a pH of 6.0. Similarly, a pH of 9.0 is ten times more basic or alkaline than a pH of 8.0 and one hundred times more alkaline than a pH of 7.0.

Hardness – Hardness refers to the presence of dissolved calcium and magnesium in the water. These two minerals are particularly troublesome in heat exchange applications because they are inversely soluble – meaning they come out of solution at elevated temperatures and remain soluble at cooler temperatures. For this reason calcium and magnesium-related deposits will be evident in the warmest areas of any cooling system, such as the tubes or plates of heat exchangers, or in the warm top regions of the cooling tower fill where most of the evaporation occurs.

Alkalinity – Alkalinity is the presence of acid neutralizing, or acid buffering minerals, in the water. Primary contributors to alkalinity are carbonate (CO_3^{-2}), bicarbonate (HCO_3^{-}), and hydroxide (OH^{-}). Additional alkaline components may include phosphate (PO_4^{-3}), ammonia (NH_3), and silica (SiO_2), though contributions from these ions are usually relatively small.

Conductivity – Conductivity is a measurement of the water's ability to conduct electricity. It is a relative indication of the total dissolved mineral content of the water as higher conductivity levels correlate to more dissolved salts in solution. Conversely, purified water has very little dissolved minerals present meaning the conductivity will be very low.

System Calculations

To properly operate and maintain a cooling tower, there needs to be a basic understanding of the system water's use. Water use of the cooling tower is the relationship between make-up, evaporation, and blowdown rates. There are a couple simple mathematical relationships between the blowdown rate, evaporation rate, make-up rate, and cycles of concentration of a cooling tower that are very useful to understand the principal flow rates. The first relationship illustrates the overall mass balance consideration around a given cooling tower:

(1) *Make-up = Blowdown+ Evaporation*

In this case, the blowdown accounts for all system losses including leaks and drift, except for evaporation.

The second principal relationship defines cycles of concentration in terms of make-up flow and blowdown flow:

(2) *Cycles of Concentration = Make-up ÷ Blowdown*

This equation can be rearranged to either of the following to solve for the make-up rate or blowdown rate:

(3) *Blowdown = Make-up ÷ Cycles of Concentration*

(4) *Make-up = Cycles of Concentration × Blowdown*

If the evaporation rate and cycles of concentration are known, the blowdown rate can then be determined by substituting equation 4 into equation 1:

(5) *Cycles of Concentration × Blowdown = Blowdown + Evaporation*

Solving for blowdown:

(6) *Blowdown = Evaporation ÷ (Cycles of Concentration -1)*

Also, if the blowdown rate and cycles of concentration are known, the make-up rate can be determined by solving equation 4, and then the evaporation rate can be determined by solving equation 6 for evaporation:

(7) *Evaporation = Blowdown × (Cycles of Concentration – 1)*

Factors That Limit Cycles of Concentration

Increasing cycles of concentration saves water because it essentially means that water is being recirculated longer through the system before being blown down. But as levels of dissolved minerals elevate with higher cycles of concentration, scaling and corrosion potential also increase. All dissolved minerals have a saturation limit that, if exceeded, will lead to scale formation.[2] Additionally, high levels of dissolved minerals (high cycles of concentration) increases the water's tendency to be corrosive (corrosion is discussed in greater detail below). Chemical and mechanical treatment programs allow the thresholds of scaling tendencies and corrosion to be pushed; however, limits still persist necessitating management of dissolved minerals (conductivity) levels through elimination of high mineral content water through blowdown. The following section discusses these concerns in greater detail.

System Concerns

Cooling towers are dynamic systems because of the nature of their operation and the environment they function within. Tower systems sit outside, open to the elements, which makes them susceptible to dirt and debris carried by the wind. Their structure is also popular for birds and bugs to live in or around, because

(2) Scaling will occur predominantly in the heat exchangers and in the fill-section of the tower structure, but may also occur in the piping or on the tower distribution deck.

