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Optimization of steam lines

Application to the Case of Iberol

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Abstract

The Iberol - *Sociedade Ibérica de Biocombustíveis e Oleaginosas, S.A*. company, exists since 1967 and ever since puts on the market the production of soybean meal and oil. In 2006 also entered the biofuel market through the production of Biodiesel Later, introduced rapeseed meal and oil.

The aim of this work was to evaluate the strengths and weaknesses of the steam network in the plant in order to find solutions to improve its quality and efficiency of its usage With this goal the work was conducted in three independent lines. In the first part the evaluation of the technical-economic feasibility of installing heat exchangers for heat recovery in steam boilers, based on a previous study[1].The implementation of heat recovery on GEVA boiler requires a total investment of 54.404 €, using treasury capital with a payback of approximately five months. The second part of this work focused on the monitoring of steam traps of all units of the plant aiming the evaluation of their behavior. The replacement of damaged or inadequate steam traps would lead to a total cost of 9.422 € with a payback of 1,2 months. In the third part of this work possible changes of the steam network such as the installation of moisture separators in the steam line of the biodiesel unit, coating some of the equipment, installation of steam traps in adequate points and recovery of flash steam among others were analyzed and economically evaluated. Base on this study a hierarchy of priority projects was set.

Keywords: Steam, Heat Exchanger, Steam Traps, Investment, Payback.

1. Introduction (Steam and condensate Loops, 2012)

Steam is one of the utilities commonly used in the industry especially in equipment where heat exchange is required, as it displays the following characteristics:

i) It is generated from water which is relatively inexpensive and safe;

ii) It is easily transported through pipes travelling long distances between generation and consumption points;

iii) It contains and carries reasonable amounts of heat adequate for most of the industrial processes needs.

Steam is produced in steam boilers which can use either fuel oil (F.O.) or natural gas (N. G.) as fuels. In the case of Iberol both of those fuels are used according to which boiler is being used. The increasing price of fuels in the last years was necessarily accompanied by an increase in the price of each ton of steam produced in the boilers. Facing this fact and because this utility is indispensable for the functioning of, industrial plants it is becoming more and more important to adopt measures leading to both the reduction in steam and in the amount of fuel consumption to produce it.

This paper it is a real case study about the steam of a Portuguese industrial company, Iberol. The objective of this work is to identify, based on current steam lines, improvements to be implemented in order to increase the quality and efficiency of steam.

2. Heat Exchangers (or Economizers) for Boilers

In the steam production facility there are four steam boilers whose functioning depends on the activity of all other units which require steam as a utility.

Installing heat exchangers in the chimney of a boiler all the heat carried by the flue gas coming from the chimney can be used as heating medium of the incoming water to the boiler. This pre-heating will necessarily provide important fuel savings.

The four boiler have the following characteristics:

Table 1: Fuel type (Fuel Oil or Natural Gas) and rated capacity of boilers.

Boiler	STB 600	STB 1400	STB 2000	Geva
Fuel Type	F.O	F.O. and N.G.	F.O.	N.G
Capacity (ton/h)	6	14	20	15

2.1 Heat Exchanger for Natural Gas Boilers

2.1.1 GEVA

The economizer for GEVA boiler must heat to 135 ºC (the temperature at the entrance of the boiler) the water coming from the degasser at 102 ºC. This is achieved by cooling the flue gases from 225 ° C to 120 ° C.

For this task several heat exchangers manufacturers were consulted. The proposals were evaluated taking into account of technical and economic factors as well as installation time and payment conditions.

Taking into account that none of the technical criteria lead to the exclusion of any of the suppliers we concluded that the most advantageous supplier for purchasing the economizer is the A as it presents the lowest payback time as depicted in Table 2.

Table 2: Payback for the suppliers of heat exchangers for GEVA boiler.

Supplier	A	B	C	D
Budget	51.300 €	54.538 €	86.157€	73.408 €
Payback (months)	**4,9**	**5,5**	**8,5**	**8,0**

2.1.2 STB 1400

This boiler operates both with fuel oil or natural gas. However, 80% of the steam production for the past year was based on the use of natural gas. So, it was concluded that the solution that best suits the operation regime of this boiler is to use an heat exchanger suited for natural gas but provided with a by-pass for the boiler when this is working with fuel oil.

