

## CASE STUDY

# USE OF CONDENSING ECONOMIZERS FOR ENERGY RECOVERY FROM EXHAUST GASES

### Introduction

In most industrial or commercial heating processes, a large amount of the heat energy that is produced through fuel combustion is underutilized and wasted in the exhaust gas streams. For boilers, turbines and dryers the typical fuel utilization efficiency is 80% (plus or minus 5%). Wasting 20% of the fuel that is fired is inefficient and extremely costly. It is also unnecessary. Very large quantities of this unused energy are recoverable and reusable. Now, even the portions of this unused energy that were previously thought to be unrecoverable can now be returned for beneficial use. The method now gaining wide spread use for recovery of this energy is called a Condensing Economizer.

Throughout the industrial, institutional and commercial heating sectors there are exhaust gas sources that contain both high grade and low grade heat energy. Both types of heat are valuable and can be reused. Figure 1 shows the vast quantities of heat energy that is currently being wasted, broken down by industry sector and shaded to show the breakdown between high and low grade heat. In some industrial sectors as much as 74% of the heat input energy is wasted in exhaust gas.

% Purchased Fuel Lost As Waste Heat

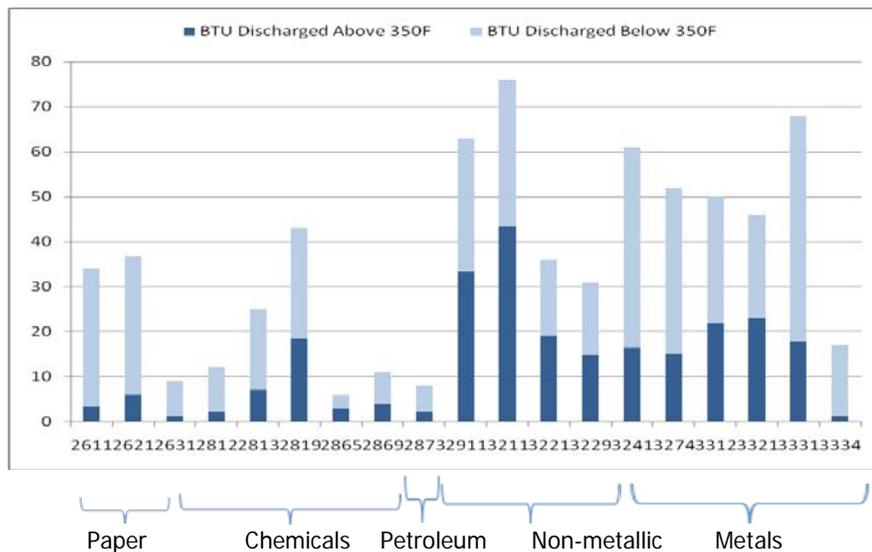
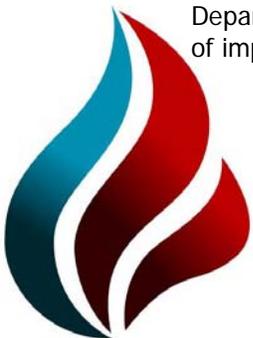


Figure 1

With such large amounts of input energy being wasted, it is easy to understand why the United States Department of Energy has identified waste heat recovery as the single largest opportunity in the pursuit of improved energy efficiency.



As the graph in Figure 2 illustrates, the possible savings through increased rates of heat recovery are more than double those related to other efficiency measures. With such large losses, and the availability of proven methods to recover and reuse this energy, the economic and emission reduction opportunities through heat recovery are readily apparent and exciting. There are many heat recovery methods available and utilized by industrial and institutional heat sources; however Condensing Economizers are widely recognized as the most effective method of heat recovery.

