An Approach to Energy Efficiency: A Focus on an Increased Operational Efficiency, Natural Resource Conservation and Carbon Footprint Reduction

A White Paper for the "Enercon Venturi Condensate Removal (EVCR) Unit"

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ABSTRACT

Commercial users world-wide are becoming more natural resource - energy and water - efficient in their day-to-day operations. Rising fuel costs, scarcity of water, and government mandates, have and will, continue to affect the “bottom line” of all commercial users. Due to the economic strains of today’s economy, all entities have implemented cost reducing cuts at every level through layoffs, postponement of capital projects, facility closures, and other actions. At the same time, facility managers are asked to stretch shrinking maintenance and capital budgets in any way possible.

Of all the expenses associated with an entity’s operating budget one of the most costly is energy, and steam is one of the most widely used sources of energy in commercial facilities. In fact, 35% - 40% of all natural gas produced in the US goes to the generation of steam related energy. For those facilities that rely on steam as an energy source, the reduction of wasted steam energy is critical - not only for the cost of replacing such energy but also for the costs related to wasted water, maintenance and damaged equipment issues, and operational inefficiencies. As agreed upon by all parties involved – commercial users, and government agencies – one of the largest, if not the single most responsible item, for such steam related losses are the operational results of mechanical steam traps. By converting to the Enercon Venturi Condensate Removal (EVCR) Unit, entities which use steam applications can experience significant economic and operational benefit from improved operational efficiency, lower energy costs, reduced maintenance and equipment related expenditures, and maximized water conservation.

THE PURPOSE OF A STEAM SYSTEM

The conceptual purpose of a steam system is relatively simple - deliver a desired quantity of energy to a specific application under a specific pressure when it is needed. Converting that concept to reality is an industrial design, engineering and operational challenge. As a result, significant inefficiencies arise in almost every steam system in operation.

In a steam system basic design, steam is generated in a boiler, travels along distributions lines to an operational process and is then either passed along to another operational process, vented as gas, dumped as condensate, or returned toward the boiler as condensate for reuse. The most efficient systems recycle the maximum amount of steam thus saving not only energy but water and associated chemical treatments.

For a steam system to operate properly, all condensate forming in the gas needs to be removed from the system as the gas proceeds through the distribution and operational system. In a perfect world, only dry BTU rich gas would reach the end process and none would be lost during condensate removal.

THE PURPOSE OF TRAPS IN A STEAM SYSTEM

Traps are a critical part of a steam system. Their function is to eliminate 100% of the condensate while keeping as much of the BTU rich gas in the distribution and process systems as possible. Located at low points, they drain condensate as steam gives up its latent heat and condenses.

ENGINEERING FACTS – CONVENTIONAL MECHANICAL STEAM TRAPS VERSUS FIXED ORIFICE TECHNOLOGY

Orifice Usage. Every type of condensate removal technology incorporates an orifice opening to purge the condensate from a steam system. The question is whether the purging through the orifice is done in a batch system with moving parts as in conventional mechanical trap technology or purged through a continuous flow technology with no moving parts as in fixed venturi orifice technology.

Conventional Mechanical Steam Trap Technology. The conventional method of eliminating condensate from a steam system is through the use of a mechanical steam trap. A mechanical steam trap is designed to open in the presence of condensate and close in the presence of steam through the utilization of internal floats, buckets, bimetals, bellows or discs. Mechanical steam traps cycle several times a minute which equates in 24-7 applications to millions of times a year. The average life expectancy for a mechanical steam trap (when considering all applications in a facility) is 3-5 years with certain functions requiring mechanical trap replacement every three months, or less.

This repetitive cycling of mechanical steam traps leads to functional failures which fall into one of two general categories;

1. Traps fail their function “open” - this results in BTU rich gas being lost to the condensate (cold) side of the system. This escaped energy results in monetary loses, operational inefficiencies, safety issues and water hammer in condensate returns systems.

2. Traps fail their function “closed” – this results in condensate remaining on the operational (hot) side of the system. Excess condensate that remains in the process side of the system reduces heat transfer, causes erosion, corrosion and water hammer in pipes, and damages equipment.

To purge the condensate it collects, a mechanical trap’s open/shut batch processing mechanism requires an opening significantly larger than the orifice that is required by a continuously flow condensate removal technology sized for the same application. Unfortunately, many times what is overlooked in analyzing the efficiency of mechanical steam traps is that they not only lose energy when they malfunction, but they also lose energy when they are operating correctly. This is due to the inherent design of a batch cycling system.