Table 3: Payback for the suppliers of heat exchangers for STB 1400.

Supplier	A	B	C	D
Budget	47.710€	70.900€	84.857€	78.055 €
Payback (months)	**16,9**	**26,4**	**32,1**	**28,9**

For the STB 1400 heat exchanger the economic analysis lead to payback times varying between around sixteen to thirty-two months depending on the supplier. Due to these high payback times the project was not considered as a priority, for the company, at this moment.

2.2 Heat Exchanger for Fuel Oil Boilers

Heat exchangers for fuel oil boilers require special conditions with respect to their configuration in order to prevent the occurrence of fouling. To meet these needs the economizers must have, preferably, smooth tubes fitted with cleaning devices. On the other hand operating conditions should prevent the occurrence of dew point acid (T= 160 °C) to avoid, the formation of H_2SO_4. For this it is necessary to keep the wall temperature of the economizer above this value. In heat exchangers for fuel boilers is necessary to ensure that the outlet temperature of the combustion gases is higher than the condensing temperature. For this it is necessary to control the outlet temperature of the combustion gases and preheating the feed water to the boiler through the use of a cross flow heat exchanger.

2.2.1 STB 600

STB 600 hardly justifies a heat exchanger, since its operation time is very scarce. During 2011 this boiler yielded only 0.13% of the steam produced in the steam central, so it does not meet the necessary operating conditions to justify placing a heat exchanger. For this reason suppliers B and C did not proposed a budget for this boiler. The payback time for the other suppliers is presented in the Table 4.

Table 4: Payback for the suppliers of heat exchangers for STB 600.

Supplier	A	D
Budget	48.045 €	78.809 €
Payback (years)	**141,0**	**157,3**

2.2.2 STB 2000

STB 2000 is the boiler with has the higher capacity.

The capacity of the natural gas network of Iberol is to be augmented. Doing so, STB 2000 will be modified and will work exclusively on natural gas. For this reason, STB 2000 was not included in this study.

3. Steam Traps

Steam traps are automatic devices used to separate and remove condensate which forms in the pipes and steam heating equipment without allowing the steam to escape. These traps should maximize the residence time of the vapor inside the equipment, so that the steam can provide all your heat. In the absence of a trap steam circulates continuously at high speed and this excessive consumption would lead to a low overall efficiency of the heating system. The installation of a trap always represents a considerable saving of steam and therefore fuel. There are many types of steam traps that are fully described in the literature (“*Eficiência Energética no Uso de Vapor”*)

The steam traps functioning in the plant are mechanical, thermodynamic and thermostatic steam trap types.

Monitoring traps (GESTRA’s Software)

The functioning of steam traps in the plant was monitored by evaluation of the sound conditions (ultrasound) produced by the steam when it passes through the discharge orifice of the trap.. This technique is ideal when applied to condensate traps discharging intermittently, because, in this case, the noise conditions of normal and abnormal operation are very distinct. In the case of steam traps with continuous discharge, a more careful and correct interpretation of the ultrasonic signals received by the detector is needed in order to avoid confusion between the passage of live steam and the flash steam formed in the discharge.

To monitor the traps functioning a VKP40 EX device was used. As steam passes it emits ultrasonic vibrations which transmitted to VKPN40 EX detector and further converted into an electrical signal by the processor and recorded graphically. In these graphs 3 lines with different colors are represented:

i) the green line - threshold value- corresponds to the sound emitted by a trap functioning properly, in a plant virtually free of noise;

ii) the red line corresponds to the maximum permissible noise that may be emitted from a trap which functions properly and

iii) the blue line which is line describing the real trap operation. The trap is faulty only if its operating line is above the red line. The data collected by the processor is then transferred to the software which estimates the quantity of steam which is lost due to bad functioning of the trap. The costs associated to these losses can then be evaluated. The payback time due to the replacement of malfunctioning steam traps was calculated based on this estimate and on the budget given by suppliers.

The most representative steam traps in the plant are located in the steam production, preparation, extraction and biodiesel units and on the park of tanks. Al the steam traps located in these units were carefully analyzed.

3.1 Steam traps of production steam unit

Of all the traps that are currently working in this unit only three presented dubious behavior. They were a bimetallic thermostatic steam trap and two float traps with the float mounted in parallel to the main collector drain the central steam.

