



CHX Heat Recovery – THE Solution



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CHX – THE SOLUTION

- Welcome & Introduction
- What is a Condensing Heat Exchanger?
- Design Considerations & Corrosion
- Typical System P&ID's
- Fuels Fired & Tube Selection
- Company History
- Manufacturing
- Independent Research
- Is Flue Gas Side Corrosion Really a Concern When Firing on Natural Gas?
- Conclusion, Summary, & Performance Example

INTRODUCTION

Genivar Ontario, Inc.
Enbridge Gas Distribution, Inc.
Union Gas, LTD

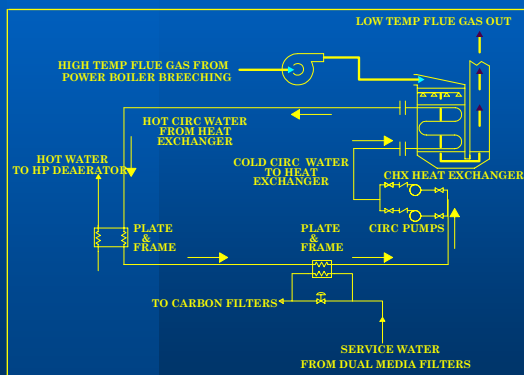
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Condensing Heat Exchanger Corp.

- **Boiler Flue Gas Heat Recovery**



Proven Track Record



WHAT IS A CONDENSING HEAT EXCHANGER?

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Definition of “Condensing Heat Exchanger”

A heat exchanger **designed** to recover heat from a hot exhaust gas stream by lowering the gas temperature to a value below both the **acid vapor** dew point and the **water vapor** dew point.

DESIGN CONSIDERATIONS & CORROSION

- Natural Gas
- Fuel Oil
- Condensation

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QUESTION

- Is the condensate formed in a condensing heat exchanger from the combustion of natural gas corrosive?
- How about from the combustion of fuel oil?

- THE FACT IS THAT BOTH ARE
EXTREMELY CORROSIVE!

What are the acid and water vapor dew points?

NATURAL GAS

Acid Dew Point ~ 130-170F due to Sulfur in the gas (0.04 – 0.4 Grains/CCF or 1.1 – 11.3 PPM) + ambient chlorides in the air.

Water Vapor Dew Point is ~ 135F depending on E.A.

