the Energy to Lead

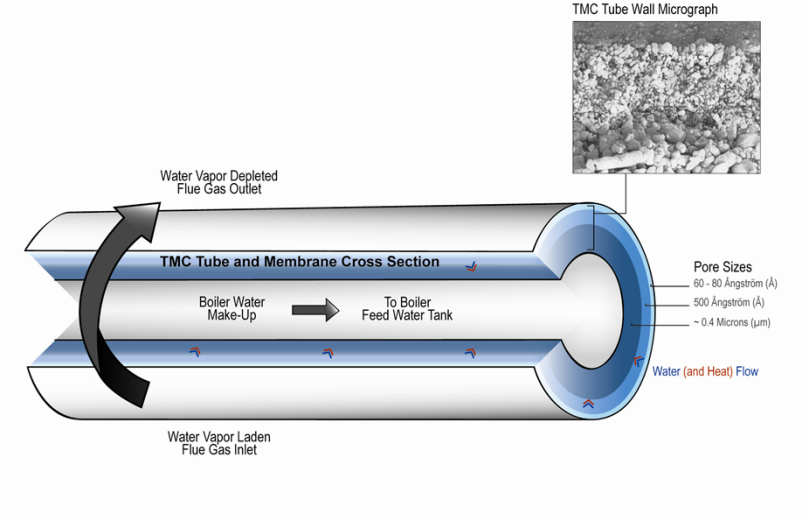
Advanced Boiler Technologies for Commercial and Industrial Applications - Ultramizer® AHRS

2012 Emerging Technologies Summit
October 16, 2012, Pasadena, CA
Neil P. Leslie, P.E., Gas Technology Institute
847 768 0926, neil.leslie@gastechnology.org

gti®

Ultramizer® AHRS Technology

- Core Transport Membrane Condenser (TMC) technology developed by GTI with support from a number of government and gas utility stakeholders
- Uses a robust nanoporous membrane to selectively recover sensible and latent heat and pure water from natural gas combustion byproducts
  - avoids corrosive condensate
- Successfully developed for Retrofit & New Commercial/Industrial boilers
  - Licensed to Canon Boiler Works (CBW)



Ultramizer® AHRS tubes in a bundle assembly

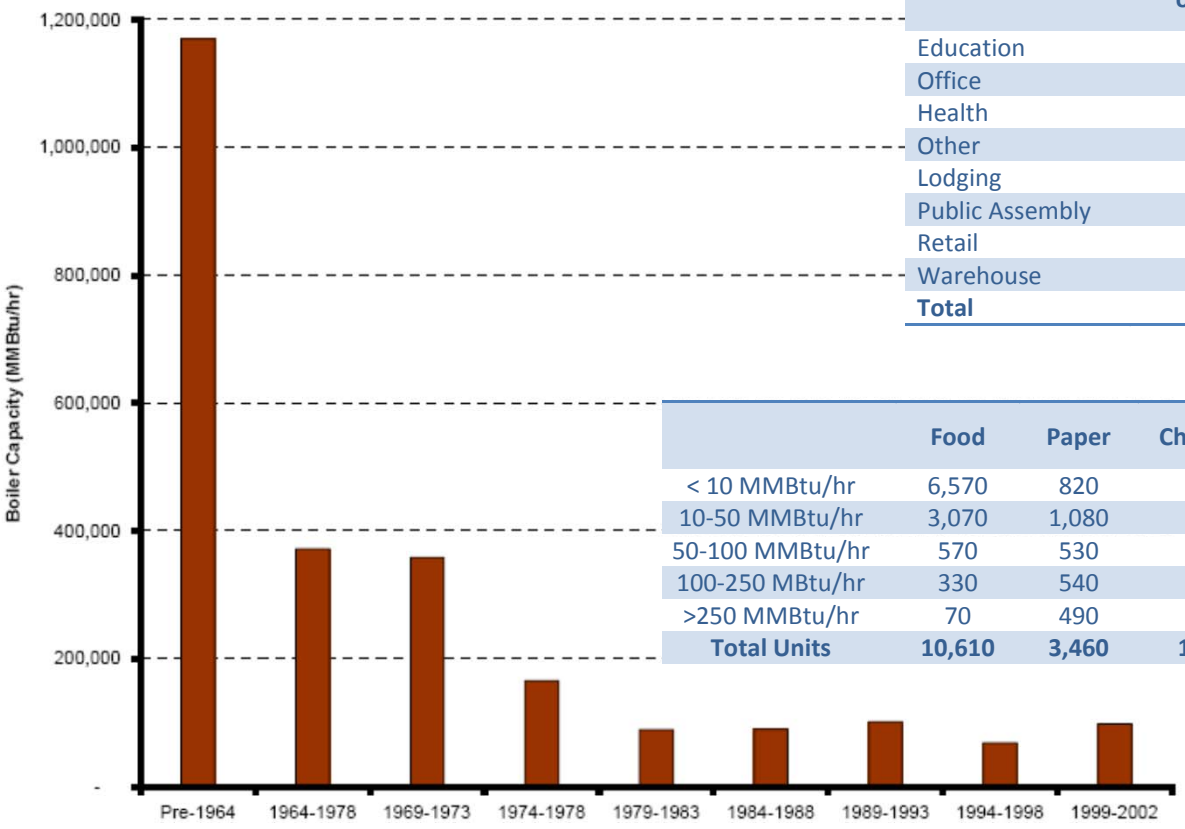
Why Heat Recovery from Boilers?