After examining the previous operating conditions represented in the graph of Figure1 and the actual ones obtained after the substitution of the steam trap by another one with a suitable diameter (Figure 2) the difference is quite clear.

In the new conditions the sound captured by the equipment (blue line) during the entire test is always below the threshold value of sound (red line) which indicates good functioning.

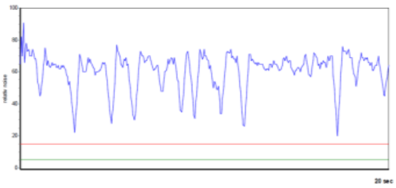

Figure 1: Operating unsuitable for thermostatic steam trap.

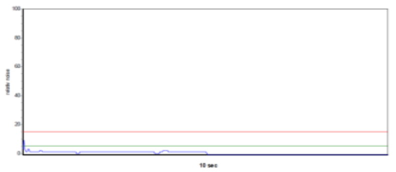

Figure 2: Thermostatic steam trap suitable for the dimensions of the steam line.

Concerning the two float traps, they proved to be totally inadequate to operate in the conditions in which they are inserted.

The collector steam is at a pressure of 16 barg and outlet of condensates is at a pressure of about 1 barg. The float trap which are arranged in the collector despite a nominal pressure of 16 barg have a maximum operating pressure of 14 barg. Another issue in the incorrect sizing of these traps is $\Delta P_{máx}$ trap. For the operating conditions in which we find the difference between the steam pressure of the condensate and pressure is 15 barg, however, that the traps are inserted have a $\Delta P_{máx}$ of 4,5 barg. The ability of the traps float as mentioned above is larger for traps with low $\Delta P_{máx}$, however, when this value is exceeded your capacity is greatly reduced. The trap ideal for this application would be a trap with a nominal pressure of 40 barg and ΔPmáx above of 15 barg (ADCA, 2011)

According to the estimates given by the ultrasound equipment concerning the steam losses per trap it was possible to estimate the payback time for the investment of replacing the existing steam traps for adequate traps.

Table 5: Economical analysis of the replacing of steam traps for the steam production unit.

Steam Loss (kg/h)	15
Annual Cost	3.723 €
Steam Trap Cost	1.425 €
Payback (months	4,6

3.2 Steam traps of the preparation unit

In the preparation unit two traps did not meet the needed requirements one float trap and a thermostatic trap. Both need to be substituted. The evaluation of the costs for this substitution is showed in Table 6.

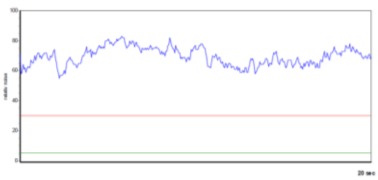

Figure 3: Running for float trap with $\Delta P_{máx}$ inadequate.

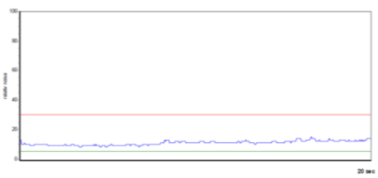

Figure 4: Running for float trap with corrected $\Delta P_{máx}$.

Table 6: Economical analysis of replacing of steam traps in the preparation unit.

Steam Loss (kg/h)	28
Annual Cost	5.155 €
Steam Trap Cost	1.433 €
Payback (months)	**3,3**

3.3 Steam traps of extraction unit

In the extraction unit eight steam traps were analyzed and all were in defective operation. Current traps were oversized regarding the steam consumption and they allow great vapor losses.

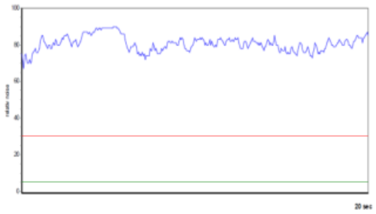

Figure 5: Chart of operation of a float trap inadequate.

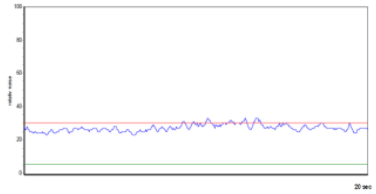

Figure 6: Chart of operation of a float trap suited to the operating conditions.

For the situation of these traps two types of investment was considered:

i) changing the installed kit by an adequate one or

ii) substituting the steam traps currently installed by new traps with threaded end connections.

