

The Preliminary Study to Removing Oil Content in Condensate Steam of Gland Seal System with Activated Carbon

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PT Badak NGL is a Liquefied Natural Gas Company based in Bontang KALTIM, in the process of liquefying natural gas using a refrigeration compressor which powered by steam turbine, the steam turbine uses gland seal system to prevent steam leakage to the environment and the air entry to the vacuum system of steam turbine that will impact the performance of the steam turbine. Gland seal system uses low pressure steam that controlled by control valve. After that the steam will be condensed by condenser, the result of condensate steam is 35 mL/s average. Condensate steam from gland seal system is contaminated by oil about 2-7 mg/L. One of the effort for efficiency the water and chemical used so the condensate steam can be reused for boiler feed water, but the oil content must be reduced to 0.5 mg/L as required by ASME (the American Society of Mechanical Engineer). From the preliminary study in the form of experiments carried out to examine the use of activated carbon in removing oil content, it was concluded that the activated carbon was effective in removing the dissolved oil content in condensate steam from gland seal system outlet. The results of the test are obtained isotherm graph with the "Freundlich" equation approach obtained the need for activated carbon as much as 25 kg and dimension of columns with a length 2.23 m and a diameter 0.14 m. From a series of pilot-scale experiments it can be concluded that the optimum flow rates are 37,09 mL/s & 12,24 mL/s.

Key word: *condensate steam, gland seal system, oil content, adsorption, activated carbon*

I. INTRODUCTION

1.1 Saving Water

The development of the world's population, the United Nations Food and Population (UNFPA) states that in 2015 there were more than 7.3 billion people inhabiting the planet Earth, with an average population growth every year from 2010-2015 reaching 1.18%. One consequence of the population growth rate is the increasing demand for consumption-friendly water. Given that clean water supplies are not able to keep up with the needs of the world population, it has the potential to cause a crisis of water availability globally (www.unfpa.org). Besides being used for household consumption needs, water is also used for industrial needs, especially in the liquefied natural gas processing industry. [12]

In the cooling process of feed gas into liquefied natural gas, groundwater and sea water are needed. Groundwater is used to feed feeders with closed cycle systems. The groundwater used is also processed for reuse through the boiler water recycling process, with the aim of minimizing groundwater extraction from its sources. The total volume of water recycled and reused in the Company during 2012 was

25.4 million m³, or 78% of the total water demand in the Badak LNG. [10]

In an effort to increase Plant Thermal Efficiency (PTE) is to reduce or save the resources of boiler feed raw material, one of the efforts that can be done is to reuse condensate steam discharged in the gland seal system for steam turbines driven with a total 31,536 tons per year.

In the process the steam sealing will be contaminated with the oil used as a lubricant in the steam turbine of 2-7 ppm so that to be used as boiler feed water there are requirements that must be met, one of which is oil content less than/equal to 0,5 ppm [13], so that processing is needed in advance to remove the oil content contained in the condensate steam.

Many techniques are available for the separation of oil-water emulsions, including various filters, mass doses, reverse osmosis, gravity separation, ultra-filtration, micro filtration, process biology, air flotation, membrane bioreactors, chemical coagulation, electrocoagulation and electroporation. [5] Dissolved oil with oil droplets smaller than 5 µm can be effectively discharged from wastewater by adsorption using activated carbon. [1]

Several studies on oil-water adsorption have been carried out by several researchers who have tried to absorb oil content in waste before being discharged into the environment to meet the required limits, the first being research by Khaled Okiel, Mona El-Sayed, Mohamed Y. El-Kady from Egypt, they examined the use of bentonite adsorbents, deposited carbon (DC) and powder activated carbon (PAC) to adsorb the oil content in wastewater from Gamasa Petroleum Company and it can be concluded that the three ingredients can be used as good adsorbents to absorb oil. [6] While other studies that have been done by Jovica Sokolović, Rodoljub Stanojlović, Suzana Stankovi C, Vojka Gardić, they examined the use of adsorbent anthracite or high quality coal that much gained in Coal Mine Vrska Cuka as an indication of the adsorbent showed that anthracite efficiently adsorb and remove the oil and fat from oily wastewater. [5] From some previous studies the adsorption process is intended for waste containing oil before being discharged into the environment to meet the required threshold in each country, while in this study aims to utilize oil-contaminated waste so that it can be reused as boiler feed water so as to reduce water use and chemicals in the processing of boiler feed water.

