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THERMAL CALCULATIONS OF A SPRAY DEAERATOR

CÁLCULOS TÉRMICOS DE UM DESAERADOR DE SPRAY

CÁLCULOS TÉRMICOS DE UN DEAREADOR DE ASPERSIÓN

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ABSTRACT
The air dissolved in condensate, feedwater, and makeup water contains aggressive gases (primarily oxygen and carbon dioxide) that cause corrosion of equipment and piping in a steam generation plant, resulting in the rapid destruction of metal parts. Therefore, it is crucial to use equipment designed to partially eliminate these gases within established tolerance limits. This protects expensive equipment. The deaerator is one of the most important pieces of equipment in a power plant, both for its degassing and preheating functions and for the cavitation and throttling problems that can arise due to malfunctions. Using a mathematical model of a spray deaerator will provide a simple and efficient way to study its behavior. We have established the standard for preparing papers for the Congress here. We ask authors to follow these guidelines to facilitate the publication of their papers. In the abstract, describe your work: the abstract is a concise and highly condensed version of the paper. It should include a brief introduction and information on the introduction and project objectives, methodology, results, and conclusions. This article presents the results of a research project carried out at Norte, S.A.

Keywords: Deaerator. Temperature. Steam. Boiler. Thermal Cycle.

RESUMO
O ar dissolvido no condensado, na água de alimentação e na água de reposição contém gases agressivos (principalmente oxigênio e dióxido de carbono) que causam corrosão do equipamento e da tubulação em uma planta de geração de vapor, resultando na rápida destruição de peças metálicas. Portanto, é de suma importância a utilização de equipamentos projetados para eliminar parcialmente esses gases dentro dos limites de tolerância estabelecidos. Isso protege equipamentos caros. O desaerador é um dos equipamentos mais importantes de uma usina elétrica, tanto por suas funções de desgaseificação e pré-aquecimento, quanto pelos problemas de cavitação e afogamento que podem surgir devido ao mau funcionamento. A utilização de um modelo matemático de um desaerador de aspersão representará uma maneira simples e eficiente de estudar seu comportamento. Estabelecemos aqui o padrão para a preparação de artigos para o Congresso. Pedimos aos autores que sigam estas diretrizes para facilitar a publicação de seus artigos. No resumo, descreva seu trabalho: o resumo é uma versão concisa e altamente condensada do artigo. Deve incluir uma breve apresentação e informações sobre a introdução e os objetivos do projeto, metodologia, resultados e conclusões. Este artigo apresenta os resultados de um projeto de investigação realizado na Norte, S.A.

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Palavras-chave: Desaerador. Temperatura. Vapor. Caldeira. Ciclo Térmico.

RESUMEN
El aire disuelto en el condensado, en el agua de alimentación y en el agua de reposición, contiene gases agresivos (oxígeno y bióxido de carbono fundamentalmente) que provocan la corrosión del equipo y de las tuberías de una planta generadora de vapor, lo que significa una rápida destrucción de las partes metálicas. Por el ello es de suma importancia el uso de equipos destinados a la eliminación de estos gases en forma parcial según límites de tolerancia establecidos. De este modo se protegen equipos de altos costos. El deareador es uno de los equipos importantes en una planta de energía, debido a su función de desgasificación y precalentamiento, pero también por los problemas de cavitación y ahogamiento que puede aparecer debido a un funcionamiento defectuoso. El uso de un modelo matemático de un deareador de aspersión representara una forma sencilla y eficiente de estudiar su comportamiento. sentamos aquí el patrón para la preparación de artículos para el Congreso. Les pedimos a los autores que sigan estos lineamientos para así facilitar la publicación de su artículo. En el resumen, describa su trabajo: el resumen es una versión concisa y muy condensada del artículo. Debe incluir una representación e información breve de la introducción y los objetivos del proyecto, la metodología, los resultados y conclusiones. En este artículo se presentan los resultados de una investigación llevada a cabo en la empresa Norte, S.A.

Palabras clave: Deareador. Temperatura. Vapor. Caldera. Cicló Térmico.