The functional design of a mechanical steam trap is such that every time it cycles, it not only releases the condensate that has built up, but it also allows energy in the form of hot gas to escape as well. The design irony is that the more a facility or plant increases operations toward full capacity, the more a mechanical steam trap will cycle and therefore the more energy it will lose. This energy loss puts additional pressure on the system to generate more steam.

Enercon's Drilled Venturi Orifice Condensate Removal Units. To enhance the physics of a fixed orifice, Enercon developed a drilled venturi orifice – the Enercon EVCR (Enercon Venturi Condensate Removal) Unit. The drilled venturi orifice opening is sized to the maximum condensate load at that point in the system. Since an orifice allows condensate to drain swiftly and continuously, the opening in a drilled venturi orifice unit is significantly smaller than the orifice opening in the batch purging system of conventional trap technology. Since it has no moving parts, its operational characteristics are fixed over its existence.

How a Fixed Orifice Unit Works. Since water is relatively dense and steam is lighter than air, an orifice has a high capacity for condensate and a low capacity for steam. This event, know as two-phase flow, explains the physical dynamics that prevent large quantities of steam escaping as loads drop below maximum. The physics are such that when 30 mph condensate and 600 mph steam try to pass through an orifice simultaneously, the denser, slower moving condensate chokes the steam flow in a highly efficient manner. Even a condensate load of 10-15% capacity will experience a markedly obstructed steam flow.

An additional physical event at work in the efficiency of a fixed orifice is the spatial relationship between condensate and steam. At sea level, it takes 700 lbs of condensate to occupy the same space as 1 lb of steam. The result is that even in the absence of any condensate, the amount of steam loss through a properly sized orifice is comparatively minor. For instance, at 10 psig, an orifice opening that would allow 50 lbs/hr of condensate through would not allow even 2 lbs/hr of dry steam through.

Enhanced Technological Advantage of an Enercon Venturi Orifice Design. A venturi effect is caused when a gas or fluid is forced to flow through a constricted section of pipe. In the presence of both gas and liquid, the physics of a venturi orifice is such that when the load drops below 100%, the solid condensate stream becomes a violently turbulent mixture of steam and water. This turbulence creates an additional barrier which significantly reduces any steam that could escape through the orifice as varying loads drop.

Obviously at 100% of load, which a properly sized orifice is calculated for, the orifice is fully and continuously occupied with condensate. Water is constantly purged and there is no room for steam to escape. As the load drops though, the question is how efficient is the turbulence from a venturi orifice in blocking the escape of gas.

The resultant turbulence from Enercon's EVCR Unit venturi design is such that even under constant system pressure (no controls), it isn't until condensate occupancy drops below 68% that any steam is lost. As loads continue to drop in a constant pressure system below this 68% threshold, the venturi design's enhanced turbulence continues to minimize the amount of steam loss such that even at 25% of condensate capacity, the steam lost through a properly sized Enercon venturi orifice is less than the steam lost through the orifice in a brand new, fully functioning mechanical steam trap.

The mathematics of the physics involved in a venturi orifice are such that in a 100-psi system producing 375 lbs/hr condensate, a drilled venturi designed Enercon EVCR Unit loses about 1.76 lbs/hr steam if the load drops to 25%. In comparison, at 100-psi, the Boiler Efficiency Institute's

'Leaking Steam Trap Discharge Rate' chart states that a failed conventional trap (1/8" internal orifice in the typical mechanical steam trap to accomplish the same function as the Enercon EVCR unit) would lose 52.8 lbs/hr (30 times the steam loss experienced by the Enercon EVCR unit).

It is rare in functioning facility operations that a load subject to a 75%, or greater, fluctuation is not subject to a control. If however such a rare instance should occur, a mechanical trap may outperform a fixed venturi orifice as condensate loads drop below 20% of capacity.