- There is a large population of outdated and inefficient commercial and industrial boilers
  - Many old boilers need replacement
  - New technology options available for improved efficiency
  - Utility emerging technology programs can be a key catalyst for new high-efficiency equipment

gti

US Commercial and Industrial Boiler Population

Over 75% of larger commercial and industrial boilers greater than 30 years old



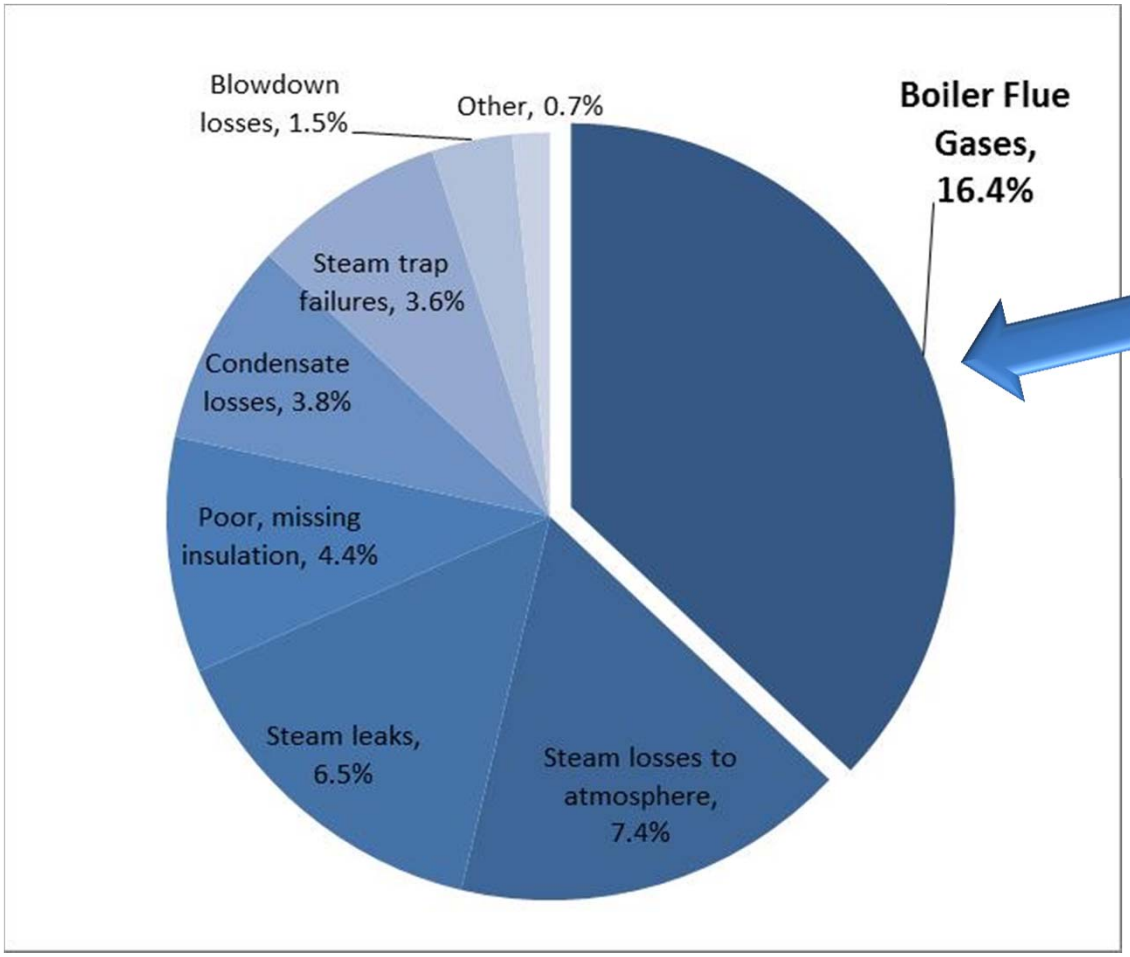
Commercial

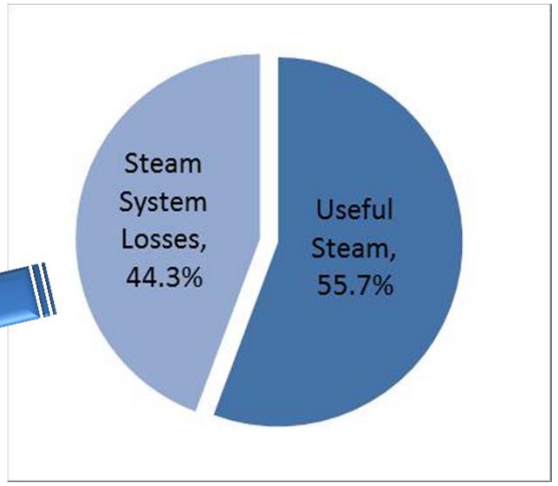
Building Type	Number of Boilers	Total Boiler Capacity (MMBtu/Hr)	Average Capacity per Facility (MMBtu/hr)
Education	35,895	128,790	3.6
Office	28,030	297,090	10.6
Health	15,190	317,110	20.9
Other	11,900	88,970	7.5