1 INTRODUCTION

The degasifier is a piece of equipment that removes oxygen and other gases contained in the feed water in order to prevent corrosion of elements and sections that make up the plant's water-steam circuit. In an aqueous medium, iron is oxidized to ferrous hydroxide by the action of the hydroxyl ion. This, by the action of oxygen in solution, passes into ferric hydroxide (reddish in color), which implies corrosion. At high temperatures, ferrous hydroxide is converted into a dense, black protective layer called magnetite, which protects the metal from water and oxygen. However, this layer, which grows according to the plant's operating hours, can cause serious breakdowns because its stacking generates cracks in the pipes and ducts of the equipment, which are subjected to high temperatures, caused by poor heat transfer and other mechanical phenomena such as tearing caused by the consequent uncontrolled thermal expansion. Because of this, an adequate intervention is required to prevent the presence of O2 and other gases in an aqueous medium such as the one treated in plants with steam as a heat transfer fluid.

2 METHODOLOGY

2.1 PROCEDURE

It will begin by making known its definition, its principle of operation, functions it performs, advantages of its implementation, a description of the sprinkler and finally a mathematical model

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will be established, through the use of equations and mathematical operations. In a steam production plant, this equipment has the following functions:

Gas removal: Eliminates, thanks to the increase in water temperature, the dissolved gases that it may contain.

It takes advantage of the inverse solubility of gases, according to which gases are less soluble in water at high temperatures.

Water preheating: Preheats the water with a new steam extraction from the low-pressure turbine, so that the temperature of the water is raised by mixing it with steam extracted from the low-pressure turbine. Even when the turbine is not in operation, but there is steam in the superheated steam line, a part of it is added directly to the tank, through nozzles located at the bottom of the tank.

Water accumulator: To accumulate water at high temperature to feed the high-pressure pumps, with which condensate water is circulated through the steam generation train.

Prevents cavitation: Provide the necessary hydrostatic pressure (NPSH) to prevent the cavitation phenomenon of feed pumps. Main advantages of using a dearear.

Among the main advantages of including this type of equipment in an installation we have:

Availability: This is equipment that does not require constant maintenance, which means higher plant availability and greater profitability.

Versatility: Small modifications to the system can provide a correct adaptation to all types of power plants (fossil fuel, nuclear, combined cycle, etc.) and all operating conditions.

Economic savings: The demand for chemical agents in the boiler is reduced by performing mechanical degassing instead of chemical degassing.

Energy savings: By dissolving fewer chemicals in the feed water, by treating the water with a degasser instead of exclusively with chemical agents, blowdown and boiler bleeds will decrease. So the necessary replacement water will be less and less heat power will be needed to produce steam.

Fuel savings: Exhaust steam from processes, generators, pumps or possible storage tanks can become sources absorbed by the degasifier in order to raise the temperature of the feed water for better removal of non-condensable gases. By raising the temperature of the feed water, this in turn affects the amount of fuel that must be fed into the boiler to generate steam later. A 10ºC increase in water temperature can lead to a 1% reduction in fuel.

Thermal fatigue: With a lower fuel flow, there will be fewer problems due to temperature gradient inside the home. This is rooted in a lower cost of maintenance.

Load demand: The availability of a storage tank in the equipment allows for better behavior in boiler operation due to the rapid response of the system to load variations.

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As can be deduced, the absence of this element in a steam plant reduces the complexity of the installation. Representing savings in investment costs, above all, and maintenance. However, as already mentioned, the implementation of this element in the system can bring with it, in addition to the protection against corrosion of the rest of the system, replacement in purges and maintenance due to problems as a result of corrosion such as breaks and cracks of pipes and elbows through which the water circulates. The latter have an associated cost that not only refers to the cost of repair, but also to the income that is lost by putting the plant down in its maintenance.

The main requirements that we must demand from this type of equipment for proper and safe use would be the following:

Ruggedness: They are designed to deliver sustained reliability over a wide range of operating conditions, including extreme conditions.

Safety and efficiency: Optimized efficiency because the amount of steam required for venting and heating the feedwater is relatively small. There is no high risk of flow into the turbine and it offers good degassing for a large part of the load range.

Quality standards: There are quality standards to strictly monitor the manufacture and use of this type of equipment that guarantees the correct use and operation in the installation.

2.2 PRINCIPLE OF OPERATION

The water enters the dewaterer dome through the corresponding connection and is spread by means of the rolling valves into a steam atmosphere, heating to a temperature close to that of saturated steam.

At this stage, most of the non-condensable, dissolved gases are released into the steam. The hot water falls into a tray where it is collected and held for a short time, from here it flows through a pipe to the steam bubbler.