MAINTENANCE ADVANTAGES OF AN ENERCON EVCR UNIT VERSUS MECHANICAL STEAM TRAPS

As stated earlier, mechanical traps cycle several times a minute which equates to millions of times a year in a 24-7 application. Therefore it is understandable that the normal life expectancy of a mechanical trap is 3-5 years. The DOE, Office of Industrial Technologies, noted that

> *"In steam systems not maintained for 3-5 years, 15% to 30% of traps may have failed…(they therefore) Recommend weekly to monthly testing of hi-pressure systems (150+ psig); monthly to quarterly for medium (30-150 psig); and annually for low pressure (under 30 psig)."* ***DOE, Office of Industrial Technologies, Energy Tips (6-99).***

Even prior to complete failure, the wear and tear of the normal cycling of a mechanical trap leads to a degradation in performance. The result is that many mechanical traps in a plant are either operating at a sub-par performance level or completely failed. Given a 3-5 year average life expectancy, the 18% to 25% inefficiency in the condensate removal function that is experienced in the field in most plants is understandable.

The EVCR Unit technology on the other hand has no moving parts. The Enercon drilled venturi unit itself is made of 316 stainless steel. This construction eliminates erosion or corrosion issues and allows the unit to function exactly the same 15 years after installation as it did on day one. Therefore, once a steam system is size properly (as to each units venturi orifice openings) and balanced, it will experience the same line pressures, 100% condensate removal, and heat transfers fifteen years in the future as experienced on day one.

These expected results have been verified by field analysis of existing install projects. An example of such analysis was performed in 2007 on a small refinery plant that performed a complete conversion to Enercon EVCR technology in 1994. This customer stated that they had performed no maintenance on the Enercon EVCR units over the 13 year period that had transpired. At this facility, the line pressure was tested from the boiler to the end of the lines, individual traps were heat tested on both the hot (process) and cold (condensate removal) side, and a sample of drilled venturi orifices were removed and examined for wear and tear. The result of the inspection was that all pressures were identical for the length of each section of the line, all the heat tested EVCR units had the same identical readings as recorded on initial installation, and there was absolutely no wear or degradation noted in the pulled drilled venturi orifices.

ECONOMIC AND OPERATIONAL BENEFITS UPON CONVERSION TO ENERCON DRILLED VENTURI ORIFICE TECHNOLOGY

Improving the efficiency of condensate removal improves the overall quality and quantity of dry steam moving through the system. This higher quality steam results in significant improvement to operational economics while eliminating safety issues and conserving natural resources.

1. **Improvement in Operational Efficiency:** A steam system is designed to operate at its most efficient when 100% of the condensate is removed from the system while keeping 100% of the dry BTU rich gas on the process side. The further you get away from this goal the less efficient the system is. Due to the design, degradation, and failure reasons stated earlier, mechanical steam traps are inefficient in the accomplishment of this objective.

   The efficiency of a properly sized EVCR Unit, on the other hand, is such that facilities fully converting from conventional mechanical steam trap technology to Enercon EVCR Units have experienced increases ranging from 8% up to 35+% in operational efficiency. This improvement translates to such results as (a) exactly the same operating pressures along an entire section of line, (b) higher temperatures, (c) shorter start up times, (d) less capacity/cost to achieve the same results, and (e) more consistent and higher quality product. Whatever the designated process of the facility, the process functions better.

2. **Reduction in Energy Costs:** Energy savings is generated from several sources. First, to the extent you minimize steam loss, you obviously are reducing the amount of steam that you have to produce and therefore the energy related to such. Furthermore, by removing all condensate from the system, you save the energy spent moving the significantly heavier condensate through a system. Finally, to the extent that operational efficiencies are increased, it takes less steam to achieve the same results.

   Historical results from plants fully converting to the Enercon EVCR unit technology show average trapped steam fuel reduction in the range of 14% to 22%. This can translate to yearly energy savings in the range of $1,500 to $2,000 per trap at an energy cost of $7/mcf.

3. **Reduction in Steam System Maintenance Expense:** As noted above, mechanical steam traps have both a significant maintenance demand and cost in (a) their replacement and repair and (b) the personnel required for an ongoing program of identifying failed and failing traps. Failure to expend the costs related to either action will result in operational inefficiency, greater energy costs, increased safety issues, greater machine and system damage, and the waste of water.

   An EVCR Unit's lack of moving parts and 316 stainless steel design/construction eliminates its wearing out and failure. Therefore the maintenance related expenditures experienced with mechanical steam trap units are not required in systems completely converted to EVCR Units.