1.2 Gland Seal System

The seal system in the steam turbine uses low pressure steam as a limiting medium between the sides of the steam

inside the steam turbine and atmospheric air. Steam is usually called a steam seal. When a steam turbine operates at full load, the steam seal is obtained from the steam inside the steam turbine. This is commonly called self sealing. Steam in the turbine, especially the HP turbine, has high pressure, while the steam seal does not require too much pressure. So to keep the steam seal pressure stable at low pressure, the steam header seal has a pipeline and control valve. This pipeline will remove steam into the condenser. In this condition the steam header seal serves to distribute the seal steam pressure coming from the HP turbine seal labyrinth to another labyrinth especially on LP turbines which have a working steam pressure in the lower turbine.

When the steam turbine is still in a start up or shut down condition, there will be no self sealing. Under these conditions the steam seal needs must be met from the outside, so that at the steam header seal there is a control channel and valve for external steam supply. In this condition the steam header seal serves to distribute the steam seal to the entire labyrinth seal turbine.

The steam seal will mix with the air inside the labyrinth seal and be contaminated with lubricating oil. The mixture is usually called a gland seal steam. This mixture is always removed from the labyrinth to go to the steam header gland and will be condensed and separated again between moisture and air in the steam condenser gland with the help of the ejector to pull the uncondensable gas/ air then discharged into the atmosphere. [9]

1.3 Steam Purity

The relationship between the chemistry of boiler water and steam purity is influenced by many variables. For each case of a watertube boiler with high steam purity requirements, the chemistry of boiler water must be set as low as possible to achieve the required steam purity, as determined by empirical measurements, for protection of super heaters and turbines and / or to avoid process contamination.

In continuous operation, observation of feedwater and tabulated boiler chemistry can produce steam from purity designated from boilers with effective feedwater control and mechanical steam mechanical steam adequate for drum diameter, steam load rating and drum pressure. However, where vapors of greater purity than indicated are needed, it is advisable to follow the chemical advice of feed water and water boiler for at least the next higher operating pressure range. If the vapor purity value is shown to be better than needed, it is possible to use the alkalinity of boiler water, specific conductance, and silica values for a lower operating pressure range. Where possible, the true value allowed for alkalinity kettle water, specific conductance, and silica must be determined by carefully monitoring the purity of steam.

When spray water is directly added to steam for experimental effort, the purity of the spray water must be in accordance with the use of downstream steam. In particular, spray water must be essentially oxygen-free and contain no contaminants at concentrations greater than non-volatile vapor or chemical chemicals.

Some parameters of chemical content in boiler feed water that need to be considered and maintained are: 1.

Dissolved oxygen (DO) 2. Iron, Copper, Hardness, and dissolved solids 3. pH 4. Organic materials 5. Silica and 6. Alkalinity.

As for the discussion is organic matter in the form of oil content. The type of organic material that can be present in industrial boiler feed water is very numerous and very varied. They may be in make up water from natural sources, or are added as part of the chemistry of boiler water or through accidental contamination of make up or condensate water. Therefore, it is not possible to define best practice conditions for all categories in all situations. In an effort to establish some partial guidelines, the table includes recommended values for oily materials and non-volatile total organic carbon (TOC).

If there is organic contamination of feed water detected by the oily or nonvolatile TOC method in certain boiler operations, the potential to cause internal precipitation and / or carry over must be taken. If this potential is significant, contaminants must be removed before entering the preboiler system.

Volatile organics can cause severe damage to turbines. Because this problem is beyond the scope of this document, readers are advised to consult with other sources of information about the problem. [13]

TABLE I. STEAM PURITY (ASME)

Drum Operating Pressure	601-750 (4.15-5.171)	751-900 (5.18-6.211)
Feed water		
Dissolved oxygen ppm (mg/l)	<0.007	<0.007
Total iron (mg/l) Fe	≤0.025	≤0.02
Total copper (mg/l) Cu	≤0.02	≤0.015
Total Hardness (ppm)	≤0.2	≤0.01
pH @25oC	8.3-10	8.3-10
Nonvolatile TOC (mg/l) C	≤0.5	≤0.5
Oily matter ppm (mg/l)	≤0.5	≤0.5
Boiler Water		
Silica (mg/l) SiO ₂	≤30	≤20
Total alkalinity (mg/l)	<200	<150
Specific conductance (μmhos/cm)	1500-300	1200-200
Total Dissolved Solid in Steam		
TDS maximum (mg/l)	0.5-1	0.5-1

1.4 Oil and Grease

Oil and Grease (O&G) are a common occurrence in waste-water. An EPA commissioned study recently concluded that O&G is an indicator of the presence of numerous other organics in a wastewater, the types that partition into oil. The most famous one is PCB, which partitions into transformer oil.

The EPA is debating new rules that would set specific limits for O&G content in wastewater, thereby encompassing an entire range of organics that partition into oil. Such organics also would include solvents such as benzene and phenols.