Lodging	10,545	140,830	13.4
Public Assembly	7,280	55,205	7.6
Retail	5,585	47,230	8.5
Warehouse	5,365	72,385	13.5
Total	**119,790**	**1,147,610**	**9.6**

Industrial

	Food	Paper	Chemicals	Refining	Metals	Other Industrial	Total
< 10 MMBtu/hr	6,570	820	6,720	260	1,850	7,275	23,495
10-50 MMBtu/hr	3,070	1,080	3,370	260	920	3,680	12,380
50-100 MMBtu/hr	570	530	950	260	330	930	3,570
100-250 MBtu/hr	330	540	590	200	110	440	2,210
>250 MMBtu/hr	70	490	350	220	120	110	1,360
Total Units	**10,610**	**3,460**	**11,980**	**1,200**	**3,330**	**12,435**	**43,015**

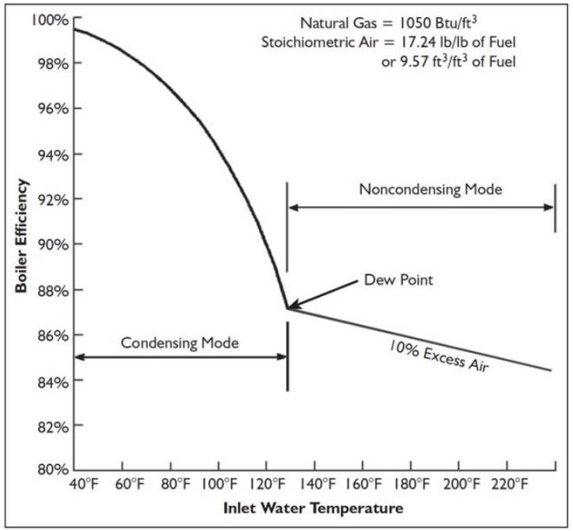
Steam Systems and Energy Efficiency Opportunities





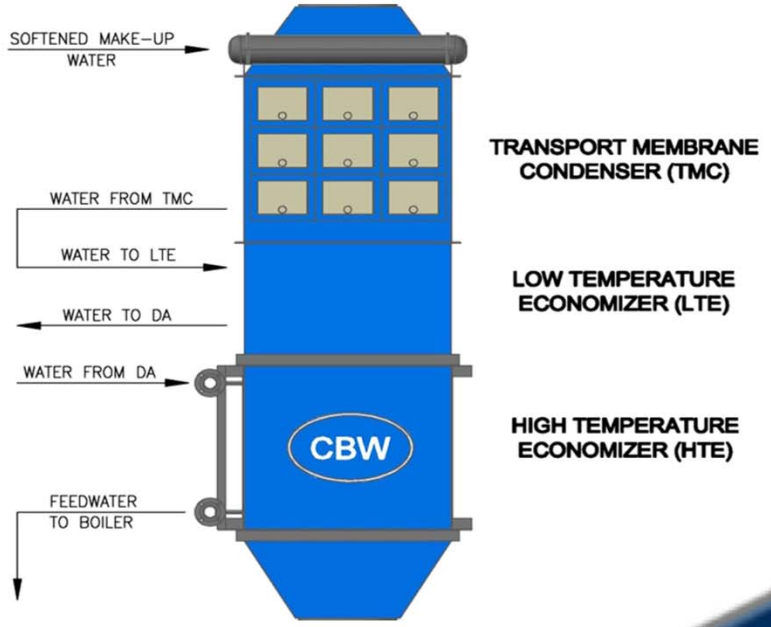
Natural Gas Boiler Flue Gas Heat Recovery