4. **Reduction in Water and Related Chemicals Usage:** Enercon achieves water conservation (and its related chemical treatment) through its technology and its technical services. First, the efficiency of the Enercon EVCR Units maximizes the water conservation of any system, as it is, in which they are installed. The amount depends on a multiple of factors such as whether the system is closed or open, steam is being vented, pipes are cracking due to condensate in the

process lines, etc. In many cases the water savings just from the installation of the EVCR Units will be significant.

The second manner in which Enercon achieves water conservation is through the design/construction of efficient condensate return systems. Sometimes condensate return systems have never existed because the past history of cheap and plentiful water made such considerations minor. Other times, the poor performance of mechanical steam traps resulted in poor line pressure conditions or in excessive water hammer that rendered existing condensate lines inoperable.

Whatever the reason, Enercon always promotes the recycling of water to maximize the usage of its energy content and overall water conservation. Our technical experience allows us to design and construct cost beneficial systems that can result in the capture of almost 100% of potentially recyclable water.

5. **Reduction in Equipment and Capital Expenditures:** Fully eliminating condensate while maximizing the dry gas remaining in the operational side not only improves operational efficiency but also reduces the wear and tear on existing equipment and sometimes even the need for additional capacity. Removal of water allows turbine blades and furnace pipes to last longer, lessens erosion in pipes, and eliminates the cracking or rupturing of pipes caused by water hammer. Increased operational efficiency results in doing more with less which translates into less boiler capacity and processing equipment to achieve the same results. Proper line pressure can mean that processing lines are now able to feed into existing smaller diameter condensate return systems. Elimination of water hammer on the return side can lead to the reopening of previously shut down condensate return systems.

6. **Increase in Safety Environment:** Steam is extremely dangerous. At pressure, the gas is undetectable to the naked eye and will sever any body part it comes in contact with. The condensate that escapes a system is potentially scalding. Cycling mechanical traps that release pressurized steam to the atmosphere pose a serious safety issue. Water hammer caused by malfunctioning mechanical steam traps poses the serious threat of ruptured piping on both the operational and return sides of the steam system. The fixed, continuous condensate removal of a properly sized, drilled venturi orifice eliminates these safety issues by keeping the dry gas in the piping of the process side of the system while safely directing the condensate to its end destination on the return side of the system.

CONCLUSION

The main challenge of a steam system is eliminating all the condensate while retaining the maximum amount of dry BTU rich gas for delivery to its end use. To date, mechanical steam traps have been the overwhelming choice to accomplish this objective. By their design though, mechanical steam traps are plagued with the following problems;

- Moving parts degrade over time leading to operational decline and ultimately to failure.

- Such degradation therefore demands labor intensive maintenance programs for identification and replacing/repairing of malfunctioning traps.

- This leads to the additional ongoing replacing/repairing expenses – material, labor, and lost production during change-out. The life expectancy of a mechanical steam trap averages 3 to 4 years with some processes causing malfunction to occur in as little as 3 months, or less.

- The result of varying stages of degradation and failure of mechanical steam traps throughout a steam system results in the average facility having steam system inefficiencies of 15% to 30%.

- “Closed” failing mechanical traps leave condensate on the operational side of the system resulting in various kinds of water damage. “Open” failing mechanical traps allows pressurized gas to escape leading to operational inefficiencies, condensate return issues, and safety concerns.