### Possible savings by application (TeraBTUs/year)

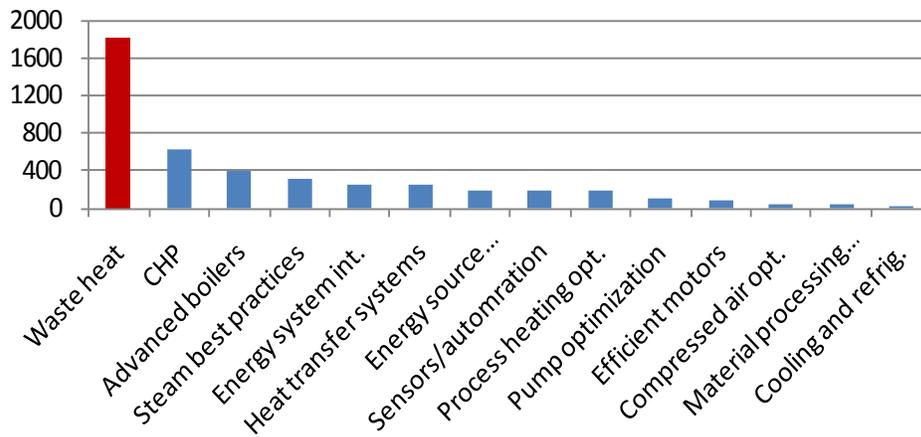


Figure 2

### Condensing Economizers

For most heat sources – boilers, dryers, ovens, etc., there is component of waste or underutilized energy, energy that is consumed but not utilized. This is often the case due to a functional disconnect between the processes being served by the thermal energy being produced and the availability of the energy still remaining the exhaust gas. For example, a boiler that is delivering steam to serve several industrial processes would traditionally have been designed to provide all of the plant heating requirements from steam. Now, by recovering heat from the boiler exhaust gas it is feasible to take the heating duty of one of the processes and provide that heating duty from recovered waste heat, rather than steam. By reducing the steam consumption, the amount of fuel required by the boilers is reduced which creates a dollar savings incentive and a commensurate reduction in emissions is also achieved. Boiler make up water is an easy example: when a process loses steam (direct injection, blowdown, etc.) the boiler plant must make up for this lost water by adding in fresh water. Traditionally this water would be added to the deaerator cold, or blended in with condensate return. By pre-heating this make up water using the energy in the exhaust gas, less fuel will be used in the boiler to heat the cold water and a savings is created.





When a flue gas contains moisture, which all hydrogen based fuel exhausts do, the heat available for recovery from the is of two types: sensible and latent heat. During the combustion process of hydrogen based fuels such as natural gas, the hydrogen in the fuel is combined chemically with the oxygen in the combustion air, this creates water which is instantly vaporized and adds water vapor content to the exhaust gas. The energy consumed by the vaporization of this water is called the "latent heat of vaporization". The vaporization process consumes approximately 17% of the input energy by volume. And this energy cannot be recovered without extracting enough energy from the flue gas to cool it to below the water vapor dew point. A condensing economizer system can complete this task of recovering the latent energy and will also recover the sensible heat energy above the water vapor dew point as well.

Figure 3, below, illustrates the increased rate of heat transfer and efficiency increase once the heat recovery process enters the latent recovery zone. The red portion of the heat transfer curve represents the sensible heat transfer rate as it relates to the exit flue gas temperature. The blue portion of the curve represents the sensible *and* latent heat transfer rate. The heat transfer rate increases exponentially once the heat transfer includes latent heat energy recovery. Also illustrated is the increase in over all fuel utilization efficiency. The pink dotted line illustrates that when a flue gas is cooled to 105 °F and the recovered energy is reutilized, the resulting operating efficiency of the fired equipment (boilers, etc.) is increased to 95%. A normal exit flue gas temperature of 450°F represents an operating efficiency of 80%, so a 15% increase in fuel efficiency is a substantial gain!