- Natural gas combustion produces ~18% water volume in flue gas ~ 10% of fuel energy input
- Steps to higher energy efficiency → sensible & latent heat recovery
  - **Sensible** = reduce exhaust temperature by preheating water (or other use) → up to 88% efficiency
  - **Latent** = condensing exhaust water vapor to liquid releases energy that can be recovered → over 88% efficiency
  - **Caution**: Exhaust condensate is usually corrosive (pH 3-5)

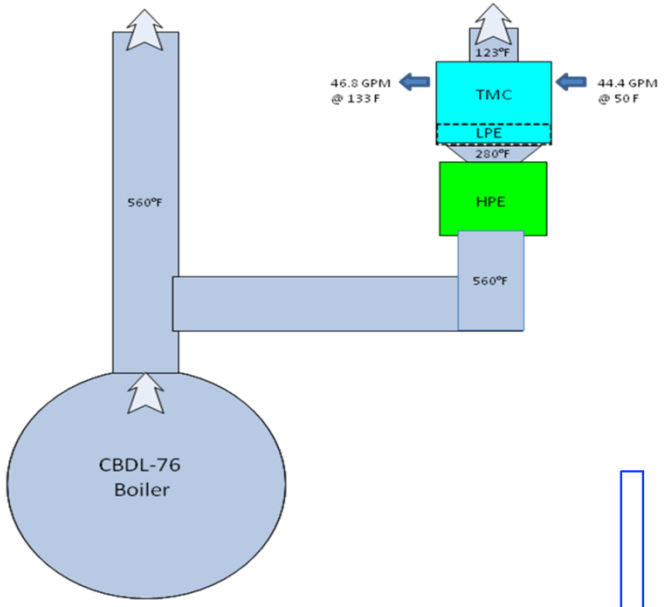


Cannon Ultramizer® System

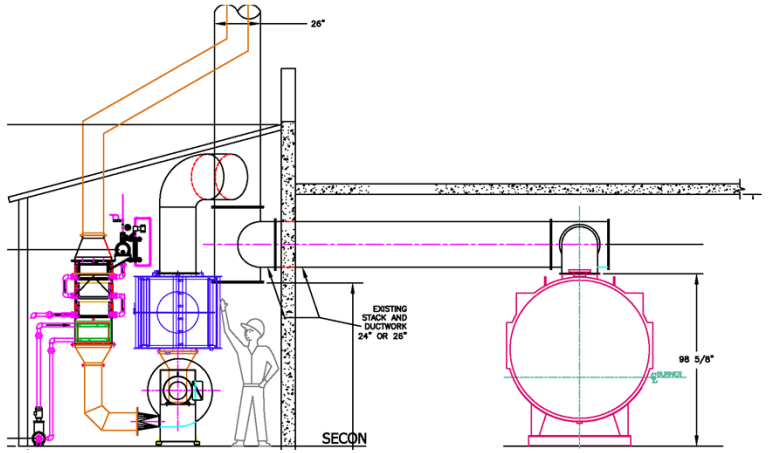
- Combines Cannon's high temperature (HTE) and low temperature (LTE) Feedwater Economizers with Ultramizer® AHRS Technology to provide the ultimate in heat and water recovery
- Recovers Sensible and Latent Heat and clean water from flue gas stream
- Boiler efficiencies of 95% are possible
- Reduction in emissions is equal to the reduction in fuel consumption
- http://www.cannonboilerworks.com/ultramizer.html