The water enters the bubbler, mixes directly, with a large amount of saturated steam, heating up to the steam's saturation temperature. In this area, practically total elimination of gases is achieved. The dearead water spills from the bubbler into the storage area.

The steam enters the deanuer through the top of the tank and flows directly into the bubbler. Because the volume of vapors is very large, compared to the volume of water, the bubbling of vapors is very violent.

After the steam comes into contact with the water in the bubbler, it passes to the top, to heat the water that is being sprayed. Under these conditions, most of the steam condenses in the spray zone and becomes part of the dearead water. A small part of the vapor is vented to the atmosphere, to drag the non-condensable gases, extracting them and thus eliminating them.

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2.3 SPRAY DEAERATOR

Spring-loaded nozzles located at the top of the tower atomize the water within a vapor-charged atmosphere to allow it to be heated to the saturation point, where the solubility of the y is minimal. Figure 1. It shows a spray nozzle with a spring system. Water enters at the top and a spring-loaded mechanism exerts pressure on the fluid that breaks into droplets as its free movement through the conduit is cut off.$O_2 CO_2$

Figure 1

Water atomized by the spray

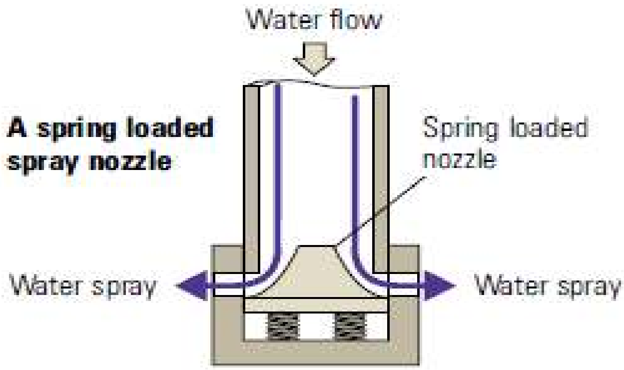

Figure 2. It gives in more detail what the upper area of a deaeration tower is like, in which water is atomized and a current of vapor creates an atmosphere responsible for raising the temperature of the returned condensate and the incoming make-up water.

In addition, two vent ducts (one automatic and one manual) are observed. The water, after being sprayed through the nozzles, creates a scattering of atomized droplets that is heated, in a first atmosphere of vapor initially, and then collected towards an atomizing valve that breaks the condensate back into small droplets to finish eliminating the dissolved gases contained in it. As elements not mentioned above, it is worth highlighting the water collectors and deflectors to redirect the flow and prevent the already treated water from mixing with gases that contaminate it.

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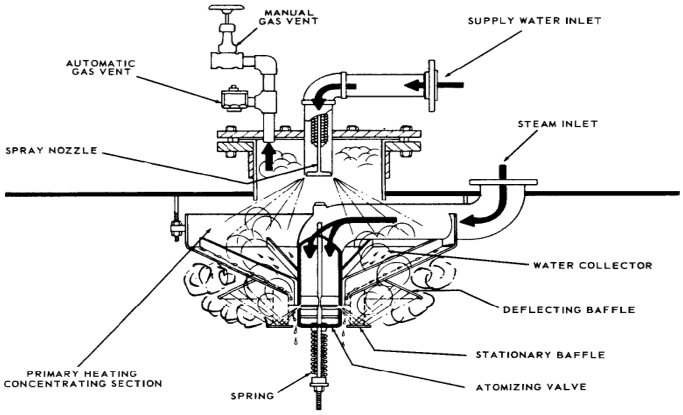
Figure 2

Spray Degasser Operation



The diagram below in Figure 3. corroborates what was said above, but marked with colors. The water is atomized by the spray, being collected and falling into a condensate accumulator that is connected to the steam line through a small diameter duct. This accumulator receives an atmosphere of vapour that rises due to a difference in densities. This part of the degasser is called the preheating zone. A stream of steam enters the degasser and comes into contact with the water that goes down the duct and increases the temperature so that the solubility of the non-condensable gases decreases and "cleans" the water. The steam creates an environment in which the temperature of the water rises, releasing the non-condensable gases that are dragged into the gas venting area. The steam that comes out of the water rinsing stage ("scrubbing") rises to the preheating area where the accumulator is located. The rinsed water falls by gravity to the storage tank where the process feed water is deposited, already released from dissolved gases.