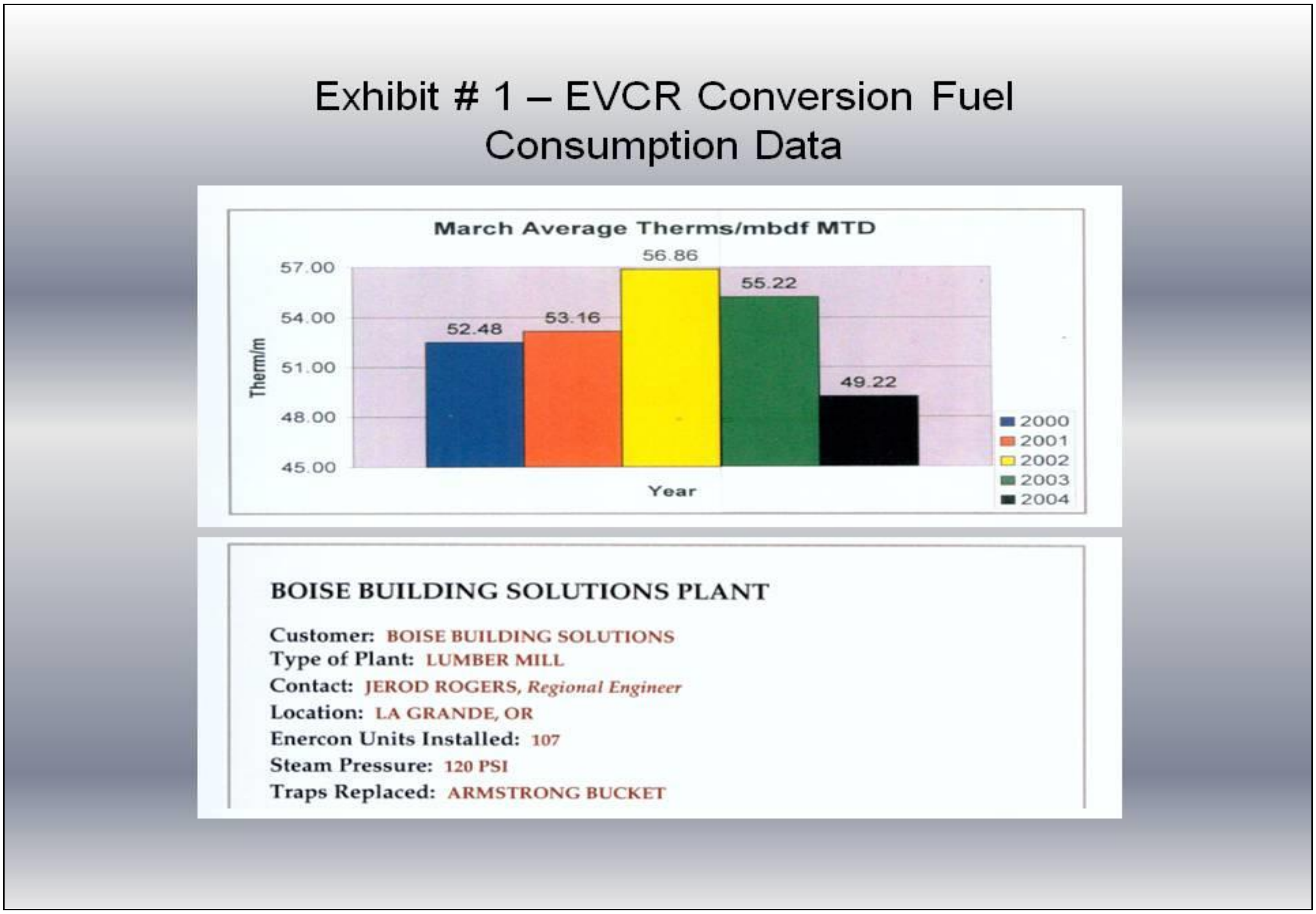
All these issues are resolved by the Enercon EVCR Unit technology. By its design, this drilled venturi device, removes condensate continuously, retains dry BTU rich gas in the operational system, and has no moving parts that can degenerate. The EVCR Unit is not another “steam trap” but rather is a permanent, superior replacement to the mechanical steam trap technology currently in use. No moving parts means it will work as well in year 14 as it did on day 1.

ENERCON STEAM SOLUTIONS – ABOUT US

Enercon Steam Solutions are steam experts, who through our innovative technology and technical services help our clients achieve increased operational efficiency. We address today’s critical issues of: Energy Efficiency, Natural Resource Conservation & Carbon Footprint Reduction by maximizing the energy efficiency of steam distribution systems, while minimizing the water lost during the operational process.