Removing oil and grease from wastewater is relatively simple and cheap. Process industries should take the lead in addressing these questions, so that they are ready when the law takes effect. Furthermore, if they design their system such that the wastewater can be recycled, they actually can use this new law to save costs and lessen public concern about discharge of contaminated wastewater.

Effective removal of O&G requires an understanding of emulsions, mechanical versus chemical. Furthermore, the operator must know how to break emulsions and how to test effective treatment methods in the laboratory. He then must know how to remove the now mechanically emulsified oil most economically (i.e., how to coalesce the oil droplets effectively and how to reduce the O&G content to non-detect) so that recycling of the wastewater is feasible. This means being familiar with post-polishing techniques, particularly the use of organically modified clays (organoclays).

Oil appears in wastewater in a number of different forms including free oil and grease (FOG), mechanically emulsified oil, oil wet solids, chemically emulsified oil and dissolved oil.

Free Oil and Grease

Free oil rises rapidly to the surface of the water tank under calm conditions. The droplet size is 150 microns. This oil can be removed by an overflow weir in the tank and a skimmer. The traces can be removed by passing the wastewater through an adsorber tank (such as a carbon tank) filled with organoclay.

Mechanically Emulsified Oil

These oil droplets range in size from 20–150 microns. Mechanically emulsified oil is stabilized by electrical charges and other forces that result in the coating of suspended solids. Such oils mix with water due to shear that can result from the wastewater traveling through a pump, wastewater splashing into a tank and anything that will break up and disperse larger oil droplets.

Oil Wet Solids

This category includes oil that adheres to sediments and other particulate matter such as metal chafings that are common in industrial wastewater. Such oil solids are removed with sand filters, bag filters, flocculants and oil/water separators. These processes are followed by polishing with organoclay.

Chemically Emulsified Oil

Oil is chemically emulsified in water when emulsifiers such as surfactants or soaps are present. The surfactants have hydrocarbon chains. The simplest ones are sodium laurel sulfate or stearic acid, which have a hydrophilic (water loving) and a lipophilic (oil loving) end. The lipophilic end enters the oil droplet, while the hydrophilic end remains in the water. Since this creates a charge on the otherwise neutral oil droplet, the droplets will repel each other and disperse. This is called a chemically stabilized emulsion. The droplets are less than 20 microns, while the color of the water is white. The white color is an indicator that the emulsion must be split to allow removal of the oil. The source of such oils is metal working fluids, coolants, lubricants, motor oil, hydraulic fluids, etc.

Dissolved Oil

These are oils from the light end of the oil spectrum such as benzene, toluene and xylene. The molecules are less than five microns in size. They are removed very effectively by activated carbon. [1]

1.5 Activated Carbon

Activated carbon is a material that has very large and wide pores. These pores function to adsorb any contaminants that pass through it. How it works Activated carbon works by adsorption. That is, when there is material through the activated carbon, the material contained in it will be adsorbed. To make activated carbon, you can use several ingredients. Among them; material from animals or plants, coconut shells, hazelnut shells, palm shells, coal, bones, and others. Lots of natural ingredients used to make activated carbon. [8]

II. EXPERIMENTAL

2.1 Laboratory Evaluation

Adsorbent media used activated carbon (coconut shells) with specifications: mesh 12-40 Inch, iodine <800 mg/g, application water treatment, sample from condensate steam of gland seal condenser outlet E4E-23 Badak LNG with specification :

TABLE II. SAMPLE SPECIFICATION

Test parameters	Specification	Result	Information
pH	8,3-9,0	8,09	OK
Conductivity (µmhos/cm)	<5,0	4,4	OK
Sodium, Na (mg/L)	<0,02	<0,003	OK
Oil content (mg/L)	≤0.5	2-7	N/Y

2.2 Experiment

Experiments adopted by laboratory testing "Calgon Carbon Corporation", as for the stages are as follows: [3] Prepare equipment and materials needed. Considering activated carbon with a variation of 25 gr, 50 gr, 75 gr, 100 gr. Prepare a bottles and take a test solution on a field of 1 liter each. Enter the activated carbon with weight variations into each bottle that has contained a test solution. Stirring the mixture of solution and activated carbon regularly and silence for 24 hours and close the bottle. After the solution is left for 24 hours to achieve equilibrium then a sample of 100 mL is taken. Sampling using a fine filter so that the activated carbon is not included in the sample. The next step is to test the oil content of each sample (Test method for APHA Ed.22 5220 C oil content).