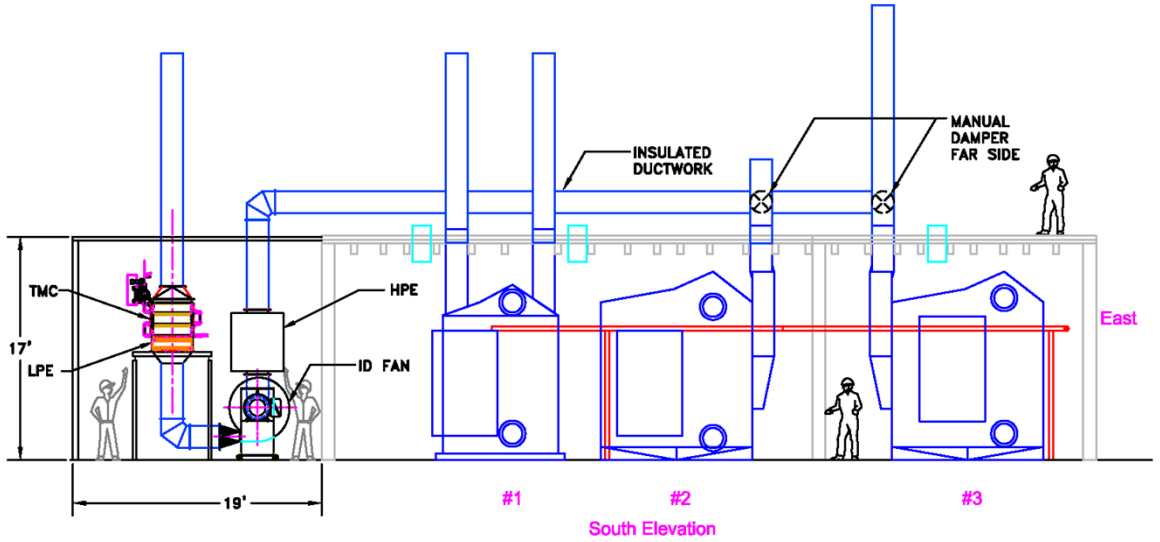


Flexible Installation Options

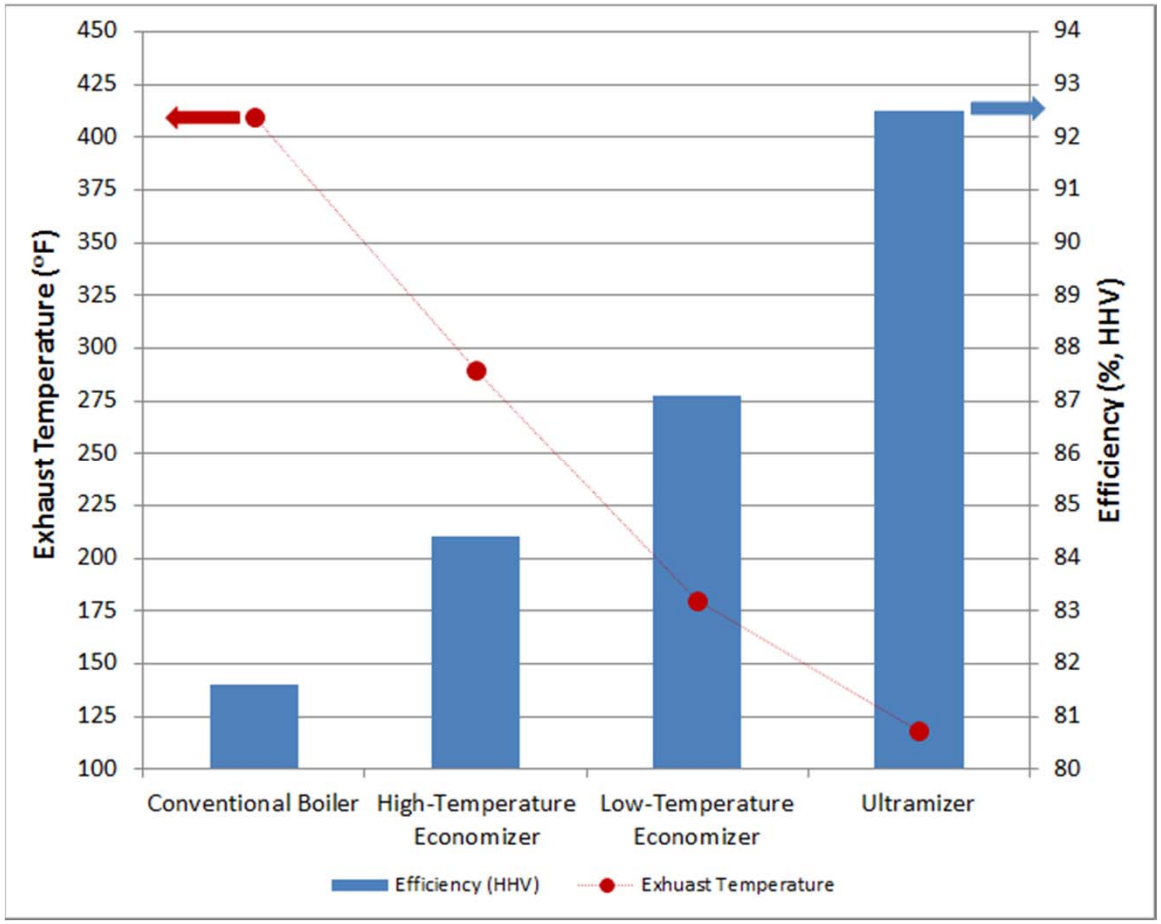


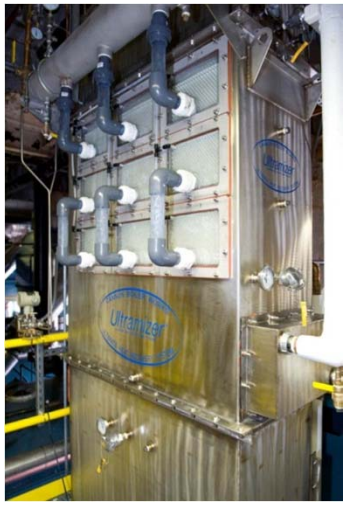
1000 HP AHRS Retrofit





Boiler Efficiency Improvement Options





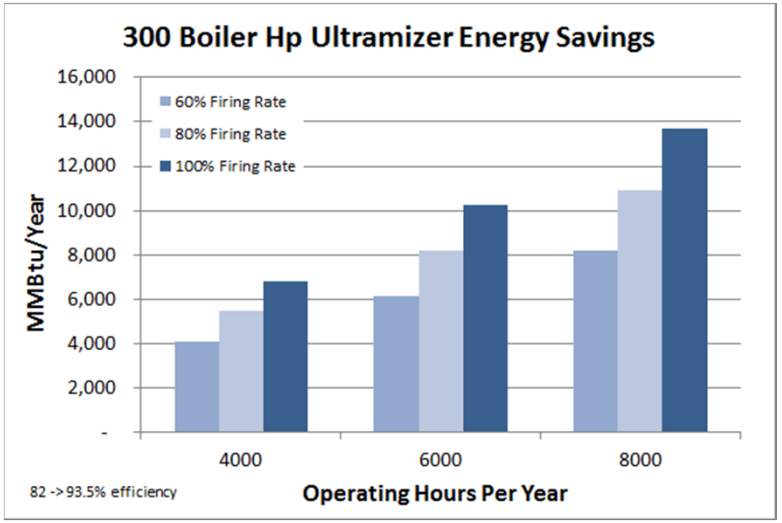
The Ultramizer® provides high boiler efficiency while:

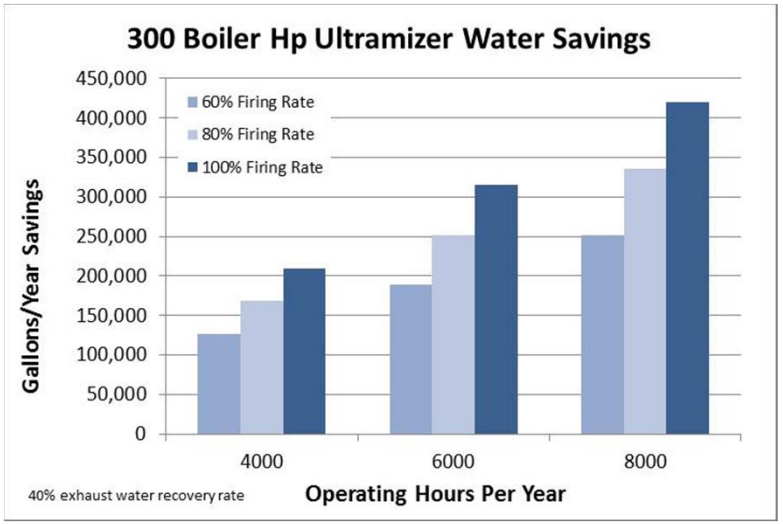
- Reducing make-up water demand
- Avoiding a corrosive condensate management issue that would otherwise cost the commercial or industrial customer