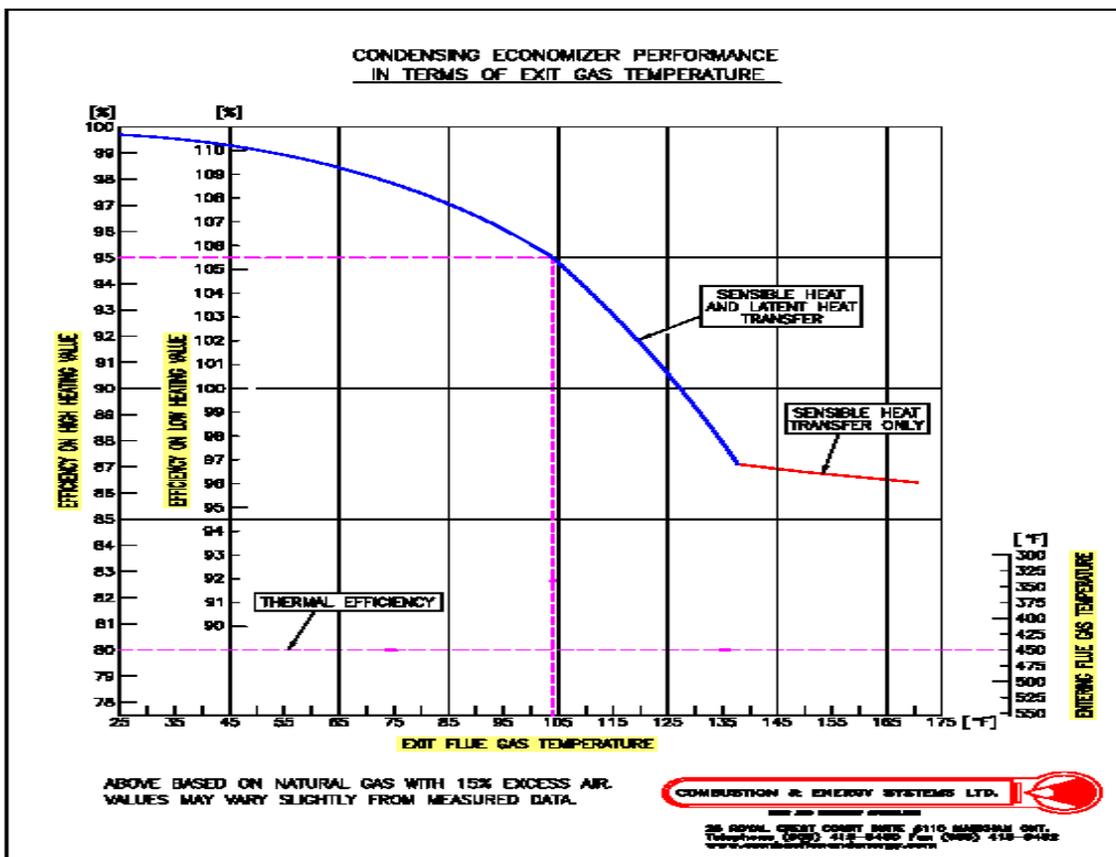
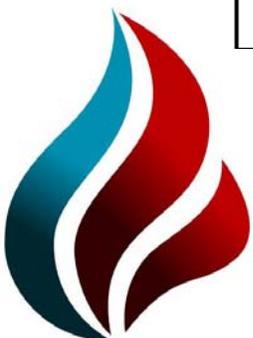


Figure 3



A condensing economizer gathers the waste heat from singular or multiple heat sources and transfers the wasted heat energy to a heat sink in the plant that would otherwise consume purchased or live energy to provide the heating duty. By utilizing waste heat for this purpose, less fuel consumption is required and an overall fuel cost savings and emission reduction target is achieved.

Traditional heat recovery methods limited their heat recovery and avoided by a wide margin cooling the flue gases to the water vapor dew point. This was done in order to avoid the corrosive effects that the flue gas condensate will create. Advancements in metallurgy and heat recovery methodology now allow for this energy to be recovered and the fuel cost savings realized. The ConDex Condensing Economizer System was one of the earliest fully condensing economizer systems to attain commercial viability in the market through rigorous testing and successful field applications which have led to wide spread acceptance for reliability and durability.