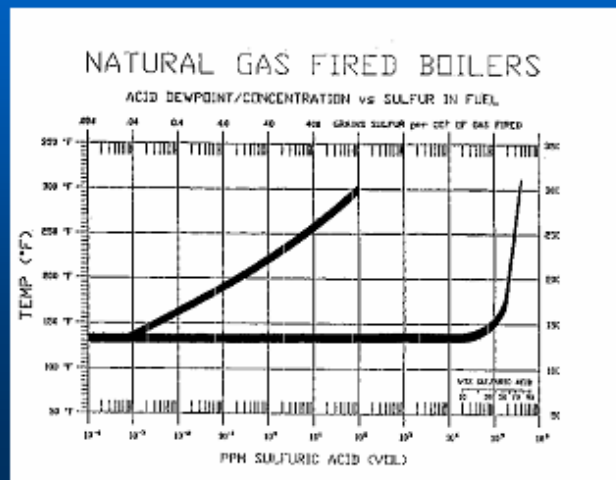
FUEL OIL

Acid Dew Point ~ 150-250+ depending on S in fuel

Water Vapor Dew Point ~ 110-115F

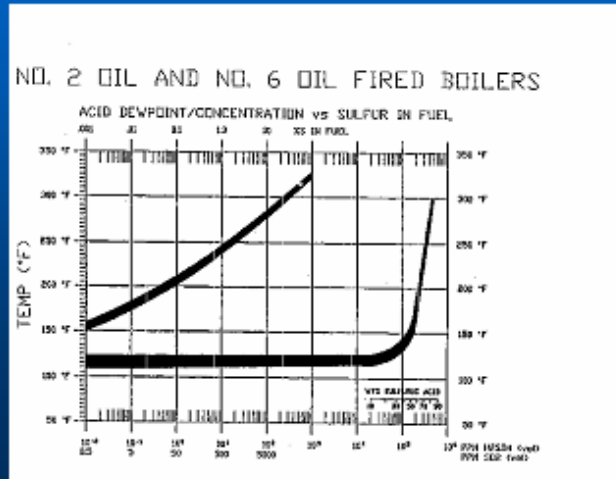
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Natural Gas Dew Point Curve



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Fuel Oil Dew Point Curve



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When does condensation take place?

When the bulk gas stream temperature falls below the **acid** or water vapor dew point

OR

Whenever the gas stream contacts a heat exchanger tube surface that is below either the **acid** or water vapor dew point.

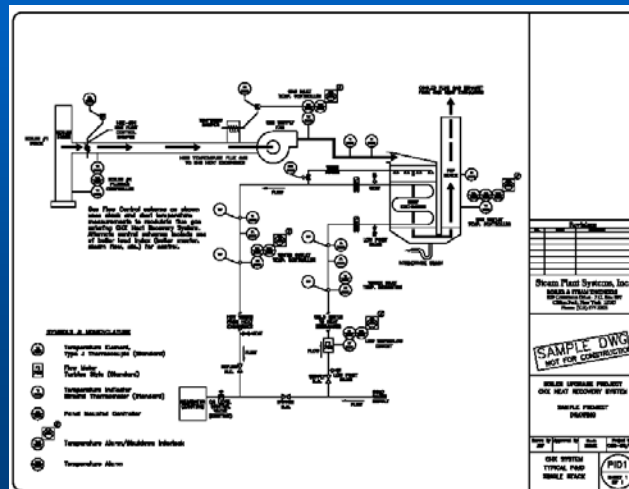
TYPICAL SYSTEM P&ID's

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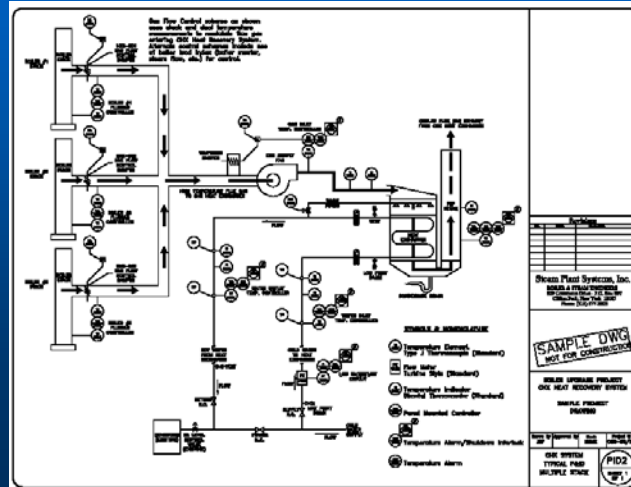
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1 Boiler P&ID



3 Boiler P&ID



FUEL FIRED & TUBE SELECTION

Can a Condensing Heat Exchanger Be Considered for Exhaust Gas Heat Recovery From Any Fired Fuel?

ABSOLUTELY

As long as it is properly designed and constructed.

- **Bare Tube Design** – All fuels including, Natural Gas, Biogas, Fuel Oils, Wood, Bark, Sludge, Refuse, Coal, TDF, Solvents, etc.
- **Finned Tube Design** – Natural gas only*

* - Water outlet temperature limits apply

COMPANY HISTORY

- **Mission**
- **Experience**
- **Capabilities**

CHX Company History

- Condensing Heat Exchanger was founded in 1977
- Company Mission
 - Flue gas heat recovery operating below the acid & water vapor dew points
 - Provide equipment design which is unrestricted by boiler fuel selection and operating outlet water temperature
 - **COMPANY EXPERIENCE – 31 YEARS**