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of the warm, wet environment. These factors present a wide range of operational concerns that must be understood and managed to ensure optimal thermal performance and asset reliability. Below is a brief discussion on the four primary cooling system treatment concerns encountered in most open-recirculating cooling systems.

Corrosion – Corrosion is an electrochemical or chemical process that leads to the destruction of the system metallurgy. Figure 7 illustrates the nature of a corrosion cell that may be encountered throughout the cooling system metallurgy. Metal is lost at the anode(3) and deposited at the cathode.(4) The process is enhanced by elevated dissolved mineral content in the water and the presence of oxygen, both of which are typical of most cooling tower systems.

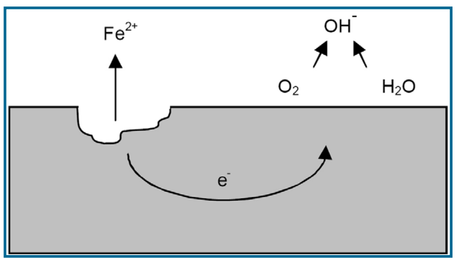

Figure 7. Example of a Corrosion Cell.

There are different types of corrosion encountered in cooling tower systems including pitting, galvanic, microbiologically influenced (Figure 8), and erosion corrosion, among others (expanded discussion is available at www.gewater.com/handbook/cooling_water_systems/ch_24_corrosion.jsp). Loss of system metallurgy, if pervasive enough, can result in failed heat exchangers, piping, or portions of the cooling tower itself.

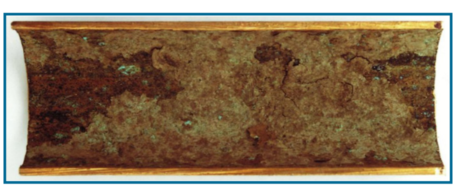

Figure 8. Microbiologically Influenced Corrosion (Source: Taprogge GmbH).

Scaling – Scaling is the precipitation of dissolved minerals components that have become saturated in solution. Figure 9 illustrates calcium carbonate scale collecting on a faucet head. Factors that contribute to scaling tendencies include water quality, pH, and temperature. Scale formation reduces the heat exchange ability of the system because of the insulating properties of scale, making the entire system work harder to meet the cooling demand. An expanded discussion for scaling is available at www.gewater.com/handbook/cooling_water_systems/ch_25_deposit.jsp.

Figure 9. Calcium Carbonate Scale (Source: Hustvedt).

Fouling – Fouling occurs when suspended particles fall out of solution forming deposits. Common foulants include organic matter, process oils, and silt (fine dirt particles that blow into the tower system, or enter in the make-up water supply). Factors that lead to fouling are low water velocities(5), corrosion, and process leaks. Fouling deposits, similar to scale deposits, impede the heat exchange capabilities of the system by providing an insulating barrier to the system metallurgy. Fouling in the tower fill can plug film fill reducing the evaporative surface area, leading to lower thermal efficiency of the system.

Microbiological Activity – Microbiological activity is micro-organisms that live and grow in the cooling tower and cooling system. Cooling towers present the perfect environment for biological activity due to the warm, moist environment. There are two distinct categories of biological activity in the tower system. The first being planktonic, which is bioactivity suspended, or floating in solution. The other is sessile biogrowth, which is the category given to all biological activity, biofilms, or biofouling that stick to a surface in the cooling system. Biofilms are problematic for multiple reasons. They have strong insulating properties, they contribute to fouling and corrosion, and the bi-products they create that contribute to further micro-biological activity. They can be found in and around the tower structure, or they can be found in chiller bundles, on heat exchangers surfaces, (see Figure 10), and in the system piping. Additionally, biofilms and algae mats are problematic because they are difficult to kill. Careful monitoring of biocide treatments, along with routine measurements of biological activity are important to ensure bio-activity is controlled and limited throughout the cooling system.(6)