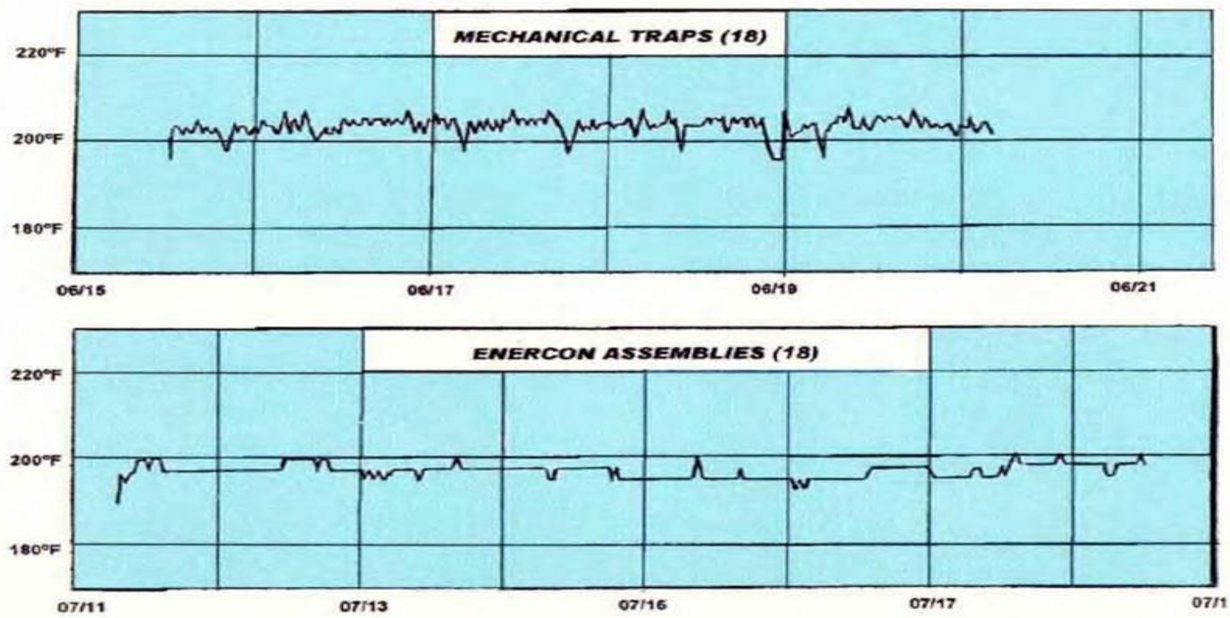
The success of a drilled venturi orifice technology is dependent on the correct sizing of the venturi orifice in order to achieve 100% condensate removal, maximize BTU rich gas retention, and balance pressures throughout the system. We supply such expertise through our combination of technical knowledge, over 20 years of field experience, and the experience from performing installations in over 1,000 facilities.

Our staff’s background also gives us expert insight in the proper configuration of steam piping, condensate return systems, and proper steam system design.



This is an example of return side improvement. The black bar is after the installation of the EVCR Units. This is a natural gas system showing a significant reduction in fuel consumption.