Company Experience

- 31 year proven track record in **MANUFACTURING (NOT Subcontracting) CHX** systems for low temperature flue gas heat recovery
- Customers with systems in continuous operation since 1980
- Any Fuel – Any Temperature
 - Oil, Natural Gas, Biogas, Wood, Sludge ...
 - Exhaust gas outlet temperatures below 100F

CHX IN HOUSE CAPABILITIES

- All Engineering & Design
- COMPLETE Heat Recovery System Fabrication & Assembly
- Control System Fabrication & Integration
- Site Assembly, Start up, & Training

- CHX DOES NOT SUBCONTRACT HEAT EXCHANGER FABRICATION

MANUFACTURING

- Teflon **COVERED** Surfaces
- Quality Control
- Tube to Tube-Sheet Seals
- Simple Proven Design

Equipment Design

- Complete Corrosion Protection
- Teflon Covered Surfaces
 - Tubes
 - Tube Sheets
 - Side Sheets



Teflon Covered Surfaces

- All tubing material used in the heat exchanger construction is protected from flue gas corrosion by an extruded 15 mil Teflon Covering



Teflon Covered Surfaces

- All tube sheet and side sheet surfaces are protected from flue gas corrosion by an applied 60 mil Teflon Covering

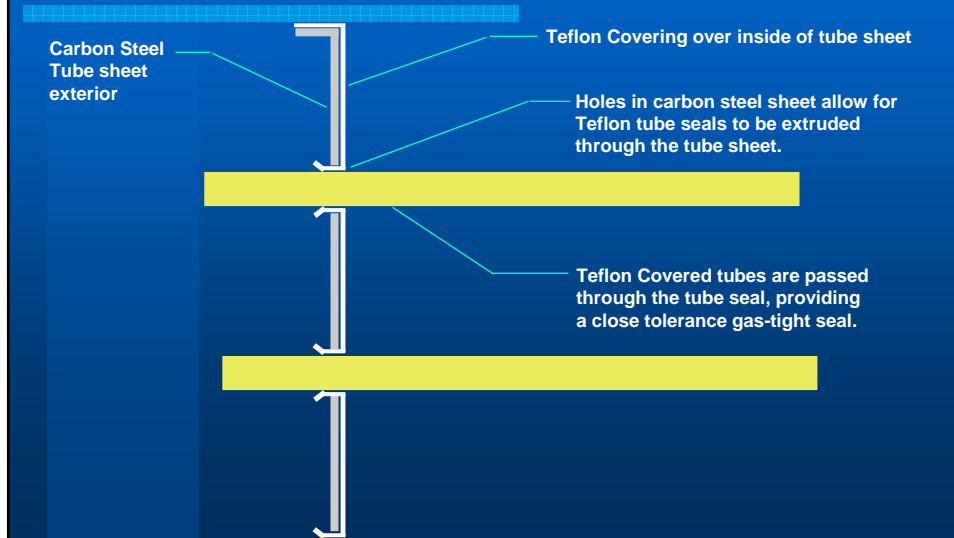


Quality Control

- On any application with sulfur bearing fuels (**including natural gas**), any metal tube exposure to flue gas will result in rapid failure due to aggressive corrosive attack
- CHX tubes are 100% Teflon Covered & tested during the extrusion process



Teflon Tube to Tube-Sheet Seals




Teflon Tube to Tube-Sheet Seals

- Dynamic Design
- Impervious to Corrosion
- Allows for Thermal Expansion
- Simple tube replacement
- 100% Reliable



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Simple Proven Design



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Simple Proven Design



Brand New Tubes **Five Years in Service**

INDEPENDENT RESEARCH

- GATC, BCL, AGA, GRI, BNL, ANL, CGA, EPRI, B&W, & ADL
- Why Teflon Covered Tubes?
- Why Not Coatings?
- Design Considerations

