International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.10, pp 235-241, 2018

Energy Diagnostic of A Steam Distribution System in an Industrial Plant

Andrea C. Miranda[1], Paola H. Barros[1], Guillermo E. Valencia[1*]

[1]Efficient Energy Management Research Group, Universidad del Atlántico
Carrera 30 No 8 – 49, Puerto Colombia, Colombia

Abstract : In plant production systems, the use of steam is of vital importance in carrying out industrial processes. Steam distribution allows us to transfer energy or driving force for the operation of equipment such as steam turbines, furnaces and heat exchangers, which are important for regulating the operating conditions of the process. Therefore, it is convenient to analyze the ranges of work and the advantages of taking advantage of the available resources to reduce the costs presented in the different processes and equipment involved.
Keywords : Energy diagnostic, steam distribution system, agro-industrial sector.

1. Introduction

Steam distribution systems are commonly used in industrial processes; they offer a simple and efficient way to transfer energy or driving force for the operation of various equipment such as steam turbines, furnaces and heat exchangers. These systems are considered as the direct link between the steam generator and the user equipment[1], therefore it is necessary that the distribution lines supply the steam in a reliable manner and with the highest possible quality to the equipment that will use it. Therefore, it is essential to control the factors that may affect this requirement, including condensate generation[2].

Within a heating process where there is a steam distribution network, the condensate, which is the liquid generated by the change of state, results from the steam that transferred its latent heat to the equipment or product that needed this energy. From this process, we obtain a high temperature condensate with a percentage between 20 and 30% of the steam heat[3]. It is for this reason that techniques have been developed for the removal of condensate within the system, in order to guarantee steam at the conditions necessary for the best operation of the process; examples of these techniques are the use of steam traps[4], the multi-effect evaporator[5], mechanical steam compression[6] and the use of membranes[7].

However, in some industries this condensate is reused to meet other needs, which allows for great savings in energy, water and fuel, because the condensate formed in the distribution line contains the same temperature as saturated steam.

Guillermo E. Valencia *et al* /International Journal Of ChemTech Research, 2018,11(10): 235-241.

DOI= http://dx.doi.org/10.20902/IJCTR.2018.111029

The main contribution of this article is to present a methodology to analyze the economic advantages of making an energy diagnosis of steam distribution lines in an industrial plant, evaluating the main opportunities for savings by verifying the operating ranges in which the production of motor fluid is obtained in the processes without investing more resources.

2. Materials and Methods

In the following, the variables of influence in the process will be analyzed, detailing the ideal operating conditions to evaluate the maximum production conditions in the industry.

2.1 Steam Generation

In the industries that require steam for the operation of their user equipment, boilers are generally used, which are vessels that heat water and generate steam. This is possible because in their combustion chamber, the fuel is burned and heat energy is added to the water by convection heat transfer[8]. The boilers can be classified according to the needs of the application, such as pyrotubular boilers where the smoke and hot gases pass through the pipes and the water passes through the outside of them, so these boilers can operate with a medium water quality, but are not used in high pressure requirements. On the other hand, the water tube boilers pass through the inside of the pipes and the hot gases through the outside of them, so they must be fed with high purity water, but they have a higher efficiency and can be used in high pressure applications.

2.2 Steam Distribution

For the generation of steam in the process, the water enters the liquid state as sub-cooled or saturated and exits in the condition of saturated or superheated steam, the former being the most commonly used because in superheated steam, although no condensate is generated, the losses are higher. At the boiler outlet, the steam is transported through a network of thermally insulated pipes in an effort to prevent heat transfer to the surrounding area and thus reduce the amount of condensate produced. The dimensioning of this piping is of vital importance, since doing so incorrectly would lead to the desired process temperatures and pressures not being reached[9]. In saturated steam lines it is recommended to handle maximum speeds between 25-40 m/s, this in order to avoid problems such as excessive noise and erosion, which are caused by the condensate droplets that are formed in the saturated steam that move at high speeds. The distribution of steam from the boiler to the end users is recommended to be carried out at high pressure taking into consideration the inverse proportional relationship between the pressure and the specific volume illustrated in Figure 1, which has direct consequences on the design of the distribution network. If the boiler works at its maximum pressure, then a drier and higher quality steam will be obtained, reducing the amount of condensate formation. As the volume per unit mass decreases with increasing pressure, smaller diameter pipes will be required, resulting in savings in the purchase of pipes and fittings. As they are smaller diameter pipes, energy losses during distribution will also decrease due to the smaller heat transfer area.

