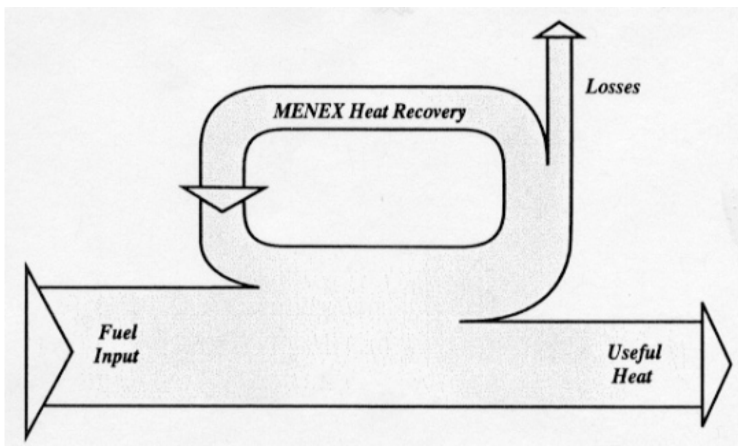
Condensing Economizers Workshop
Enbridge Gas, Toronto

MENEX Boiler Plant Heat Recovery Technologies

Prepared by: Jozo Martinovic, M A Sc, P Eng



MENEX Innovative Solutions

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MENEX INC.

683 Louis Drive
Mississauga, Ontario, Canada L5B 2V4
Tel: (905) 276-1774, Fax: (905) 276-8871
e-mail: menex.jozo@bellnet.ca

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1. Introduction

At boiler plants fired with natural gas, a significant amount of heat is wasted with flue gases, in two forms:
- Sensible heat, as the flue gas is exhausted at about 300ºF, in order to avoid condensation and corrosion.
- Latent heat of combustion-generated water vapor contained in the flue gases.

In addition to flue gas heat losses as major losses, other smaller heat losses occur in boiler plants, which are:
- Latent heat of the deaerator vent steam, which is rarely recovered.
- Boiler blowdown heat losses, which are typically recovered.
- Radiation heat losses; keeping boiler insulation in good conditions can reduce these losses.

As the flue gases are exhausted at higher temperatures, there is a great opportunity for recovery of the remaining sensible and latent heat exhausted in the flue gases. MENEX is offering a *Two-Stage Heat Recovery* (TSHR) System, as well as Heat Recovery using *Condensing Economizers*.

2. General Overview

Energy costs continue to rise and *global warming* has become a very serious problem. As boiler plants are major energy users, heat recovery at boiler plants is essential. However, very little hard information has been published on boiler plant heat recovery. We hope that the information provided in this *Paper* will help potential clients to gain a basic understating of the different heat recovery technologies available.

The main challenge with boiler plant heat recovery is the balance between the recoverable waste heat contained in flue gas - the *heat source* - and the demand for recoverable waste heat at the *heat sinks* - boiler makeup (BM) and process-washing (PW) water. The *heat source* is usually much greater than the combined *heat sinks*.

All our process design and other design work are based on sound thermodynamic principles. We construct a psychrometeric chart for the flue gas at each site and optimize the elementary process for each heat recovery step achieving optimum performance and maximum heat recovery.

By offering three different and competing technologies, each of which are the principal technologies used in heat recovery at boiler plants, we evaluate all heat recovery options in order to determine a *perfect solution* for each boiler plant case, based on optimum thermodynamic principles.

This *Technical Paper* provides a brief system description and preliminary performance of the MENEX *Boiler Plant Heat Recovery Technologies*. We offer three different technologies for boiler flue gas heat recovery:

Direct-Contact Heat Recovery (DCHR) system using a packed spray tower where cold spray water cools flue gas below its dew point. Water vapor contained in the flue gas is condensed and its latent heat is recovered. The DCHR system is shown in Figure 1.

Two Stage Heat Recovery (TSHR) system, which incorporates a new *Secondary Economizer* as the first-stage to recover the sensible heat and the MENEX *DCHR Unit* as the second-stage to primarily recover latent heat. BM water and/or PW water are *first preheated* in the DCHR unit and *then reheated* in the secondary economizer. The TSHR system is shown in Figure 2.