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Independent Research

- Gas Appliance Technology Center (GATC)
- Battelle-Columbus Laboratories (BCL)
- American Gas Association (AGA)
- Gas Research Institute (GRI)
- Brookhaven National Laboratory (BNL)
- Argonne National Laboratory (ANL)
- Canadian Gas Association (CGA)
- Canadian Gas Research Institute (CGRI)
- Electric Power Research Institute (EPRI)
- Babcock & Wilcox (B&W)
- Arthur D. Little (ADL)

Independent Research

The following major points will be addressed for natural gas applications –

- **Acids** (HCl, H₂SO₄, etc.) concentrate within a Condensing Heat Exchanger.
- **Coated tubes**, both bare and finned, do not work and will fail.
- **Standard metallurgy** is satisfactory only for natural gas firing when heating water to a maximum temperature of ~ 130F.

THE REASONS FOR THE CHX HEAT EXCHANGER TEFLON COVERED TUBE DESIGN

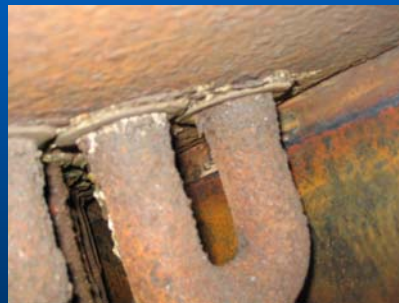
- **REASON # 1** - The next 17 slides provide **documented independent research** from **Internationally recognized Laboratories, Associations, and Corporations** addressing:
 - Sources of corrosion
 - Corrosion test results
 - Test results for coatings
- **REASON # 2** – See Reason # 1, above.
- **REASON # 3** – See Reason # 2, above.
- **REASON # 4** – Knowledge of Competitor's failures.

Why Not Coatings?

- **EPRI Materials Evaluation CS-3700**
 - “**All of the coatings** failed in some manner during the exposures”
- **Argonne National Laboratory ANL-83-81**
 - “**Several plastics and several coating methods** were used to coat various finned and corrugated tubes... It is clear that such a thin coating does not give adequate protection.”
- **EPRI Condensing Heat Exchanger Demonstration Project**
 - “**It is well documented that coatings**, even Teflon coatings, do not provide the level of protection required to eliminate corrosion from the acids formed when combustion gases condense.”

Design Considerations

- **Particulate Accumulation**
- **Coating Failure**
- **Loss of Corrosion Protection**
- **Rapid Failure From Flue Gas Corrosive Attack**
- **This photo illustrates the failure of a competitor's tube to tube-sheet seal**



IS FLUE GAS SIDE CORROSION REALLY A CONCERN WHEN FIRING ON NATURAL GAS?

- Why Not Use Finned Tube?
- Sources of Corrosion & Test Results
- Coatings vs. Coverings
- Independent Testing & Evaluation

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Why Not Finned Tube?

Experience Database

David S. Hibbard and Associates, Metallurgical Consultants, 3/18/86

304L SS with carbon steel fins fails in 4 months on natural gas fired application - Heat exchanger manufacturer suggests replacement with Carpenter 7-Mo+

- Recommended against using finned tubes since sections of the heat exchanger were condensing acid only and not being diluted with condensate.
 - Fin base is a stress riser point for stress cracking
 - If fins are not integral, there is a crevice
 - Expect acid concentrations of 75% and higher
 - Finned tubes are not suitable for condensate drainage
 - **FINNED TUBES CANNOT BE COVERED**

Sources of Corrosion & Test Results

Battelle-Columbus Laboratories Condensing Heat Exchanger Systems – Oct 1985 Phase IV

- Phase III work of this study showed high corrosion rates from No. 2 oil firing was caused by chlorides
- Phase IV work – Natural Gas Firing
 - Chloride ion **concentrates to >100,000 ppm (10%) prior to dry out**
 - Al and SS alloys experienced significant corrosion unless the tube surface was condensing water vapor
 - Initial acid condensing zones have very aggressive corrosivity conditions even under steady-state operation

Sources of Corrosion & Test Results

Condensate pH exiting the outlet drain from a Condensing Heat Exchanger –

- pH 2.2 for 2% S No. 6 Oil Fired
 - pH 3.8 for Natural Gas Fired
- What do you suspect the pH is –**
- At the point of onset of condensation?
 - At the moment of dry-out?