Based on Baxter test conditions.
Efficiency can go as high as 95% depending on operating conditions.

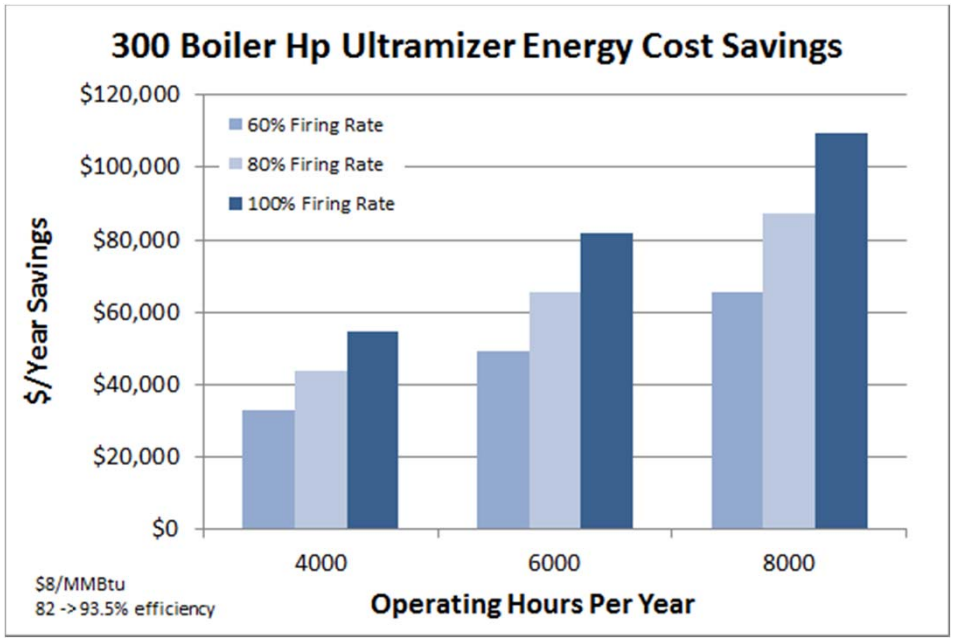
gti®

Ultramizer® Energy & Consumer Savings





300 hp Boiler @80% average firing rate				
	Energy Savings MMBtu/yr	Energy Cost Savings ($/yr)	Water Savings (Gallons/yr)	Water Cost Savings*
6000 hours/year	8,200	$65,590	251,900	$2,519
8000 hours/year	10,930	$87,450	335,900	$3,359