These gases are eliminated from the degasser through a vent located in that area of the equipment. This type of dewaterer allows the content of a boiler's feedwater to be reduced by a range of 7 - 50 ppb.O_2

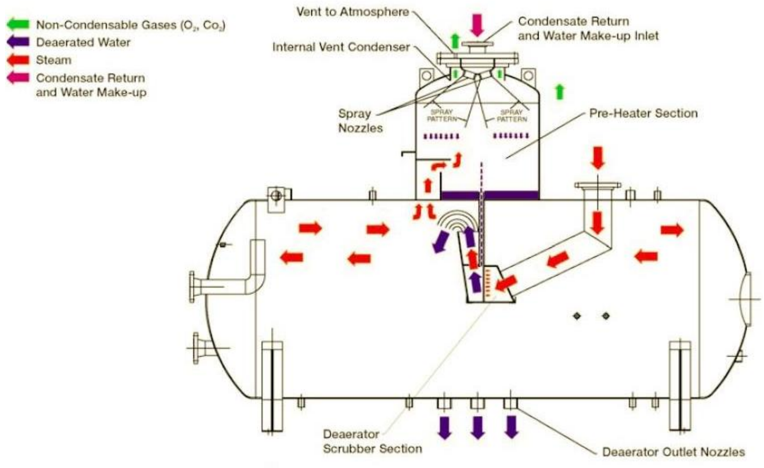
The graph shows the degassing system of a Hurst OM degasser with the operation described above

In it you can see the inputs to the system: return condensate, heating steam stream and make-up water. The outlets: feed water, purged non-condensable gases and overflow flow from traps.

The main elements of the equipment are: pressure reducing valve (to reduce the steam pressure to the design of the degasifier), vent duct, relief valve (to maintain safe pressure conditions in the equipment), boiler feed pumps, hatches for drains and sight glass to visualize water levels of the storage tank.

Figure 3

Operation of the spray degasser



Pressure degassers, whether spray or tray, are used in any industry where the heat transfer fluid is water-vapor and this water must be reduced in chemical substances intended for the elimination of gases for reasons of size, function, etc. The use of spray type in practice has been carried out for process plants where the size of the equipment is relatively important.

Tray or tray type are also used in power plants, but these equipment bring with them a greater weight and size of the equipment compared to the previous ones.

However, when these power plants are very large, tray-spray plants are usually used. It is a combination of both that allows for more efficient degassing and where the risk of corrosion damage in the plant is reduced.

3 BIBLIOGRAPHIC REFERENCES

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4 RESULTS

Mathematical model of the sprinkler dewaterer.

Mass-thermal balance, thermodynamic, and other calculations will be carried out; to determine the operation of the spray deaer.

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Overview of the dearear's parameters:

P: Degasser Operating Pressure: 0.689 bar (10), gauge. 1,702 bar, absolute.$Lb/pulg^2$

$\dot{m}_{L,sal}$: Effluent degassed water flow: 25.25 Kg/s (90 900 kg/h or 200 000 Lb/h).

$T_{L,sal}$: Temperature of effluent degassed water (saturated liquid): 115.32°C.

$h_{f,L,sal}$: Enthalpy of effluent degassed water: 483,844 kJ/kg. According to steam tables.

$T_{L,R}$: Available make-up water temperature 20°C.

P_{L,C_o}: Available pressure of condensate entering the degassing assembly: 65 or PSI, gauge. 5,494 bar, absolute.$lb/pulg^2$

$P_{V,ent}$: Pressure of saturated steam entering the degasifier: 0.696 bar (10.1 PSI), gauge 1.709 bar (24.79 PSI), absolute.

$T_{V,ent}$: Temperature of saturated steam entering the degasifier: 115.32 °C 240°F, according to steam tables.≅

$h_{V,ent}$: Enthalpy of saturated steam entering the degasser (quality considered x 0.95): according to steam tables and calculation. 2588,413 kJ/kg.=

$C_{G,L,R}$: Concentration of the mixture of atmospheric air gases dissolved in the make-up water that is saturated at a temperature of 20°C and at atmospheric pressure of 1.01325 bar: 0.0187 L of air gases *1* L of water (18.7 of air gases cm^3 *1* L of water).

$C_{O_2,L,sal}$: Oxygen content in effluent degassed water: shall not exceed 0.005 This concentration refers to the conditions of and 760 mmHg.cm^3/L

The amount of air gases dissolved in the water.