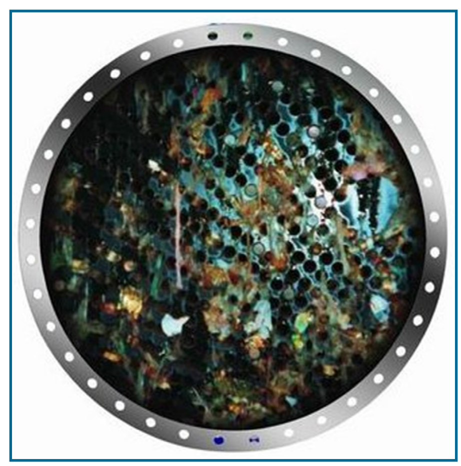

Figure 10. Biofouled Heat Exchanger (Source: Taprogge GmbH).

(3) The anode in a corrosion cell is defined as the site where metal is lost from the system structure and goes into solution.
(4) The cathode in a corrosion cell is defined as the site where the metal lost at the anode is deposited.
(5) Low water velocities may occur in poorly designed or improperly operated heat exchangers, in the cooling system piping, or in locations across the tower fill where uniform distribution is not maintained.
(6) Beyond the operational and mechanical problems bioactivity causes in cooling tower systems, there is a human health issue if the system develops a specific bacterium known as Legionella. For more information regarding Legionella and Legionnaires' disease go to www.cdc.gov/legionella/patient_facts.htm.

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Treatment Options

Traditional water treatment programs are designed and implemented to account for the system concerns outlined above. This ensures the tower system operates optimally and achieves the needed cooling requirement. These programs consist of chemical additives including corrosion inhibitors, dispersants, scale inhibitors, and biocides that function to protect the cooling system and keep heat exchange surfaces clean and free of deposits or bio-films. When this is accomplished, maximum cycles of concentration can be achieved, and the cooling system can be operated at peak efficiency both in terms of water use and energy use. Beyond traditional water treatment programs there are options to build upon the current program, improve the current program, or replace the current program.

Water Modeling – Software platforms provide the ability to model the system's scaling tendencies, corrosion characteristics, and view optimal chemical application (also referred to as "dosing"). This can be a powerful tool to better understand if the system is operating at the maximum cycles of concentration possible, to see problem points in the system (low flow velocity, high temperature heat exchangers, for example), and to see impacts of varying water characteristics. Additionally, these modeling platforms allow a facility to review the potential impact of integrating water reuse resources, altering chemical treatment programs, or variations to certain operational parameters such as pH set-point. In some cases, local and regional water treatment professionals may have the capability to supply similar modeling results as a part of your existing water treatment program or for a consulting fee.

Green Chemistries – "Green" chemistry programs exist primarily to replace traditional treatments that have been deemed harmful for environmental reasons. "Green" chemistries often don't result in improved thermal efficiency or reduced water consumption, but provide environmental compliance and reduced discharge of harmful or illegal substances.

Examples of "green" chemistry programs include polysilicate corrosion inhibitors (used for many years in potable water systems), polyaspartic acid dispersants, and hydrogen peroxide for biocide applications. Another biocide that received the 1997 Environmental Protection Agency (EPA) Green Chemistry Award is THPS – tetrakis (hydroymethyl) phosphonium sulfate.[7]

Automation – Automation systems are available providing a broad range of capacities to control single or multiple parameters in the cooling system such as conductivity and blowdown control, pH control, and real-time chemical monitoring and dosing.

Blowdown controllers are available from several different commercial suppliers and offer a range of control points from simple conductivity/blowdown control, to timed or meter relay chemical dosing. Many of them incorporate water meter inputs and alarm relays if threshold measurements are exceeded.