Sources of Corrosion & Test Results

GATC, BCL, AGA, GRI - Research on Heat-Exchanger Corrosion, September 1984

- Factors influencing local condensate corrosivity are design dependent making the corrosivity issue highly unit-specific
 - Crevices create oxygen deficient zones and a reducing environment
 - Early condensate locations result in high corrosivity
 - Corrosivity increases due to cyclic dry-out
- Chlorides and sulfur were found in all corrosion deposits
- Modes of attack are: General, Pitting, Weld Crevice, Joint Crevice, and Stress Corrosion
- The most corrosive location is the point of onset of acid condensation

Sources of Corrosion & Test Results

- Canadian Gas Research Institute – Evaluation of Stainless Steel Materials for Resisting Chloride-Induced Corrosion in Condensing & Partially Condensing Gas Fired Units
- “A total of 20 candidate materials selected from the four principal classes of stainless steels were evaluated for resistance to chloride-induced corrosion from combustion air in condensing and partially condensing gas-fired units”
- The commodity grade stainless steels types 316, 304, 304L, and 430 appeared acceptable in the fully condensing zones, however, for partially condensing operation showed failures in as little as one year.
- “The corrosion experienced in a condensing heat exchanger is strongly influenced by its geometry.”

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Test Results

GATC, BCL, AGA, GRI - Research on Heat-Exchanger Corrosion, September 1984

Materials that exhibited **SIGNIFICANT CORROSIVE ATTACK in one or more corrosion modes:**

Austenitic Stainless Steels	- 304, 304L, 309, 310, & 316L
Ferritic Stainless Steels	- 409, 430, 439, 444, & ELI-T18-2
Duplex Stainless Steels	- 329, 44LN, 2205, & Ferralium
Nickel-based Alloys	- 800, 600, 6-8, & 671
All Aluminum and Copper-Based Alloys Tested	
Duriron	

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Sources of Corrosion & Test Results

Argonne National Laboratory – Plastic Heat Exchangers, 9/83

“The liquid which condenses has a much higher concentration than the flue gas does. When the vapor condenses, **the acid condenses first**, with relatively little water, producing a very concentrated acid solution. For example, a flue gas with 10% water vapor and 50 ppm acid vapor will produce a condensate approximately 84 weight % sulfuric acid.”

- Teflon has a slippery non-stick surface expected to resist fouling, is easy to clean, and has excellent acid resistance
- Finned tube coatings (including Teflon) had inadequate corrosion protection on the fin edges and experienced severe corrosion and blistering.
- **Teflon Shrink Film Performance was EXCELLENT!**

Sources of Corrosion & Test Results

Battelle-Columbus Laboratories Condensing Heat Exchanger Systems – August 1985 Phase IV

“During transient operation of heating equipment, there often exists some surface area of a condensing heat exchanger that experiences a temperature transition from below the local dew-point to above the dew-point. Depending on the design, this condition provides the opportunity for condensate droplets that are large enough to be visible to produce extremely high concentrations of acid ions. It may seem that the initial concentration is unimportant; whether it is 0.1 ppm or 100 ppm to start with, it still reaches about 100,000 ppm (**10% acid**) at the moment of dry-out.”

Sources of Corrosion & Test Results

Condensate pH exiting the outlet drain from a Condensing Heat Exchanger –

- pH 2.2 for 2% S No. 6 Oil Fired
- pH 3.8 for Natural Gas Fired

NOW what do you suspect the pH is –

- At the point of onset of condensation?
- At the moment of dry-out?