* Assuming $10/1000 gallons for water purchase and clean-up

Ultramizer® AHRS Demonstrated at Baxter Healthcare & Richardson Brand Candy

> Demonstrations provided key engineering information for further advancement of the Ultramizer® AHRS

> Pump speed control, cavitations, and humidity instrument failures have led to design modifications that ultimately improved the Ultramizer® AHRS product offering

> Knowledge gained facilitated the transfer of this technology into non-boiler installations, thus dramatically increasing the impact of the newly commercialized Ultramizer® AHRS

Ultra-High Efficiency Boiler

AHRS at Richardson Brand in New York

- Operating since 2011
- Over 15% savings in steam production costs
- Up to 20% less make-up water consumed
- Lower NOx and CO_2 emissions

Ultra-High Efficiency Boiler

AHRS at Baxter Healthcare

- Operating since 2010
- Providing energy, carbon and water savings
- Measured efficiency ~92.5%
- Over 250,000 gallons of annual estimated water savings

Independent Evaluation: Baxter Healthcare, May 2012

- Ultramizer® AHRS retrofit to Boiler No. 1 of two 250HP boilers
  - Includes HPE, LPE & 2nd Generation TMC
- Boiler produces saturated steam at 110 psig
- Installed Data Acquisition System
- Validation tests conducted using portable analyzer and manual data collection over 2 days
  - DAS found unreliable

gti®

Validation Testing Approach

- Boiler No.1 in manual control
- Boiler No. 2 in auto control to accommodate load swings
- Boiler No. 1 tested from 10% to 95% firing rate on control panel in 10-15% increments on May 1, 2012
- Tests repeated on May 2, 2012
- Flue gas data - portable Testo 350 analyzer
- Combustion air temperature - Fluke handheld thermometer
- Feed water flow rate – Strap-on ultrasonic meter
- Pre-installed instruments and meters – manually recorded