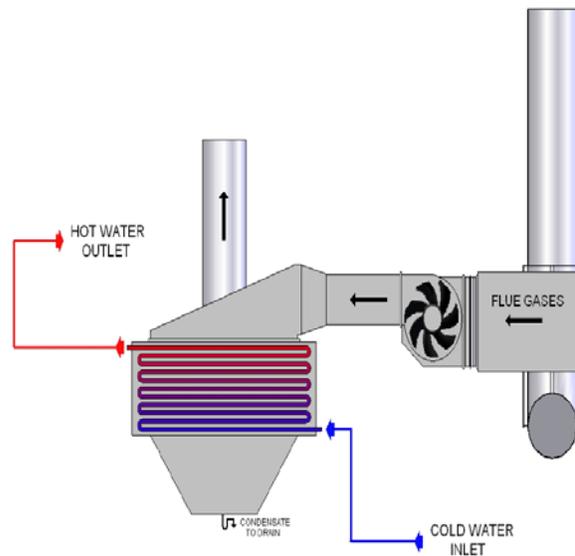


Figure 4

By heating cold process fluids such as boiler make up water, process water, etc. the ConDex system can recover both sensible and latent heat and put it to substantive work that would otherwise require the use of purchased energy. The image in Figure 4 above summarizes how the ConDex system recovers and transfers the waste heat energy. The system uses counter current heat transfer flow, where incoming fluid enters the exchanger at the bottom and is heated as it travels upwards against the hotter flue gases. Because some of the tubes in the exchanger are below the water vapor dew point temperature, the flue gas water vapor begins to condense and latent heat is recaptured in addition to the sensible heat. The tubes keep the water being heated separate from the flue gas which avoids contamination of the water. The indirect contact aspect also allows the system to recover greater amounts of heat and heat the water to higher temperature than the direct contact, spray tower type of flue gas heat recovery system.

The system uses a fan to convey the flue gas away from its normal pathway out of the existing stack which protects it against the colder flue gas and allows for the flue gas condensate water to be collected for potential reuse.





the flue gas which allows for a more precise level of control of the steam output, while not affecting the electrical generation capacity of the turbine.

Graphic Packaging recognized that there was considerable heat (thermal) energy being exhausted out of the turbine stack and approached ConDex Condensing Economizers about exploring the potential recovery and reuse opportunities for this wasted energy. The initial phases of the investigation centered around finding plant processes that were using steam to heat liquids that could otherwise be heated with recovered energy from the turbine exhaust. The plant personnel forwarded the idea to investigate using the recovered energy to heat the mill paper machine water. The investigation revealed that the mill water was consuming approximately 25,000 lb/hr of live steam energy to maintain the required temperature of the water. A recovery balance investigation by ConDex confirmed that the turbine flue gas contained enough energy to fulfill this heat requirement and create a substantial savings opportunity.

By using the recovered energy to heat the water, less steam output would be required from the HRSG. This would allow the plant to turn down the fuel input to the duct burners, as less energy would be required in that section and create the opportunity for substantial fuel expenditure savings as well as a significant associated emissions reduction ( $\text{CO}_2$ ,  $\text{NO}_x$ ). By pre-heating the mill water, less steam would be required from the steam generator which would allow the plant to turn down the amount of fuel sent to the duct burners which would in turn generate a substantial fuel expenditure savings. This is what the plant decided to do.

In addition to heating the paper mill water, the investigation also revealed that additional savings opportunities were available by heating the HRSG make up water. Instead of sending steam to the deaerator to heat the incoming cold fresh water, recovered energy, even after the mill water heating section, was available for this process as well. The plant decided to immediately undertake the heat recovery for the mill water and contracted ConDex to design the system.



Figure 6



Figure 7

The ConDex condensing economizer is a stand-alone heat recovery system that attached to the existing turbine/HRSG exhaust stack. As shown in Figures 6 & 7 above, the ConDex system uses a large fan to pull the flue gases away from its current pathway up the existing stack and sends the hot gases to the ConDex exchanger to recover and transfer heat to the cold process water.