Two-Stage Condensing Economizers in which both sensible and the latent heat are recovered indirectly using finned tubes. The first-stage is our secondary economizer, the same as used in our TSHR system. The second-stage is a *truly condensing economizer*. Cold BM and/or PW water and condensate return are preheated and reheated in the condensing economizers.

3. System Performance - General

We construct a psychrometric chart for the flue gas at each site and use it to optimize each elementary psychrometric process step in order to maximize heat recovery. We also construct *Combustion Efficiency Charts, Energy/Sankey Diagrams* and provide summary *Tables* in order to illustrate the performances of our systems.

About 90% of the total natural gas heat input (HHV) represents sensible and about 10% latent heat. The latent heat could be recovered only if the gas is cooled below its dew-point and if the water vapor is condensed. The total fuel energy input can be split into two parts: a) available heat (about 80%) used for steam generation and for other boiler losses, and b) heat still remaining in flue gases (about 20%).

Hot flue gas, at about 300ºF, still contain about 15.5% of the fuel energy and the combustion efficiency is about 84.5%. Thus, the flue gas represents a fairly good waste *heat source*. Cold BM water represents a *heat sink*, if the quantity of BM water is large enough and if it is not currently preheated using other waste heat. If BM water is 100% (no condensate return) and based on a *winter operation* when the average temperature of fresh water is about 45ºF, only a portion of the flue gas (about 56.5%) is needed to preheat the BM water. The excess hot flue gas could be utilized for other *heat sinks*, for cold process/washing (PW) water, etc.

4. MENEX *Direct-Contact Heat Recovery* (DCHR) System

As shown in Figure 1, the recovered waste heat is used for the preheating of cold BM and/or cold PW water. Hot gas is exhausted by a *new exhaust fan*, which directs it to a packed *Spray Tower* and to a new stack, or to existing stack(s). Only a portion of the flue gas is required to preheat BM water.

In the *Spray Tower*, cold spray water is sprayed on packing. The flue gas is cooled below its dew-point. Water vapor is condensed and its latent heat is recovered and absorbed by the spray water. The preheated spray water is slightly acidic due to absorption of CO_2. For this reason, the preheated spray water is pumped through a *heat exchanger* to transfer the recovered waste heat to cold BM and/or to PW water. Condensate is continuously bled off. Corrosion-resistant materials are used for all parts in contact with saturated gas and with acidic spray water. Acidic condensate can be treated and recycled, can be directly used as the makeup water at cooling towers to control precipitation, or it can be diluted, neutralized and severed.

In some cases, when slightly acidic preheated spray water can be directly utilized as preheated process makeup or washing water, a *once-through* spray tower can be employed. Preheated water is pumped to the users.

In the spray tower, the flue gas is cooled to about 65ºF. The combustion efficiency of scrubbed gas is close to 99%, i.e. a tiny amount of heat (about 1.0% of HHV) is still exhausted with the scrubbed gas.

5. MENEX *Two-Stage Heat Recovery* (TSHR) System

There are many boiler plants with inefficient existing economizers and flue gases are exhausted at over 350°F. There are also boiler plants that do not employ economizers, where the flue gases are exhausted at a temperature of 450-600°F. In all these cases, we use our *Two-Stage Heat Recovery* (TSHR) system, where a new *secondary economizer* is used as the *first stage* to recover the bulk of the remaining sensible heat and our *DCHR unit* is used as the *second stage* to recover primarily latent heat. Cold BM water and/or cold PW water are *first preheated* in the second stage (in DCHR) and *then reheated* in the first stage (in Economizer #1) to its *final temperature*, see the *Flow Schematics*, Figure 2. Also, the second economizer may be used to reheat condensate return and/or preheat/evaporate other process water and liquids. In the MENEX *secondary economizer*, the flue gas is cooled down to 150-160°F, just about 20 °F above its dew-point, using *carbon-steel finned tubes*. We have a ***specific design feature***, which allows operation at low gas temperatures without any corrosion of carbon steel tubing.