Sources of Corrosion & Test Results

Gas Research Institute – Technology Report for Corrosion-Resistant Condensing Heat Exchangers, October 1985.

“Those alloys that showed some corrosion resistance might provide adequate service in an environment which consists of stable conditions – i.e. continuously wet or dry zones. It has been shown, however, that these conditions **DO NOT EXIST** in a Condensing Heat Exchanger due to the changing operating conditions and shifting wet and dry zones.”

Coatings vs. Coverings

Battelle-Columbus Laboratory - Applications of Polymeric Materials For Condensing Heat Exchangers, Sept. 1983

- Coatings are sensitive to the presence of pinholes
- Thickness must be at least 10 mils
- **Coverings**, rather than coatings, **are pinhole free**
- Coatings depend on adhesion to the substrate

Independent Testing & Evaluation

Brookhaven National Laboratory Emissions and Thermal Efficiency Evaluation At A Flue Gas Condensing Economizer, June 1981

- **2% Sulfur No. 6 Oil Condensing Heat Exchanger Report**
 - Data From Evaluation of CHX Teflon Covered Design
- **Particulate Removal Efficiencies**
 - Soluble Particulate Removal – 19%; Insoluble Removal – 86%
 - TSP – 70%
- **Flue Gas Properties**
 - SO₂ for Oil Fired Applications – 980 ppm (Study Data)
 - Particulate for Oil Fired Applications – 85 mg/m³ (Study Data)

Independent Testing & Evaluation

Arthur D. Little - Performance Test Results on the B&W IFGT System, February 1992

- **Proven reliability based on a detailed evaluation of three CHX installations for IBM, US Army, NYSERDA**
- **Testing directed toward removal efficiency for particulates, SO_x, and HCl.**
- **Condensation without corrosion is made possible by Teflon covered tubes and walls**

Independent Testing & Evaluation

Babcock & Wilcox - Pilot Performance of the IFGT Condensing Heat Exchanger, March 1995

- Teflon ensures adequate material lifetime in the corrosive condensing environment
- Demonstrated performance and lifetime
- Alloy C70600 and 304L SS are commonly used tube materials in boiler water applications
- Particulate mass loading of 1-30 grams/MMBtu (1.2-30 pph)

Conclusion, Summary, and Performance Example

YOU BE THE JUDGE

Years of independent research and history have proven that for conventional finned tube metallurgy to work in a condensing heat exchanger application –

- The fuel fired **MUST** be natural gas and
- The water outlet temperature **MUST** be limited to ~ 130F to make certain that the entire heat exchanger is condensing in order to prevent the acid concentration effect.

For this application and this application ONLY, CHX will offer an extended surface SS tube design.

CHX Condensing Heat Exchanger

- **2X the Price of Others For Good Reason – Materials of Construction, AND**
 - 31 years in business
 - 5 years of R&D
 - 25+ years of references
 - 30 years of design experience
 - Track record based warranty of five (5) years
 - **ALL MANUFACTURING DONE IN HOUSE**
 - **CORROSION IMPERVIOUS** bare tube design

CHX Heat Recovery – Proven Track Record in The Toughest Applications

Early High Sulfur Fuel Oil Applications -

- Morgan Linen – 26 years
- IBM – 23 years
- Quail Uniform – 22 years
- Friskies – 22 years
- Rochester District Heating – 20 years
- Morflex Chemicals – 19 years
- LAACP – 18 Years

CHX Heat Recovery – Best In Class

- Teflon Covered Tubes
- Teflon Covered Side Sheets
- Teflon Tube Seals
- 31 Proven Years
 - Experience
 - Product
 - People



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<p>COMPANY LOCATION CHX PROPOSAL NO. REPRESENTATIVE PROPOSAL STATUS PROPOSAL DATE APPLICATION TOTAL BOILER CAPACITY</p>	<p>PULP & PAPER MILL USA 080505 PPE EXAMPLE AUGUST 5, 2005 HEAT PROCESS WATER 150,000 LBS/HOUR</p>
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CASE 1 OF 1 CHX SYSTEM MODEL # 336-100 DW 12