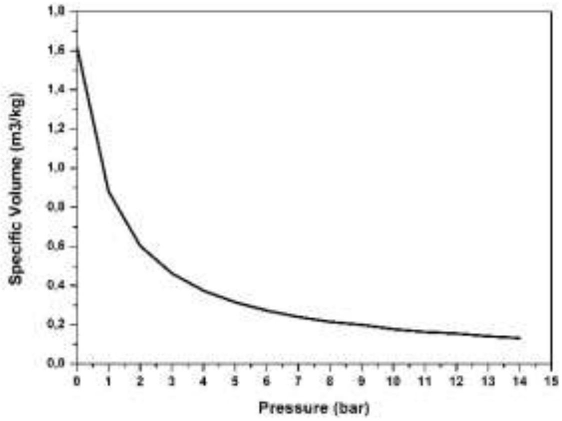

Figure 1. Relation between pressure and specific volume in steam

2.2.1 Pressure reducing station

Due to the reasons explained in the previous section, it is preferable to distribute high pressure steam and reduce pressure at the points of use that require it, either because the design pressure of the user equipment is lower than the available pressure or to save energy, due to the fact that steam at low pressures has greater latent heat.

To meet the purpose of reducing the pressure at the point of use, pressure reduction stations are generally installed[10] as shown in Figure 2, which generally consist of elements such as the moisture separator which allows moisture to be removed from the vapor, so as to prevent erosion and corrosion, and also protects the elements, mainly in this case the pressure reducing valve. Trap systems are used to drain condensate from the moisture separator to the condensate return line. Pressure and safety reducing valves, which are used to ensure the necessary amount of steam at the proper pressure and to relieve any excess pressure in the event of regulator failure, to prevent damage to equipment.

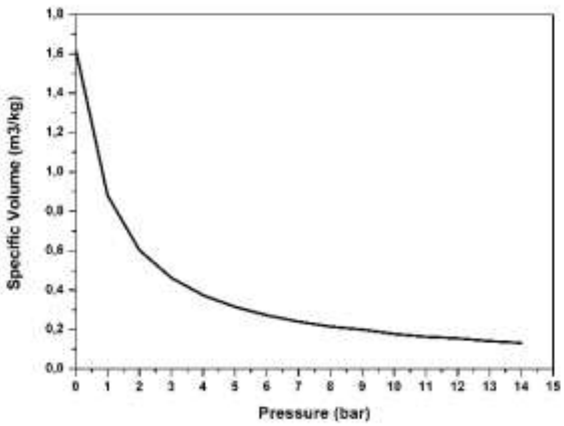

Figure 1. Relation between pressure and specific volume in steam

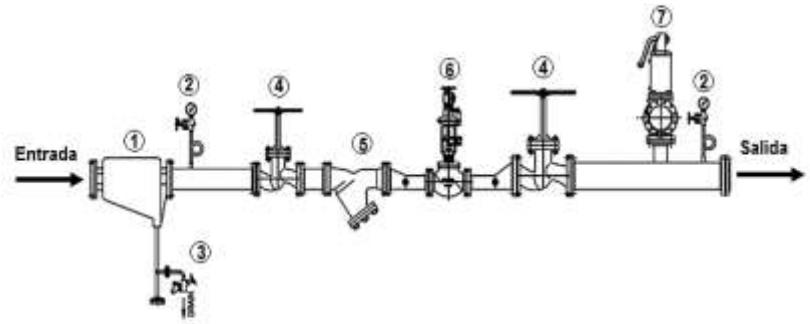

Figure 2.Pressure Reducing Station: 1. Humidity Separator 2. Pressure Gauges 3.Trapping or Drainage System 4.

2.2.2 Assessment of boiler energy efficiencies

The energy efficiency of a steam generator, in general terms, is defined as the ratio of input energy to output energy. For its calculation the ASME Steam Generation Unit Code PTC 4.1 defines two methods which are:

Direct method: Energy efficiency is defined as the difference between steam and feedwater energy as a percentage of fuel energy[11], as shown in equation (1).

$$\eta: \frac{Q_{aprovechado}}{Q_{suministrado}} x100\% \quad (1)$$

For this method it is necessary to evaluate the total chemical energy available in the incoming fuel and the total energy absorbed by the working fluid, not recovered within the steam generator enclosure. For the measurements, steam and fuel mass meters are used, pressure and temperature measurement at the point where the steam flow is measured, a procedure supported by a PLC because the measurements must be made in a period of time in the stability of the boiler conditions, which is why the method is not considered very accurate, since it does not reach accuracies greater than 1% in the calculations.