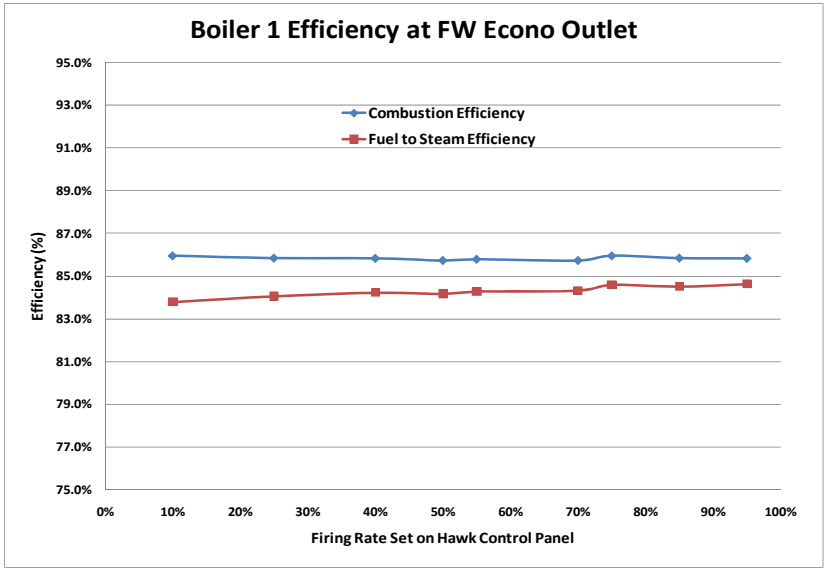
Boiler Efficiency Calculations

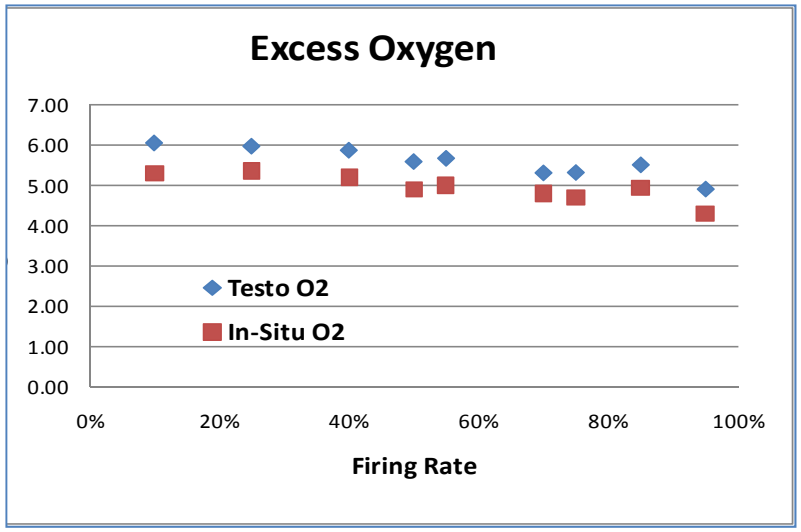
- Indirect Heat Loss Method (ASME PTC 4.1 procedure)
  - Used flue gas combustion data to calculate stack losses (dry gas, moisture, and unburned CO and hydrocarbon)
  - Fuel to steam efficiency = 100% - percent stack loss - radiation loss (assumed 0.5% of input) – blow down loss (assumed 3% of feed water flow rate)
- Direct Input/output Method
  - Calculated from natural gas input and steam output flow rates and heat contents
  - Found unreliable because of erratic steam flow measurements

gti

Boiler Efficiency Results

- Combustion efficiency similar across firing rates indicating good air-fuel ratio control
- Fuel to steam efficiency lower at low firing rates due to increased percent radiation losses





	Boiler 1	Boiler 2
Average Gas Consumption (MMBtu/hr)	5.658	3,214
Average Steam Production (pph)	4,788	2,615
Combustion Efficiency (at Feed Water Economizer outlet for Boiler 1)	85.7%	83.2%
Fuel-to-Steam Efficiency	84.3%	81.1%

Heat Recovered by AHRS

- LPE and TMC recovered an average of 307,172 Btu/hr, or 5.6% of input
- 55% of heat was recovered by LPE and 45% by TMC

		Test 2B	Test 4	Test 7	Test 9B	Average of Tests 1 -9
Firing Rate Set on Hawk Control Panel		**25%**	**50%**	**75%**	**95%**	54%
Flue Gas Temp Entering Condensing Economizer	oF	245.6	251.4	259.4	267.3	251.6
Flue Gas Temp Exiting Condensing Economizer	oF	122.5	122.1	121.8	125	123.1
Remaining Sensible Heat in Flue Gas	BTU/h	136,820	170,436	226,480	289,458	187,252
Latent Heat in Flue Gas	BTU/h	94,123	119,214	155,201	139,874	119,920
Total Available Heat	BTU/h	230,944	289,650	381,682	429,332	307,172
Heat recovered by TMC and LPE - Available Heat	Btu/hr	**230,944**	**289,650**	**381,682**	**429,332**	**307,172**

Boiler Efficiency with AHRS

- Ultramizer® AHRS increased combustion efficiency from 85.7% to 91.3%
- Average NO_x corrected to 3% O2 was 9.7 ppm.

		Test 2B	Test 4	Test 7	Test 9B	Average Test 1-9
Firing Rate Shown on Hawk Panel		25%	50%	75%	95%	
Average Firing Rate	[%]	40%	49%	62%	78%	53%
Natural Gas Cinsumption	MMBtu/hr	4.190	5.115	6.486	8.201	5.544
Losses (Heat in Flue Gases out of FW Economizer)	MMBtu/hr	0.596	0.729	0.934	1.190	0.791
Heat Recovered by LPE and TMC	MMBtu/hr	0.231	0.290	0.382	0.429	0.307
Heat in Flue Gases Outlet of TMC	MMBtu/hr	0.365	0.440	0.552	0.760	0.484
Combustion Efficiency at FW Economizer Outlet		85.8%	85.7%	85.6%	85.5%	85.7%
Combustion Efficiency at TMC Outlet		91.3%	91.4%	91.5%	90.7%	91.3%

Additional Information

- Ultramizer® versus Other Technologies
  (http://www.cannonboilerworks.com/Ultramizer®_pages/other_tech.html)
- Frequently Asked Questions and Answers:
  (http://www.cannonboilerworks.com/Ultramizer®_pages/faq.html)
- Ultramizer® Calculator designed to show potential financial savings based on simplified operating conditions that may be similar to many customer's operations, this is a tool intended to help justify the detailed study time and expense required for proper evaluation of each customers savings potential.
  http://www.cannonboilerworks.com/ultramizer_pages/index.html

General Boiler Application Criteria

- Boiler sizes ranging from 100 to 1,200 boiler HP output range
- Greater than 15 - to 300-psig saturated operating steam pressure
- Natural gas fired (Can consider a bypass arrangement for backup fuel systems)
- Makeup water requirements of more than 25% of total boiler feed water
- Annual capacity factor of minimum 50%

Thank you for your participation and interest!

For additional information, please contact:

David Cygan
R&D Manager
End Use Solutions
Gas Technology Institute
847-768-0524
David.Cygan@gastechnology.org