Exhibit # 2 – Temp Profile Test

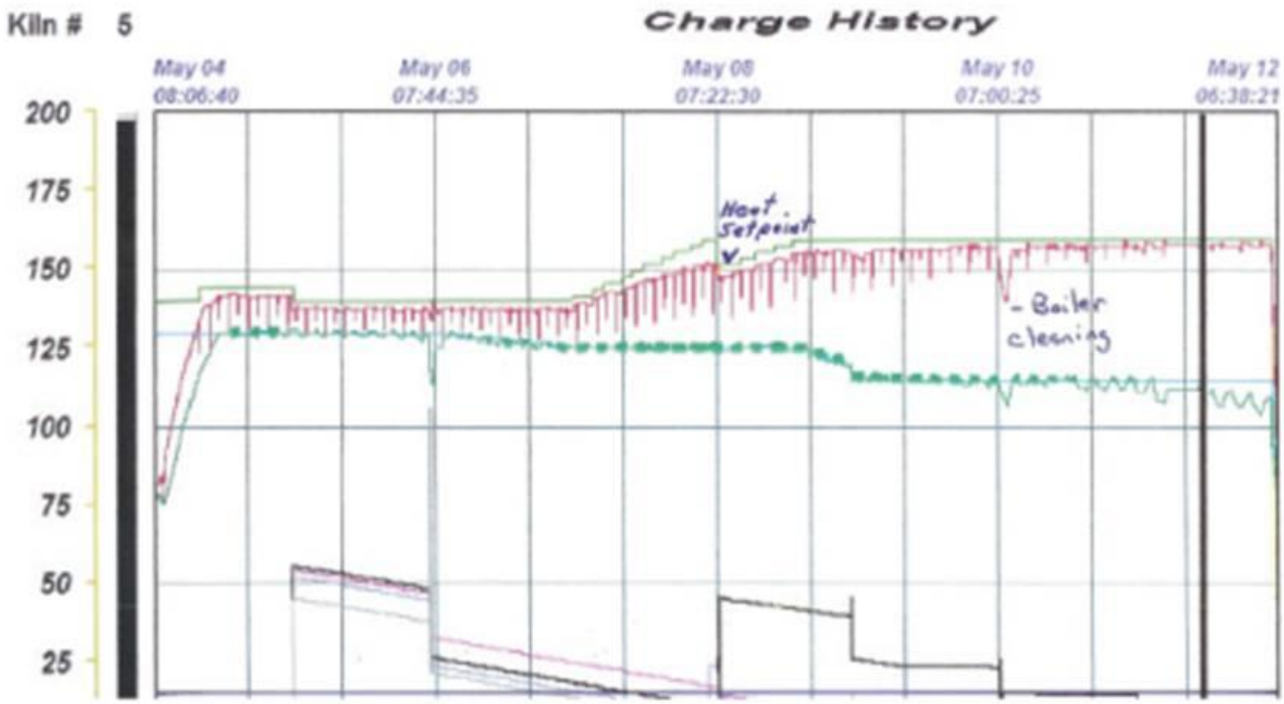


TEMPERATURE PROFILE TEST COMPARING ENERCON WITH MECHANICAL TRAPS

InteliCoat Technologies, South Hadley MA, international producer of quality paper products, compared temperature variations when 18 Enercon assemblies were installed on a photographic paper drying system vs. performance of mechanical traps they replaced. The Enercon assemblies were installed in September 2000.

This is an example of a hot side improvement. The flats on the ENERCON graph show a more consistent drying. Note, the EVCR Units were so effective in reducing the variation that the temperature was lowered in the steam box. This improved product quality, as well as steam consumption.