Indirect method: Also known as the loss method, the percentage of heat loss is subtracted from 100%[13] as seen in equation (2).

$$\eta: (100 - pérdidas)\% \quad (2)$$

This method achieves errors in the order of +/-0.1%. The most common losses are the losses of sensitive heat in combustion gases, by unburned fuel, convection and radiation, purges and water coming out of the chimney from the humidity of the air. To calculate the losses, it is necessary to know the combustion composition of the fuel used and its temperature, which are not known to the plant's engineering department.

Therefore, the efficiency of the three boilers will be found using equation (2), but they will be used using the values for typical losses proposed by [8] which consider an approximate load of 75%, the operating pressure in the range of 70-125 PSI and an output for medium boilers between 981-3433kW.

Calculation of the actual steam flow of the boiler with equation (3)[12],

$$Flujodevaporreal = \frac{34{,}5 * Capacidadnominal}{Factordeevaporación} \quad (3)$$

Equation (4)[2] shall be used to calculate the unit cost of the energy produced by the boiler.

$$Ce = \frac{100Cf}{PCI\eta} \quad (4)$$

Where Ce is the unit cost of energy ($/1000kJ) and Cf is the unit cost of fuel ($/tonne).

Under the given conditions, equation (5)[2] is used to calculate the unit cost of steam

$$Cv = Ce(h_v - h_{fw}) \quad (5)$$

3. Results and Discussion

3.1 Description of Boilers

In Table 1, a brief description of important operating characteristics of existing boilers in the plant is given

Table 1. Description of the boilers

Steamgenerator	RatedCapacity (BHP)	OperatingPressure (PSI)	Type	Fuel
Boiler 1	150	70	Pyrotubular	Oilpalmshell
Boiler 2	200	70	Pyrotubular	Oilpalmshell
Boiler 3	300	70	Pyrotubular	Oilpalmshell

3.2 Energy Efficiency of Boilers

Using the mean values for the losses to the working conditions, the values in equation (2) are replaced and the approximate efficiency of the boilers are obtained as show in Table 2

Table 2. Approximate energy losses

Loss of energy due to combustion gases (%)	**Loss of energy by convection (%)**	**Loss of energy by radiation (%)**	**Approximate boiler efficiency (%)**
20	0.7	3	76.3

Table 3. Results of ultrasonic inspection of traps

Location of thetrap	**Diameter (in)**	**Types of traps**	**Operation Pressure(Psi)**	**Temperature (ºF)**	**State**
Pocket 1 (Before oven 1)	1”	Floater	70	217.4	Good
Pocket 1 (Before oven 1)	1”	InvertedBucket	70	195.8	Good
Pressurereductionstation	1/2”	Thermodynamics	70	224.6	Good
Pocket 2 (Before oven 2)	1”	InvertedBucket	70	-	-
Pocket 3 (Before oven 3)	1”	InvertedBucket	70	-	-
Dryer	1”	Floater	70	-	-

3.3 Ultrasound Reporting To Steam Traps

Table 3 shows the results of the inspection of the traps present in the plant,

The "Good" state of the traps is due to the fact that the surface temperature is close to the saturation temperature and there is no ultrasound sound associated with detected steam leaks. The traps in pockets 2 and 3 and the dryer were not checked for condition due to their difficult access, so for the study it will be assumed that they are in good condition.

3.4 Steam Flow Generated by Boilers

Once the characteristics of each of the boilers present in the plant are known, the actual steam generation capacity will be calculated, considering the evaporation factor of 10,638, which is a function of the operating pressure and the temperature of the feed tank at 65°C and is replaced in equation (3), as shown in Figure 3.

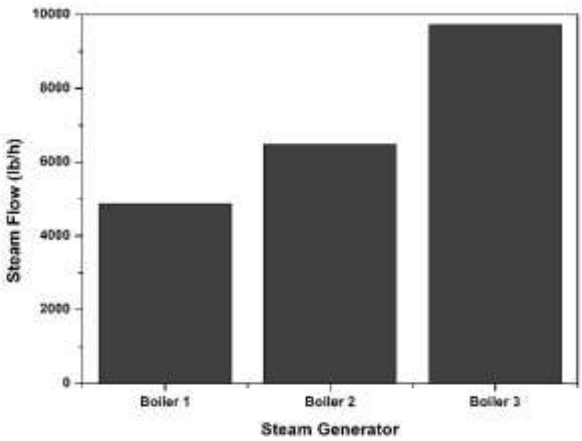

Figure 3. Actual steam flow for each boiler

3.4.1 Unit cost of energy

The values to find the unit cost of energy are shown in Table 4, the values were provided by the plant's Engineering department

Table 4. Process parameters for finding the unit cost of energy

Date	**Value**
Unitcost of fuel	Cost: $60/kg
	Transport: $58/kg
Boiler efficiency	76.3%
Lower calorific value	12560 kJ/kg

Replacing the values in (4) costs the company approximately $12,313 pesos to produce 1000 kJ.

