A STUDY OF HYBRID INDUCTION HEATING IN DISTILLATION PROCESS

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Thesis Is Submitted In Fulfillment of the Requirements

For The Award of the Degree of

Bachelor in Chemical Engineering (Gas Technology)

Faculty of Chemical Engineering and Natural Resources

UNIVERSITI MALAYSIA PAHANG

JANUARY 2012

ABSTRACT

Contamination of the conventional water resources created several technological problems for industry and domestic water supplies. Apart from that, in order to develop more economical sustainability for researchers, industrial chemical and pharmaceutical processing, so the investigation of hybrid separation processes is proposed. The induction heating concept will be applied because of this technological method will improved the distillation process. Due to this, there are two kinds of method will carried out, which are the induction heating technique and also the traditional heating technique. For the hybrid technique, the heating mantle will be used as the medium of heating element and also used reservoir water as the inlet of the process. The reservoir water will be used optimally without losing single drop of water (prevent wastage). Then, the temperature will be set on 80^0C (inlet) and constantly at 50Hz. Onward, repeated on 90^0C, 100^0C and 110^0C. Similarly for the traditional heating method, equivalent procedure will used but different in heating element technique. Further on, the results of these kinds of methods will be comparing to determine the best results. Therefore, the expected results are; the best quality of distilled water is produced by using induction heating technique and also can reduced the electrical energy consumption.

ABSTRAK

Pencemaran sumber air konvensional mencipta beberapa masalah teknologi bagi industri dan bekalan air domestik. Selain daripada itu, dalam usaha untuk membangunkan kemampanan yang lebih menjimatkan untuk penyelidik, bahan kimia dan industri pemprosesan farmaseutikal, jadi penyelidikan dalam proses pemisahan hibrid dicadangkan. Konsep induksi pemanasan akan digunakan kerana kaedah ini akan menambah baik proses penyulingan. Oleh yang demikian, terdapat dua jenis kaedah yang akan dijalankan iaitu teknik induksi pemanasan dan juga teknik pemanasan tradisional. Bagi teknik hibrid, batu mortar akan digunakan sebagai pengantara bagi unsur pemanasan dan juga menggunakan takungan air sebagai masuk proses. Air takungan akan digunakan secara optimum tanpa kehilangan seetitik air (mengelakkan pembaziran). Kemudian, suhu akan ditetapkan pada 80^0C (masuk) dan di tetapkan pada 50Hz. Dan seterusnya, diulang pada 90^0C, 100^0C dan 110^0C. Begitu juga untuk kaedah pemanasan tradisional, prosedur yang sama akan digunakan tetapi berbeza dalam teknik unsur pemanas. Lanjut mengenai, keputusan ini pelbagai kaedah akan membandingkan untuk menentukan keputusan yang terbaik. Oleh itu, keputusan yang dijangkakan, kualiti air suling dihasilkan dengan menggunakan teknik pemanasan induksi dan juga boleh mengurangkan penggunaan tenaga elektrik.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The distillation process has been known and used for million years. Although initially has been used as a method of producing alcoholic beverages like whisky and vodka, distillation also works as a technique of water purification. In the 1970s, distillation process was a popular method of home water purification, but its use is now widely confined to science laboratories or industries. Distilled water is produced by distillation process using tap water. The distillation process utilizes a heat source to vaporize the water. The objective of distillation process is to separate pure water molecules from contaminants with a higher boiling point than water. In the distillation process, water is heated until it reaches its boiling point and starts to evaporate. The temperature is then kept at a constant. The stable temperature ensures continued water vaporization, but forbids drinking water contaminants with a higher boiling point from evaporating. Next, the evaporated water is captured and brought through a system of tubes to another container. Lastly, removed from the heat source, the steam/the vapor condense back into its original liquid form. Contaminants which having a higher boiling point than water remain in the original container. So, this process removes most minerals, bacteria and viruses, and chemicals that have a higher boiling point than water from water. For this reason, distillation is sometimes valued as a method of obtaining pure water. (Source from http://www.allaboutwater.org)

However, there is no yet proved that might be possible to produce water free of contaminates without utilize substantial amount of energy. In this study, an economical induction for distillation water production is proposed. Therefore, the convection system using hybrid heat transfer will reduce the energy consumption to 90% less. This hybrid induction steadily obtaining high purity distilled water includes a distillation vessel, a convection and conduction condensers, a north-north pole permanent magnet based on continuous stirring system. So, for the heat source, the heating induction concept will be applied. The use of hybrid induction heating transfer has been found extremely effective (Derra et al., 1988). Induction heating is a non-contact heating process and it uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact process, the heating process does not contaminate the material is being heated. It is very efficient since the heat is actually generates inside the workpiece. This can be compared with other heating methods where heat is generated in a flame or heating element, which is then applied to the workpiece. For these reasons, induction heating lends itself to few unique applications in the industry. Therefore, a method uses induction heating energy to heat the water does not release contaminants to the water.