The paper machine water plays an important role in the paper making process and has a direct effect on the speed that the paper machine can operate at. By maintaining the water temperature at higher temperatures the machine can operate faster and produce more paper in less time. In order to maintain the temperature, the water is sent to the condensing heat recovery system from the coldest section, and looped back to maintain the target. This sends the coldest water to the heat recovery system. Because the temperature of the water is below the water vapor dew point of the turbine exhaust gas, the water vapor condenses and turns back to a liquid state and releases the latent heat of vaporization and transfers it to the process water. This requires that the system be comprised of robust metallurgy in order to withstand the flue gas condensate which becomes mildly acidic due to the absorption of CO<sub>2</sub> from the flue gas.

### Water Recovery

For every pound of natural gas combusted 2.25 pounds of water vapor is produced. This not only represents a significant amount of latent heat energy, but a significant amount of water that can also be recovered. Graphic Packaging is recovering 2.7 gallons per minute of water from the flue gas that would otherwise be lost to atmosphere. This water is recoverable and reusable post treatment for a variety of purposes. In many cases it is used also to blend with and neutralize steam generation blow down. Figure 9 shows a picture of the flue gas condensate water in its collection basin. As water is also a valuable resource, this is often a very important secondary benefit of condensing heat reclamation.



Figure 8

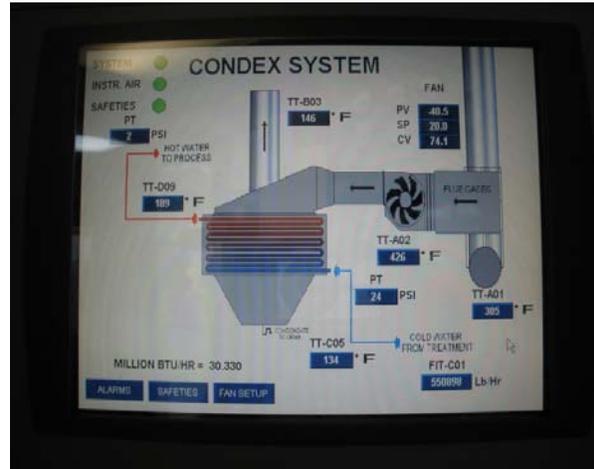


Figure 9

### System Control

The Condensing heat recovery system uses a variable speed drive on the fan that conveys the waste flue gas. Depending on the amount of heat required to heat the process fluid, the fan speed modulates accordingly. This maintains a balance between the availability of waste heat and the heat sink requirements. In order to maintain safe operation and offer zero impact on the operation of the turbine, there is also a fail-closed damper between the condensing economizer fan and the turbine exhaust stack. This damper can also modulate to allow greater or reduced flow rates of exhaust gas.





## System Performance

The ConDex condensing heat recovery system recovers over 25,000,000 Btu/hr at average load and heats 1,300 GPM of water up to 180 F. The flue gas is cooled from 405 °F down to 120 °F, which represents a substantial improvement in the plant fuel utilization efficiency, from approximately 81% up to a much improved 92%.

The Santa Clara Graphic Packaging plant as well as the entire Graphic Packaging organization were pleased with the overall results achieved by installing the condensing economizer system:

David W. Scheible, president and CEO of Graphic Packaging International, Inc. Said: "By adding state-of-the-art heat exchange and recovery technology to its cogeneration power plant, the paper mill can now capture and recycle valuable waste heat energy from the exhaust gases to reduce significantly the volume of natural gas required by the power plant to heat process water essential to paperboard production. Duct burner consumption of natural gas has been cut by 50 percent, eliminating more than 15,700 tons of CO<sub>2</sub> emissions annually, equivalent to removing 2,198 cars per year off the road or saving enough natural gas to annually heat over 5,000 homes.

"Every step to use energy more efficiently - like installing heat recovery technology to reduce natural gas demand at our Santa Clara mill - improves the environment and sustains important energy resources like natural gas. Starting in our workplace and in our communities, we must carefully examine what we do and find new ways to increase our energy efficiency by at least ten percent. This will make a difference in controlling energy costs, improving the U.S. economy and reducing greenhouse gas emissions – those are good outcomes for all of us,"

Additional information on the ConDex condensing economizer project at Graphic Packaging can be obtained at [www.condexenergy.com](http://www.condexenergy.com)