3.4.2 Unit cost of steam

Replacing the unit cost of energy obtained in the previous paragraph and the specific enthalpies of both steam (at boiler pressure) and feed water (at the provided temperature), the values in equation (5) are replaced, obtaining that the unit value of steam is $30,560,866 pesos per ton of steam.

According to[13], the minimum feedwater temperature in coal-fired boilers is around 115°C for good combustion. In the plant, the boiler feedwater temperature is 65°C, which makes it less efficient than it could be under better conditions.

With the 1.8°C increase in the feed tank temperature, savings of approximately 1% in the cost of steam produced per hour were obtained. The temperature of the boiler feed tank could be further increased with flash steam recovery, which can be re-injected into the boiler to heat the water.

The verified traps are in good condition, i.e. the surface temperature is close to the saturation temperature and there is no ultrasound sound associated with detected steam leaks, and they are well dimensioned.

4. Conclusions

With the results obtained, it can be concluded that condensate recovery increased the energy efficiency of the process by between 1% and 2%. Energy improvement opportunities were identified such as the installation of pressure reduction stations before each piece of equipment, the construction of a main steam distributor to guarantee better steam quality, the installation of thermal insulation in the pipes, correction of leaks, recovery of flash steam, which would optimize the productivity and competitiveness of the production process, not only by reducing energy costs, but also by reducing CO2 emissions. The implementation of the project would result in a reduction in water and fuel consumption. A decrease of 30.8% in current water consumption was calculated for the reuse of condensate as feed water for the boiler and 0.98% and 1% for fuel due to the increase in feed water tank temperature.

References

1. Bureau of Energy Efficiency, “Steam system,” *Energy Effic. Therm. Util.*, pp. 55–87, 2004.
2. TLV, “TLV Compañía especializada en vapor,” 2009. .
3. S. Zhao, P. Wang, C. Wang, J. L. Langer, G. Abulikemu, and X. Sun, “Recycling of high temperature steam condensed water from petroleum refinery by thermostable PPESK ultrafiltration membrane,” *Chem. Eng. J.*, vol. 219, pp. 419–428, 2013.
4. N. Chikezie, “Successful management of steam traps,” *Filtr. Sep.*, no. September, pp. 27–29, 2008.
5. D. Zhao, J. Xue, S. Li, H. Sun, and Q. dong Zhang, “Theoretical analyses of thermal and economical aspects of multi-effect distillation desalination dealing with high-salinity wastewater,” *Desalination*, vol. 273, no. 2–3, pp. 292–298, 2011.
6. L. Liang and D. Han, “Energy-saving study of a system for ammonium sulfate recovery from wastewater with Mechanical Vapor Compression (MVC),” *Res. J. Appl. Sci. Eng. Technol.*, vol. 3, no. 11, pp. 1227–1232, 2011.
7. D. Han, C. Yue, W. He, L. Liang, and W. Pu, “Energy saving analysis for a solution evaporation system with high boiling point elevation based on self-heat recuperation theory,” *Desalination*, vol. 355, pp. 197–203, 2015.
8. M. C. Barma, R. Saidur, S. M. A. Rahman, A. Allouhi, B. A. Akash, and S. M. Sait, “A review on boilers energy use, energy savings, and emissions reductions,” *Renew. Sustain. Energy Rev.*, vol. 79, no. May, pp. 970–983, 2017.
9. N. O. Armijos Correa and L. D. Morales Muyulema, “Diseño y Construcción de un Sistema de Calentamiento de Agua para la Curtiduría Cueros & Cueros.,” Escuela Superior Politécnica de Chimborazo, 2013.
10. F. Marshall, “Forbes Marshall.” .
11. J. C. Campos Avella *et al.*, “Eficiencia energética en la generación y distribución del vapor.”
12. R. Bohórquez, “Auditoría Energética al Circuito de Vapor y Condensado de una Planta de Elaboración de Café Liofilizado,” ESCUELA SUPERIOR POLITÉCNICA DEL LITORAL, 2013.
13. Thermal Engineering LTDA., “Análisis de la eficiencia en calderas,” Santiago, Chile.

*****