AVERAGE OPERATION

<p>AVERAGE STEAM LOAD FOR CASE AVAILABLE FLUE GAS MASS BOILER FEEDWATER TEMPERATURE STEAM PRESSURE (750 DEG. F) EXCESS COMBUSTION AIR FLUE GAS TEMP @ SOURCE MAXIMUM WATERFLOW AVAILABLE TO HX FLUE GAS WATER VAPOR DEWPOINT FLUE GAS DENSITY SPECIFIC HEAT OF FLUE GAS HOURS OF OPERATION FOR CASE FUEL FIRED FUEL COST EXISTING FUEL TO STEAM EFFICIENCY EXISTING THERMAL EFFICIENCY</p>	<p>DESIGN PARAMETERS 110,000 LBS/HOUR 131,157 LBS/HOUR 270.0 DEGREES F. 850 PSIG 11.45 PERCENT 356.0 DEGREES F. 220 GAL/MIN 135.7 DEGREES F. 0.0490 LBS/CU.F.T. 0.2671 BTU/LB DEG. F. 8760 HOURS/YEAR NATURAL GAS 87.00 DOLLARS/MM BTU 81.2% PERCENT 82.84 PERCENT</p>
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HEAT EXCHANGER PERFORMANCE

<p>FLUE GAS MASS FLOW @ HX INLET FLUE GAS FLOW @ INLET TO HX FLUE GAS INLET TEMP FLUE GAS OUTLET TEMPERATURE WATERFLOW THROUGH HX WATER INLET TEMPERATURE WATER OUTLET TEMPERATURE SENSIBLE HEAT RECOVERED LATENT HEAT RECOVERED TOTAL HEAT RECOVERY SAVINGS FOR THIS CASE</p>	<p>131,157 LBS/HOUR 44,570 ACFM 356.0 DEGREES F. 128.3 DEGREES F. 220.0 GAL/MIN 50.0 DEGREES F. 188.9 DEGREES F. 7,978,429 BTUS/HOUR 4,918,448 BTUS/HOUR 14,896,877 BTUS/HOUR \$1,124,548 DOLLARS/YEAR</p>
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ENGINEERING DATA

<p>NEW BOILER FUEL TO STEAM EFFICIENCY NEW THERMAL EFFICIENCY EFFICIENCY INCREASE FUEL SAVINGS WATERSIDE PRESSURE DROP THEORETICAL FAN POWER HEAT EXCHANGER FLUE GAS PRESSURE DROP PLENUM, DUCT AND BREACHING LOSS CONDENSATE FLOW RATE</p>	<p>90.99 PERCENT 92.60 PERCENT 9.76 POINTS 12.02 PERCENT 13.32 PSIG 77 HORSEPOWER 7.31 IN. W.C. 0.88 IN. W.C. 13.7 GAL/MIN</p>
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NATURAL GAS ANALYSIS USED FOR THIS CASE

%C	%H2	%N2	%O2	%S	%H2O	%ASH	%HHV
75.20	23.50	1.30	0.00	0.00	0.00	0.00	23000

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SYSTEM SCOPE & PRICE

- CHX HEAT EXCHANGER WITH
 - SS Inlet & FRP Outlet Plenums
 - Inlet & Outlet Water Manifolds
 - SS Inlet Screen with Automatic Wash System
 - CHX Fan, Motor, & Inlet Box
 - Fan Discharge Transition
 - Unitary System Base
 - Complete Instrument & Control Package
 - Flue Gas Flow Control Damper(s)
 - Engineering, Design, AutoCAD Drawings, Documentation, & Manuals
 - **FACTORY** Assembly Supervision, Start up, & Training
- **US\$650,000**