Evaluation of costs for both situations is showed in Table 7.

Table 7: Economical analysis for the replacement kit / trap for extraction unit traps.

Steam Loss (kg/h)	350
Annual Cost	71.675 €
Steam trap kit cost	2.836 €
Payback (months)	**0,5**
Steam Trap Cost	4619
Payback (months)	**0,8**

3.4 Steam traps of biodiesel and tank's park units

In biodiesel production plant and tank park only proceeds to replacement / maintenance of steam traps because they were inside of operational conditions and they were suitable for the applications.

In both of these units all the damaged steam traps which were substituted by repaired ones stocked in the plant warehouse.

The payback times for the replacement of the steam traps for these two units are shown in Tables 8 and 9.

Table 8: Economical analysis of the substitution of steam traps for biodiesel unit.

Steam Loss (kg/h)	22,5
Annual Cost	4.159 €
Steam Trap Replacement Cost	1.335 €
Payback (months)	**3,9**

Table 9: Economical analysis of the substitution of steam traps for tank's park unit.

Steam Loss (kg/h)	20
Annual Cost	3.483 €
Steam Trap Replacement Cost	620 €
Payback (months)	**2,1**

4. Other improvements

4.1 Coating equipment

The coatings of equipment and pipes using steam are a very important issue. Adequate coating allow a higher heat retention, resulting in greater energetic efficiency and hence in a reduction in steam consumption.

The most commonly used coatings are fixed to the equipment. However, they must be disposed if, for some reason, the replacement or maintenance of equipment would be necessary. The solution here is to use removable coatings (Figure 7) which are more expensive but have the advantage of being easily be removed and replaced without being damaged.

Figure 7: Jacket for valves.

The possibility of placing this coating on valves and filters that so far were unprotected was analyzed and the respective costs evaluated based on the supplier information.

The results are shown in Table 10.

Table 10: Economical analysis for the supply of coatings for valves and filters.

Total Investment	14.704€
Annual Savings	13.957 €
Payback (months)	**12,6**

The two expanders working in the preparation unit are subjected to elevated temperatures which lead to high heat losses by conduction and convection. These losses are detected by thermography (Figure 8).

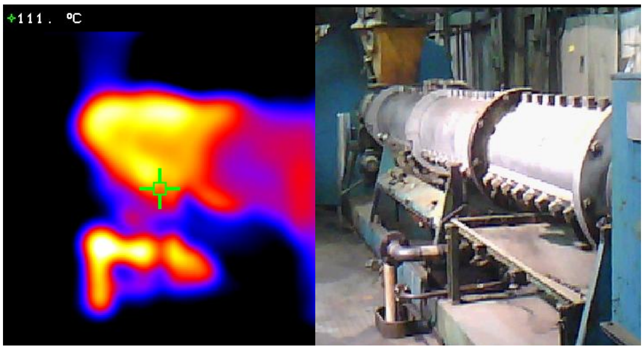

Figure 8: Thermography of the expander.

For this equipment a fixed coating is not adequate as this is an equipment that requires regular maintenance and also because one of its stages, need to be changed when as the grain's fed are soybean or rapeseed. Thus, the best solution would be to put a removable coating similar to that used for valves and filters. The results of the economical evaluation of this situation is shown in Table 11.

Table 11: Economical analysis of jacket for expander's.

$\dot{q}$ loss without coating (kW)	282
$\dot{q}$ loss with coating (kW)	56
Investment	3.980 €
Payback (months)	**1,3**

4.2 Humidity Separator

State of dryness of the steam is very important in some of the parts of the units were steam is used. If steam is very wet the efficiency of heat transfer decreases.

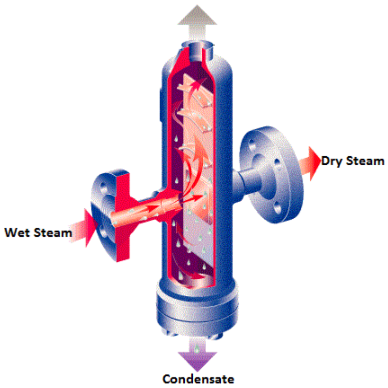

Figure 9: Humidity separator.