Blowdown controllers offer continuous monitoring and control of the blowdown of the tower system. This ensures high conductivity is avoided, minimizing scaling and corrosive conditions and minimizes excessive blowdown which wastes water. Figures 11 and 12 provide two opposing trends – one showing manual blowdown control and the other showing blowdown controlled with a conductivity controller. The charts illustrate the impact of implementing blowdown controllers, revealing conductivity rates that stay much closer to the ideal set point compared to manual control.

More robust automation platforms are also available from several manufacturers that provide system-wide monitoring and dosing. These platforms are scalable depending on the need, but offer conductivity/blowdown control, pH control, real-time chemical monitoring and dosing, continuous corrosion monitoring, web-enabled reporting, and alarm relays. The benefit of these systems is tightened control of the various control points of the water treatment program, not only eliminating excessive water use and high cycle conditions, but also controlling chemical residuals and treatment dosing based on real-time corrosion and scaling indices. In trend terms, similar results to the conductivity improvements shown by Figures 11 and 12 can be achieved on chemical treatment residuals, pH set point and acid feed, biocide dosing, and corrosion monitoring. Figures 13 and 14 illustrate the performance improvement real-time dosing achieves on chemical residuals, ensuring the proper dosage of corrosion and scale inhibitors at all times and eliminating overfeed or underfeed of

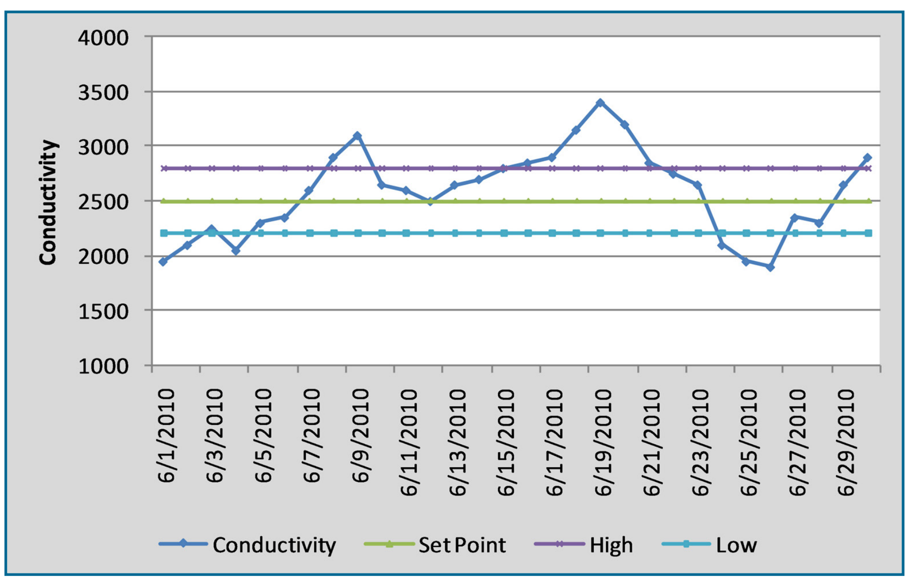

Figure 11. Conductivity Trend for Manual or Timed Blowdown Control.

(7) To view the details of the THPS Green Chemistry Award go to www.epa.gov/gcc/pubs/pgcc/winners/dgca97.html. The complete list of recipients for the EPA's Green Chemistry Awards is available at www.epa.gov/gcc/pubs/pgcc/past.html.

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these products. These platforms offer web-enabled reporting interfaces so operators and maintenance staff can view tower performance remotely. Additionally, alarms for out-of-compliance measurements can be sent via email or text message alerting maintenance or operations personnel so corrective actions can be taken.

Filtration – Filter systems are nothing new to industrial water systems, and have been used as pre-treatment in many different applications for many years. In recent years, side-stream filtration systems have become popular among many water treatment professionals. They function to remove suspended solids, organics, and silt particles down to 0.45 microns from a portion or all of the system water on a continual basis, thereby reducing fouling, scaling and microbiological activity. This allows the cooling system to work more efficiently and often reduces the amount of water blown down. However, the net impact on water consumption must consider the fact that these platforms require back-washing to clean the filter system. The amount of water used to regenerate the filter system should be added to the water lost due to evaporation and blowdown.