As indicated, the entire quantity of hot flue gas is passed through the new *secondary economizer* and is cooled from 300ºF to about 155ºF. At 100% BM water, only about 56.5% of the cooled gas is needed and passed through the *DCHR unit* and is cooled to about 65ºF during winter.

A new *exhaust fan* is used to exhaust the cooled flue gas at 150-160°F from the secondary economizer and direct it to the spray tower. The new fan handles cooled (not saturated) gas, minimizing fan brake horsepower.

Combined-cycle plants could be attractive for our TSHR system. If HRSGs use supplementary firing, which increases humidity in the gas turbine exhaust gases, the gases become attractive for DCHR and our secondary economizer. At combined-cycle plants using condensing steam turbines, condensate is returned at 115-120°F, which can be reheated in our secondary economizers, i.e. in Economizer #2, see Figure 2.

Our *secondary economizer* could be implemented as a stand-alone project at boilers and HRSGs exhausting flue gases at 275ºF-400ºF, achieving fuel savings of about 3.0-5.0%. The simple payback could be less than 1.5 yrs.

As indicated above, hot flue gas at about 300ºF enters the new *Secondary Economizer*, where it is cooled to about 155ºF. Its combustion efficiency is increased to about 88%, i.e. by about 3.5%. BM water is *reheated* in the new economizer is close to 155 ºF.

Cooled gas, exhausted from the secondary economizer at 155 ºF, is split into two streams. Excess cooled gas is directed to the existing stack(s). A large portion of cooled gas (about 56.5%) is directed to the spray tower for heat recovery, where it is cooled to about 65 ºF. The combustion efficiency of scrubbed gas is close to 99%.

Table 1 provides key operating parameters and main performance data, including heat recovery rates, equivalent fuel savings and combustion efficiency gain.

6. MENEX Condensing Economizer

Our *Condensing Economizers* are somewhat different than condensing economizers offered by our competitors. It is a two-stage package. The first-stage is exactly same as the secondary ecocomizer in our TSHR system and the second-stage is a *true condensing economizer*, as it replaces the DCHR unit, see Figure 2.

Our condensing economizer unit is fabricated from *stainless-steel finned tubes*, not from stainless steel tubes with aluminum fins. Aluminum and stainless steel have different thermal expansion coefficients, which may cause cracks. Also, soft aluminum fins can be easily damaged. Our condensing economizer is significantly more efficient, less expensive and has a longer life than the economizers using *bare teflon-coated* tubes.

The first stage is our *secondary economizer* uses carbon-steel finned tubes and cools hot flue gas to about 155ºF. Cooled gas at 155ºF enters the second-stage, the *condensing unit*, and is cooled to about 106ºF. Cold BM water is *first preheated* from 45ºF to about 128ºF in the second stage and is *then reheated* to the final temperature of about 160ºF in the first stage.

Combustion efficiency would be increased from 84.5% to about 88% in the first stage and from 88 % to 98.3% in the second stage during winter. However, as not all cooled gas is scrubbed, the combined efficiency would be about 94.9%.

7. General Comments

Sections 1, 2, 3, 4 and 5, together with *Flow Schematics* shown in Figure 1 and 2, provide the overall concepts and general description of our DCHR and TSHR systems, and our Condensing Economizer.

In either case, hot flue gas at 300ºF is the same *heat source*, containing about 15.5% waste heat. The question is, which technology should be applied to recover most of waste heat and at a higher quality.

Implementation of the MENEX ITSHR/DCHR systems and condensing economizers also results in significant environmental benefits. The reduction of greenhouse gas emissions is directly proportional to the fuel savings achieved. In addition, any pollutants that are soluble in water (such as NO_2) will be scrubbed off in the spray tower.