Exhibit # 3A – Customer Setpoint/Charge Test



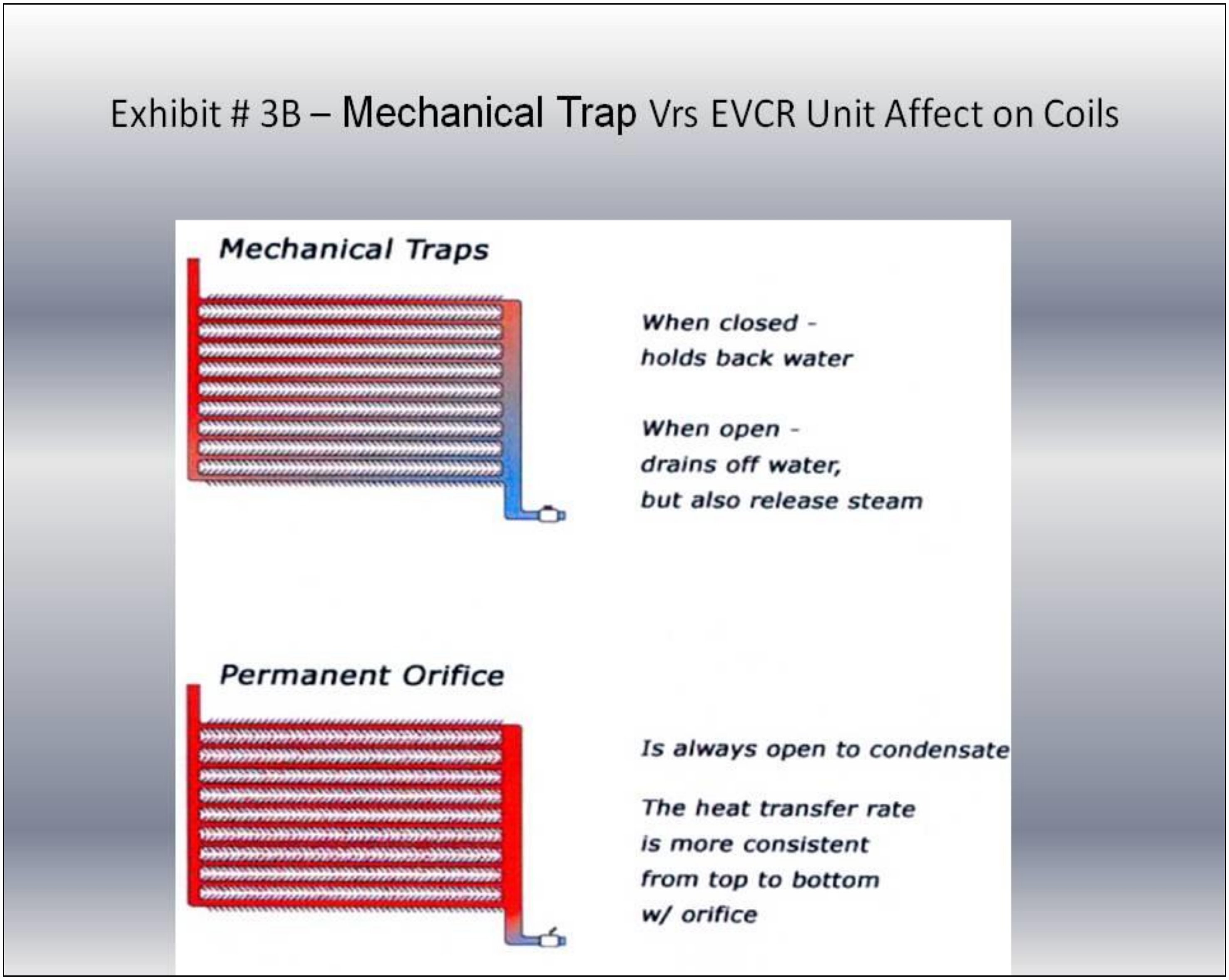
NEW ENERCON FIXED ORIFICE TRAPS

Time to Setpoint: 6 hours, 8 Minutes; Days to Charge: 7

CONCLUSION: Using the same kiln (#5), the same species (6/4 Poplar) and the same drying schedule, the Enercon units reduced initial setpoint temperature by 7 hours, 52 minutes and total charge time by 3 days. And with the Enercon units installed, kiln temperatures responded more quickly to setpoint changes.

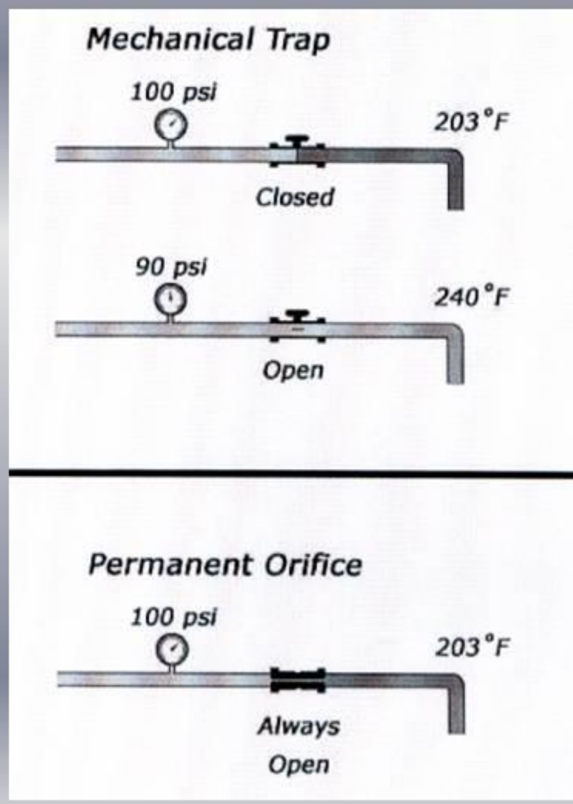
Data and graphs compiled by hardwood mill Dry End Manager
Survey and Technical Assistance on Enercon Installation by Bill Holub, Operating Manager, MARCL, Ltd., National Enercon Distributor

These two graphs are examples of hot side improvement. They are an independent, direct comparison of new mechanical traps to EVCR Units on the same kiln with virtually the same drying conditions. The EVCR Units followed the kiln temperature set point more directly and brought the kiln up to temperature quicker. This reduced drying time and improved production.



This is a comparison to show why the EVCR Units accomplished what they do in coil related operations. The mechanical traps are closed for the majority of the time while the coil is still transferring heat. This reduces the energy to pound mass and the total heat transfer capability of the coil. It also, creates a severe temperature variance from the inlet to the outlet of the coil which causes uneven drying. With the EVCR Units, these problems are dramatically reduced.

Exhibit # 4 – Pressure Drop Experiment



A simple experiment can be performed by any customer using steam. If you put a pressure gage before a mechanical trap, the pressure drops every time the trap opens. At the same time, the return temperature will rise significantly above accepted heat loss levels. The orifice will discharge the same condensate with no movement on the pressure gage and will permanently maintain accepted heat loss levels.