Softening – Softeners function to remove hardness (calcium and magnesium) from the make-up water, or can be incorporated as a side-stream system to soften a portion of the water continuously. This effectively manages (or eliminates) the amount of calcium and magnesium in the tower bulk water, thereby reducing the scaling potential of calcium and magnesium related deposits. By reducing or eliminating the scaling potential of calcium and magnesium, higher attention should be given to corrosion monitoring and the corrosive characteristics of the water. Calcium and magnesium function naturally as corrosion inhibitors, so if they are minimized or removed from the water, the corrosive conditions will increase putting more importance on the corrosion management program and tighter requirements on pH and alkalinity control.

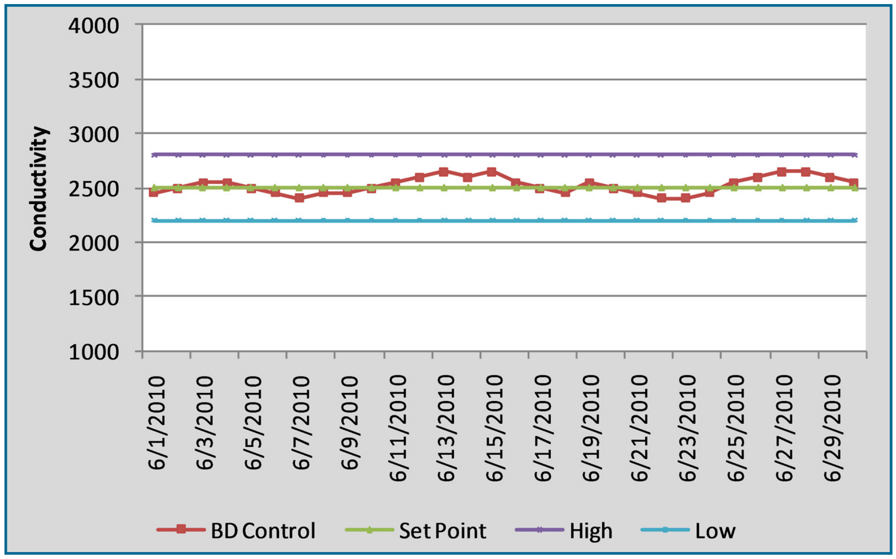

Figure 12. Conductivity Trend for a System Using a Blowdown Controller.

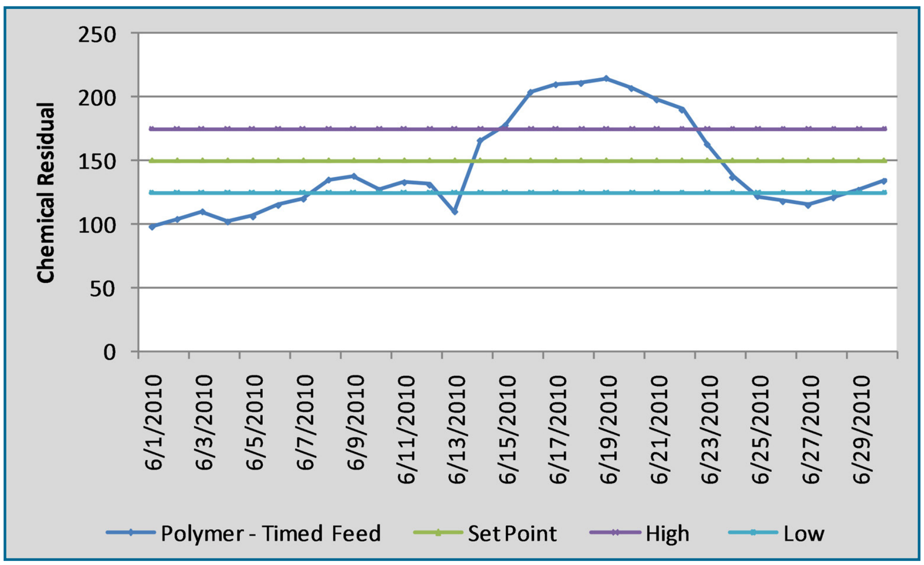

Figure 13. Chemical Residuals Trend for Timed Feed.