For this calculation, make-up water and condensate, respectively, are considered to dissolve gases from the air at the temperature of 20°C and at the atmospheric pressure of an atmosphere (1.01325 bar).

Then, the gas content of the air, in volume, referred to normal conditions, in water saturated with air at 20°C and at the pressure of one bar (0.987 atm). is: 0.0187 L of gases/L of water.

Whereas atmospheric air at a total pressure of one atmosphere contains saturated vapour; At 20°C, the dry air pressure is 0.985 atm. (1 bar).

The density of the mixture of atmospheric air gases dissolved in water, measured under normal conditions, is calculated by considering the approximate composition of air gases dissolved in water at 0°C and 1 atm. pressure is 35% of and practically 65% of:$O_2 N_2$

If you take 1 00 moles of this mixture:

35 moles x 32 g/mol = 1120 g
65 moles x 28 g/mol = 1820 g.

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2940 g.

$O_2 = \frac{1120gx100}{2940\ g.}$ =38.1 % by weight

N_2 ≅ 61.9 % by weight

If 1 00 g of the mixture is taken as a base:

O_2	38.1 / 32	=	1.191 moles
N_2	61.9 / 28	=	2.211 moles
			3.402 moles

Then, the volume of the mixture at 0°C and 1 atm. Be:

$V = \frac{nRT}{P}$

n = Number of moles = 3.402 moles

R = Universal Cte. of ideal gases = 0.082 L.atm. / mol.°K

T = Temperature = 273° K.

P = Absolute pressure = 1 atm.

$$V = \frac{3.402\ x\ 0.082\ x\ 273}{1} = 76.16\ L$$

So, the density at 0°C *and* 1 atm is:

$$\rho = \frac{100\ g}{76.16\ L} = 1.313\frac{g}{L} = 1.1313\frac{kg}{m^3}$$

The mass flow of atmospheric air gases dissolved in the make-up water entering the degassing equipment is:

$\dot{m}_{G.L,R}$ = 0.0187 L gases / L agua x 16.41 L agua / s x 1.313 g. gases / L gases = 0.403 g/s = 4.030 x kg/s10^{-4}

The mass flow of air gases dissolved in condensate water is:

$\dot{m}_{L,C_o}$ = 0.0187 L/L X 5.007 L/S X 1.313 g/L

= 0.1229 g/s = 1.229 x kg/s10^{-4}

The total mass flow of air gases dissolved in the water entering the equipment is:

$\dot{m}_{G,L,ent}$ = 4,030 x + 1,229 x = 5,260 x kg/s$10^{-4}10^{-4}10^{-4}$

The mass concentration of the atmospheric air gas mixture dissolved in the effluent water of the degassing (remnant mixture) is:

0.005 x 1.313 kg/ x 1 $\frac{100}{35} cm^3/Lm^3 m^3/10^6 cm^3$

= 1.875 x kg/L = 0.01875 mg/L10^{-3}

0.005 : Concentration by volume of in the degassed water coming out of the appliance, referred to at 0°C and 1 atm.cm^3/LO_2

35%: Volume content of 02 in the mixture of atmospheric air gases dissolved in water at 0°C and 1 atm.

1.313 : Density of the mixture of gases in atmospheric air dissolved in water at 0°C and 1 atm.kg/m^3

Then, the mass flow of the remaining gas mixture dissolved in the thermal degasifier effluent water is:

$\dot{m}_{G,L,sal}$ = 1.875 X kg/L x (16.41 + 5.014) L/s10^{-8}

= 4,017 x kg. /s10^{-7}

The mass flow of the gas mixture from the air separated from the water and delivered to the venting steam is:

$\dot{m}_{G,v}$ = $\dot{m}_{G,L,ent}\dot{m}_{G,L,sal}$ = 5.260 X – 4.015 X $10^{-4}10^{-7}$

= 5,260 X kg/s.10^{-4}

CONCLUSIONS

Degassing is part of what could be called basic processes for the maintenance and care of a steam installation. It works preventively in situations that would cause serious problems for companies and industries in any sector if they had to act in a corrective manner, due to the fact that this gas elimination process has been omitted. Bringing with it economic problems both for the recovery of the elements of the plant that have been affected and for the zero income that comes with leaving the production chain stopped with the collateral damage that this entails.

The development of this work has served to formulate a mathematical model that should be used to guide the student to understand the operation of the thermal processes present in a thermal degasifier.

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