The humidity in the steam will also increase the occurrence of water hammer and fouling leading to occurrence of leaks in steam pipe. For this reason, all units have an humidity separator placed between the steam production unit and its consumers. The only consumer that does not have this humidity separator is the unit of production of biodiesel.
The budget for the installation of a humidity separator is summarized below in Table 12.

Table 12: Economic analysis for the installation of humidity separators.

Supplier	D	E
Budget	2.029 €	5.646 €
Payback	**≈1 year**	**≈2 years**

The payback of investment was estimated based on costs of maintenance, replacement of valves, steam meters, expansion joints and leaks in steam pipe caused by wet steam in the last five years of operation of the plant.

4.3 Utilization of flash steam

Flash steam is the designation of the steam which is formed from the condensate resulting from the drainage of steam traps when passing from a higher pressure to a lower pressure.

To have this steam flash unit a flash separator is necessary. This is a tank where the condensate falls by gravity to the base of the container. The steam formed is extracted through the top of the container and is further used in any equipment needing low pressure steam.

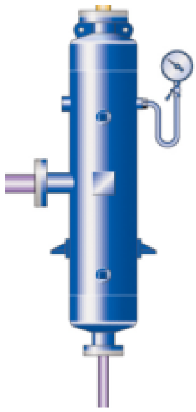
Figure 10: Flash steam receiver.

Biodiesel production unit is currently the only unit that does not use this flash steam.
In this unit neutralization and transesterification do not always operate simultaneously. When only neutralization is laboring the flow of condensate formed and its pressure is not sufficient to produce a flash which justifies the investment but the same is not true when both operations neutralization and transesterification operate simultaneously or even when transterification is working only.
For the implementation of this project it was necessary to verify which equipment requires low pressure steam for further integration and what would be the flash steam pressure that should be used in order so as not to disrupt the normal functioning of steam traps.
Steam flash of 2 barg and 1 barg could be used in heat exchangers, and in a water tank, respectively

The quantities of steam produced at the two re-evaporation pressures are, according to Table 13:

Table 13: Steam flow for both re-evaporation pressure.

Re-evaporation Pressure (barg)	Steam Flow (kg/h)
2	60
1	113

When using pressures of 2 barg for heat exchangers in the choice of this equipment it must been taken into account factors such as the continuous demand of steam and the guarantee that the entire flash steam is consumed.

In the neutralization water tank the flash vapor produced is used directly. So, there is not a problem related with the steam network underpressure. Therefore a better utilization of steam due to reduced pressure re-evaporation is achieved.

Table 14:Economic analysis for flash tank.

Supplier	D	E
Bugdet	2.318 €	2.296 €
Payback for 2 barg (months)	**2,8**	**2,8**
Payback for 1 barg (months)	**1,5**	**1,5**

4.4 Localization of steam traps

Other improvements suggested in this work are placing traps at the end of the line, particularly in steam lines feeding the tank parks and low points where there is a greater probability of condensate accumulation. It is also suggested the placement of automatic drain valves that assist the drainage of condensate traps accumulated in the steam pipe for starting and stopping situations. The total cost of these modifications is 1,430 € excluding labor costs, condensate boots, valves and filters.

5. Conclusions

This paper presents some improvements that should be implemented by Iberol in order to increase the quality and efficiency of the steam produced by the plant and consumed by its different units.

The conditions of the steam lines were analyzed from the moment that steam is produced until it was consumed in the preparing, extraction, and biodiesel units as well as in the parks of tanks. All the implementations which are suggested showed to be very are important to ameliorate the conditions of steam lines. Unfortunately, however, as it is not possible for the company at this time to implement all projects a hierarchy of priorities has to be established.

6. References

[1] Adca, Valsteam- Product handbook, May 2011.

[2] Moço, Tiago – "Estudo e Integração de Processos de uma fábrica de Extracção de Óleos Vegetais e Produção de Farinha", Setembro de 2009.

[3] Spirax Sarco – "The steam and the condensate loop book"

[4] ITT Industries- " Steam traps engineering data manual" Hoffman Specialty

[5] CENTRAIS ELÉTRICAS BRASILEIRAS, FUPAI/EFFICIENTIA- "Eficiência Energética no Uso de Vapor". Rio de Janeiro: Eletrobrás, 2005.

[6] Documentation available on the product software VKP 40 EX.