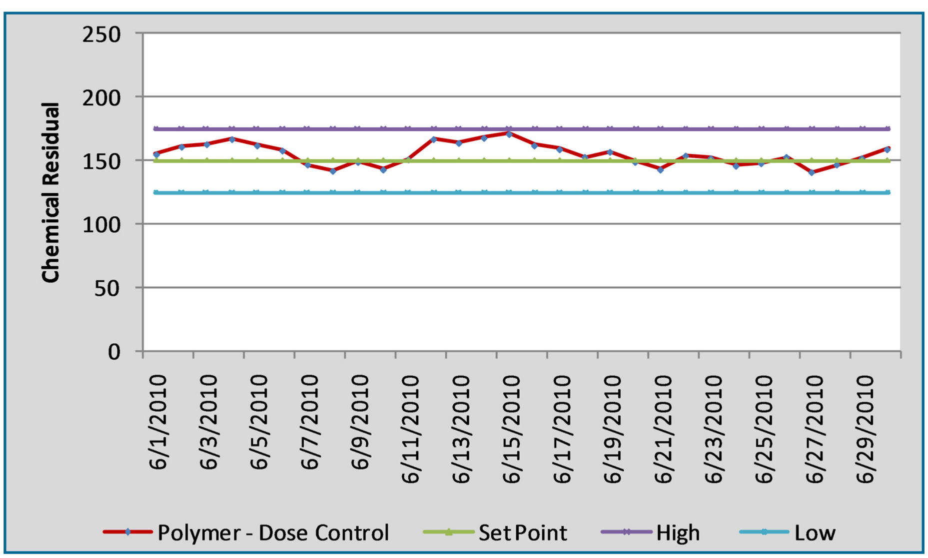

Figure 14. Chemical Residuals with Real-Time Dosing.

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Chemical-free Platforms – In recent years many innovations have been made in systems that provide chemical-free treatment replacements to traditional treatment platforms. These include systems that are singular in their target treatment, such as ozone[(8)] and ultraviolet biocide systems. These systems are very effective disrupting and eliminating biological activity in the treatment zone, are flexible across a broad pH range, have low operating costs, and no undesirable byproducts. These systems treat an isolated point in the system, so far-reaching parts of the cooling system may have bioactivity due to extended distances from the treatment application point. Additionally, sessile bioactivity in the system beyond the point treatment may not be affected by the ozone and ultraviolet treatments.

There are also other types of comprehensive chemical-free platforms and the market has evolved, offering many different types of platforms, which currently have varying degrees of success in the commercial marketplace. Several have been available for many years, but the evolution of the differing technologies has allowed for many more platforms to be developed.[(9)] The exact mechanisms used to alter the water's characteristics vary from platform to platform, including electromagnetic and hydrodynamic principles as point treatments to control scaling and corrosion along with microbiological activity. Systems that employ electromagnetic principles feature a treatment zone where an electric field courses through the flow of the recirculating water creating a "seeding" mechanism for dissolved minerals, principally calcium carbonate (also known as calcite). The seeding process creates a location for other dissolved minerals to agglomerate, or come out of solution, and then be removed via in-line filtration systems that follow the treatment system. The pulses of electricity also behave to counter bioactivity by damaging cell walls of potential microbes that pass through the treatment zone. Corrosion is controlled naturally by these systems as they allow the water to run at elevated pH levels, or alkaline conditions.