2.3 Pilot Test

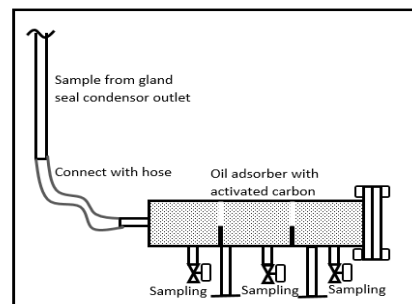


Fig 1. Oil adsorber (pilot)

Installation and use of oil adsorber procedures

Using PPE (personal protective equipment). Open the cover end 4 ", then insert the activated carbon until it is fully filled,

then close the cover end and tighten the bolts. Connect the hose to the oil adsorber inlet and tighten it using a clamp. Connect the other side of the hose to the condensor gland seal pipe and tighten it using a clamp. Oil adsorber is equipped with 3 taps that serve for sampling with a variety of column lengths (20cm, 40cm, and 60cm) which are restricted to using baffles. The flow rate of the inlet is varied by adjusting the tap openings at each variation in column length : 37.09 mL/s, 12.24 mL/s, and 7.54 mL/s.

III. RESULT & CONCLUSION

3.1 Laboratory Evaluation

TABLE III. LABORATORY EVALUATION RESULT

m (gr AC/L)	c (mg/L)	x (mg/L)	x/m	log x/m	log c
0	3	0	0	-	0,48
25	3	0	0	-	0,48
50	3	0	0	-	0,48
75	2	1	0,013	-1,88	0,30
100	1	2	0,02	-1,70	0

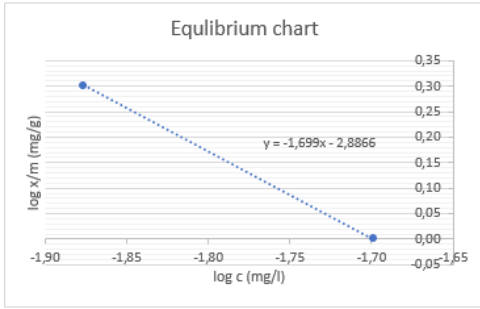


Fig 2. Equilibrium chart of laboratory test

Equation from equilibrium chart :

$$y = -1,699x - 2,8866$$

Constant of the equation : k = 0,0013 & 1/n = 1,6990

Freundlich equation :

$$x/m = kc^{1/n}$$

Calculate the mass of activated carbon :

$$x/m = kc^{1/n}$$

$$10/m = 0,0013.(0,5^{1,6990})$$

$$m = 25.006,33 \text{ gr} \approx 25 \text{ kg}$$

Where x is amount of impurity adsorbed (mg/L), m is weight of carbon (gr), c is contaminant concentration in the solution after adsorption equilibrium achieved (mg/L), x/m is concentration of the adsorbed state (mg/gr).

3.2 Design of Oil Adsorber

After obtaining the required mass of activated carbon, the required diameter and height of the column can be calculated, while the calculations are as follows:

TABLE IV. DESIGN OF ACTUAL OIL ADSORBER

Specification	Value
Density of carbon	729,17 kg/m ³
Volume of column	0,03 m ³
Lenght	2,23 m
Diameter	0,14 m
Flow rate	0,13 m ³ /h
Contact time	15,41 min
Linier velocity	29,29 m/h

3.3 Result of Pilot Test

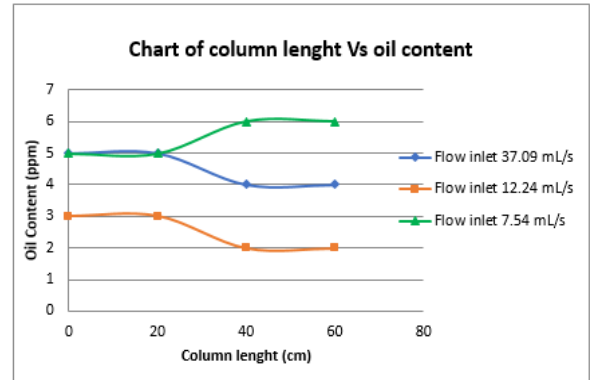


Fig 3. Chart of lenght vs oil content

Pilot test with variable column length and flow rate of sample. Optimum flow get 37,09 mL/s and 12,24 mL/s but flow rate 7,54 mL/s too low so it happens channelling effect make oil content increase before then.

3.4 Conclusion

- 1) The oil content dissolved in condensate steam is effectively removed by the adsorption method using activated carbon media.
- 2) From the "Freundlich" equation it can be estimated that the required weight of activated carbon is 25 kg.
- 3) The dimensions of the oil adsorber design are as follows: Lenght of column 2,23 m & diameter of column 0,14 m.
- 4) Optimal flow rate are 37,09 mL/s & 12,24 mL/s.
- 5) Need economic study for implementation.

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