Table 1. Summary of the TSHR System Operation During Winter

Item	Description	Units	Quantity
1	Steam Generation (Steam: 250 psig, sat.)	lb/h	100,000
2	BM Water, incl. 5% Boiler Blowdown	lb/h	105,300
3	Temperature of Cold Fresh Water	°F	45
4	Cooled Gas Temperature	°F	155
5	Cooled Gas to Spray Tower, % of Total Gas	%	66.9
6	Temperature of Scrubbed Gas	°F	65
7	Approx. Temperature of Reheated BM Water	ºF	155
8	Heat Recovery: At New Economizer	Btu/h	2,666,000
9	At Spray Tower	Btu/h	8,730,000
10	Total Heat Recovery	Btu/h	11,396,000
11	Equivalent Heat Savings	Btu/h	13,486,000

Notes:

1. Only operating data for the winter operation are given in Table 1.
2. The information in Table 1 are given for a steam generation of 100,000 lb/h of steam.
3. Equivalent Heat Saving in Item 10 is based on the combustion efficiency of 84.5%, at the flue gas temperature of 300 °F and excess combustion air of 15%.

MENEX DCHR/TSHR SYSTEMS
FLOW SCHEMATICS

MENEX INC.
Missassauga, Ontario
Canada

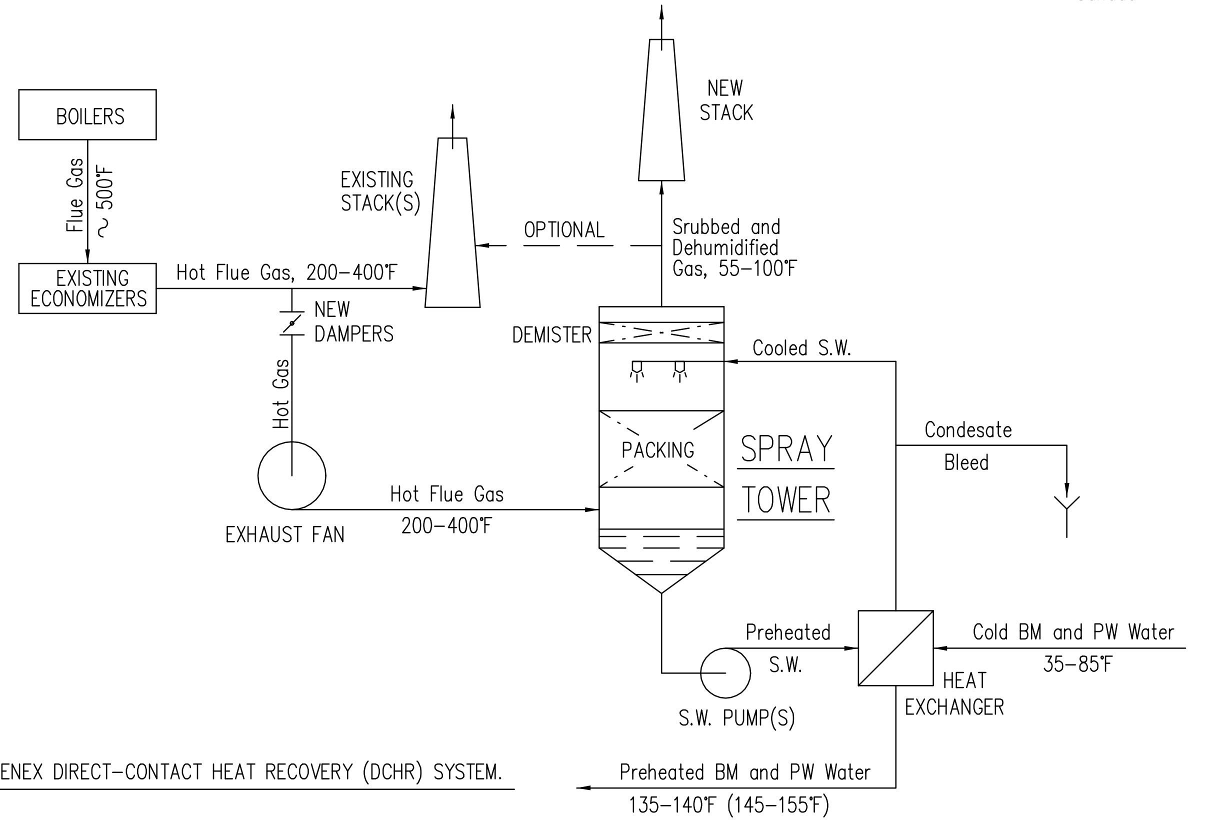

FIGURE 1. MENEX DIRECT-CONTACT HEAT RECOVERY (DCHR) SYSTEM.