Similarly, systems employing hydrodynamic cavitation impact the water's characteristics to control scaling, corrosion, and biological activity. Instead of imparting electromagnetic principles to accomplish these ends, hydrodynamic cavitation impacts the water mechanically by rapid changes in pressure and mechanical collision in the treatment zone. Again, scaling is controlled through the seeding mechanism of calcium carbonate (calcite) formation, which in turn collects any other dissolved minerals nearing their respective saturation points and removes them through in-line filtration. Low pressure zones strip the passing water of CO_2, maintaining naturally alkaline conditions to control corrosion. Lastly, the cavitation process ruptures cell walls of microbes passing through the treatment zone, thereby managing bioactivity in the cooling systems.

These systems and many others like them have case studies and testimonials posted to demonstrate successful replacement of standard treatment options, including energy savings and water efficiency gains. They offer the advantage of reduced or eliminated need for treatment chemicals and have had many successful installations with documented improvements. However, some installations have had difficulty depending on the water quality, especially where the natural tendencies of the source water lean toward corrosive conditions. Furthermore, point treatments may have some difficulty with systems that are extensive and have far reaching-pipe runs or heat exchangers that are a substantial distance from the treatment system itself.

Water Reuse – Water reuse options vary depending on the nature of water uses from site to site along with a broad range of other considerations, including local and regional water reuse laws and the availability of an adequate reuse resource. The concept is relatively simple: take discharge water from one application, apply sufficient treatment to it if needed, and then use it as a make-up water resource for the cooling tower system. Two examples of reuse are collecting the condensation from air-handlers and then pumping them back to the tower system make-up, or implementing a reverse osmosis system on the cooling tower blowdown. The condensed water that collects in air handlers is an excellent resource of high quality make-up water for the tower system. Because it is condensation, by nature it will be relatively pure, and therefore will not require much additional treatment to make it sufficient for using as tower make-up water.[(10)] These systems are not difficult to engineer, nor are they typically very capital intensive.[(11)]

Reverse osmosis (RO) systems (similar to Figure 15) are common in many

Figure 15. Desalination Plant Using Reverse Osmosis Technology (Source: James Grellier).

(8) Ozone is a reactive form of oxygen that has strong oxidizing characteristics making it very effective at controlling microbiological activity.
(9) This document features mechanisms of a few different available systems and is not intended to be a comprehensive overview of all commercially available chemical-free water treatment systems.
(10) The purity of the water will increase its natural abilities as a solvent and stagnant water systems are ideal for bioactivity. Care should be taken when considering the materials of construction for the collection and distribution system and if needed a small amount of biocide may be needed to minimize bioactivity. Additionally, the corrosion program for the tower system will need to reviewed or modeled to ensure proper corrosion control steps are taken to protect system metallurgy.
(11) For more information on condensate recovery systems a case study is available at www.femp.energy.gov/program/waterefficiency_csstudies.html.

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applications including desalination, industrial pre-treatment platforms, and applications where the purity requirements for water are very high. In the case of water reuse from a tower system, the blowdown water would be sent directly into an RO system, which would purify a portion of the water (the permeate flow) and concentrate the bulk of the dissolved minerals into a smaller waste stream (the concentrate flow) that would be discharged from the system. These systems can be difficult to operate correctly, and are expensive to purchase and operate. However, locations where water resources are limited or discharge permits prohibit excessive cooling tower blowdown, RO platforms are a consideration to minimize the overall losses from a cooling system.

Where to Get More Information

FEMP Water Efficiency:
www.femp.energy.gov/program/waterefficiency.html

Cooling Technology Institute:
www.cti.org/

American Society of Heating, Refrigeration, and Air-Conditioning Engineers:
www.ashrae.org/

American Society of Mechanical Engineers:
www.asme.org/

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Federal Energy Management Program

DOE/PNNL-SA-75820 • February 2011

Prepared and produced by Pacific Northwest National Laboratory (PNNL) on behalf of the U.S. DOE-Federal Energy Management Program

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