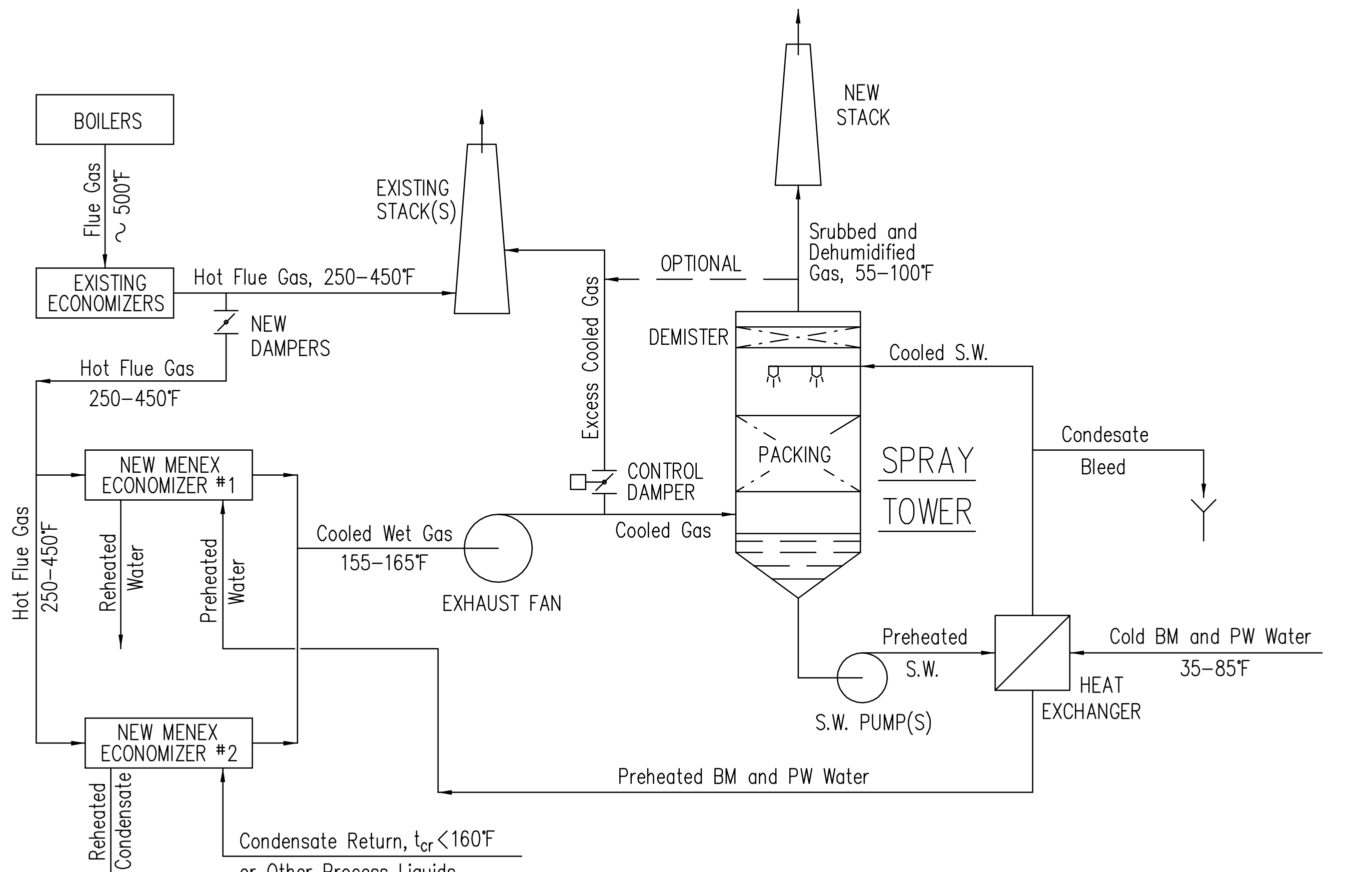

FIGURE 2. MENEX TWO-STAGE HEAT RECOVERY (TSHR) SYSTEM.