1.2 PROBLEM STATEMENT

A growing demand for water along with the progressing contamination of the conventional water resources creates several of technological problems for industry and domestic water supplies. Chronic water pollution and growing economies are driving municipalities and companies to consider the desalination as a solution to their water supply problems (Viessman and Hammer, 2005). In order to develop more sustainable and economic production processes for chemical and pharmaceutical products, the focus on academic and industrial research is presently set on the investigation of hybrid separation processes (P. Kreis and A. Go'Rak, 2006). Apart from that, filtration and ion exchange methods have been proposed to provide high purity distilled water but, these methods are not too effective. Other than that, the combination of filtration, ion exchange and

distillation is rather complicated, time consuming and high-priced to build, operate and maintain. However, it has not yet proved possible in a production of water that free of contaminants. Thus, the distillation process assisted by induction heating should be one of method to produce high purity distilled water. Therefore, it is importance to investigate the effectiveness of hybrid separation phenomenon by applying induction heating in distillation process.

1.3 OBJECTIVES

The aim of this study is to produce high purity distilled water without losing single drop of water at minimum amount of energy. Hence, the objective is

- To investigate the effectiveness of hybrid separation phenomenon by applying induction heating in distillation process

1.4 SCOPE OF RESEARCH

Based on the objective, the scopes of study are highlighted as follows:

- To study the heat effect of temperature to the heat change
- To study the purity of the water after the distillation process

1.5 RATIONALE AND SIGNIFICANCE

The purpose of this study is to produce high purity distilled water without losing single drop of water at minimum amount of energy. By using distillation process and assisted by hybrid induction heating. The application of this hybrid heat transfer phenomenon will reduce the energy consumption, accelerate the heating speed and the time consuming will subtract. Besides that, the most important is, hybrid induction is very quick responses and have good efficiency. The cost for the production of high purity distilled water will be decrease when this hybrid induction implemented in distillation process system.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

One of the simplest methods of purifying water, distilling is the process of boiling water into steam, and then condensing the steam back into water. As gases (including chlorine) and volatile organic compounds (VOCs) can be re-condensed back into the drinking water, most steam distillers use a carbon post filter which adsorbs gases. It is important that the carbon filter be replaced regularly, as the filters that are included with most distillers are small, and can easily become saturated with toxins. When a carbon filter has reached the saturation point, toxins and bacteria can be passed into the distilled water. Apart from that, distillation removes heavy metals, micro-organisms, poisons, bacteria, contaminants, sediment, minerals and viruses. Another, distillation cannot remove substances with lower boiling points than water including oils, petroleum and alcohol. The boiling chamber collects these contaminants and requires regular cleaning. (Source from http://www.opus.net)

In the present, distilled water is needed for daily necessities such as drinking water because this type of water is free from any kind of contamination or impurities such as bacteria and debris. Besides that, it is used in various industries and chemical and biological laboratories where highly purified water is essential. Sometimes, in cases where

considerably high degree of purified water is required, double distilled water will used. Other than that, it is used for making various drinks by many beverage manufacturers to ensure a high quality product in terms of both taste as well as purity. Another is, it is often preferred to tap water in automotive cooling systems too. This is because the ions and minerals are presents in tap water are usually corrosive in nature and tend to demolish the anti-corrosive additives present in the radiator. But, there has been a regular demand for high purity water for pharmaceutical, industrial chemical processing and also for researchers.

Steam distilled water systems utilize either a plastic or stainless steel holding tank to hold the distilled water. Most systems have a spigot that is used to fill large plastic bottles for water storage. Glass bottles are preferred, but they are hard to find, very heavy, and dangerous if dropped. The boiling tank must be drained regularly, and depending on the model, cleaned every few weeks to remove scale deposits. Some models offer optional expensive auto drain kits that eliminate the need to clean the boiling tank where the impurities collect. Other options include pump kits and pressure tanks that allow steam distilled water to be connected to a kitchen mounted faucet for on demand water. (Source from http://www.opus.net)

Other than that, distilled water is particularly corrosive. With no minerals to give the water pH balance, distilled water acts like a magnet, absorbing chemicals (phthalates and bisphenols) from plastics, nickel from stainless steel, aluminum from aluminum containers, and carbon dioxide from the air. With no minerals to buffer the water, and the absorption of carbon dioxide from the atmosphere, distilled water will have an acidic (<7) pH. (Source from http://www.opus.net)

Unfortunately, there is still no proved that possibly to produce water free contaminates without using huge amount of energy. Usually, quality steam distillers are expensive, time consuming and costly to maintain, with electrical costs ranging from $.20 to $.40 per gallon. If scale is allowed to build up on the heating element, the efficiency of the unit will be affected resulting in higher operating costs.

2.2 DISTILLATION PROCESS SYSTEM

Doherty Malone stated that "Distillation separates, or fractionates, chemically different species by exploiting the fact that the compositions of coexisting vapor and liquid phases are generally different. The liquid and vapor mixtures that coexist in distillation are at or very near the boiling point temperature. In many mixtures the coexisting vapor and liquid phases rapidly approach equilibrium, and thermodynamics provides a framework for describing the composition differences". Therefore, distillation process has been used widely in the chemical, petrochemical, refining and even in food industries for the separation of liquid vapour mixture of substances. However, this process demands large inputs of energy, and small improvements of this system can save large amounts of energy (de Koeijer and Rivero, 2003). Distillation is the separation method that most frequently applied in the chemical industry, which is based on the difference of the volatility of the components of a liquid mixture. Because of high demand of energy, the optimal design and operation of the distillation columns is a very important issued (B. Kotai et al., 2006). The proper selection of the technology after consideration of the economical, technological and energy resources on site is important (Armenta-Deu., 2001). Therefore, the purpose of this study is to produce high purity distilled water without using huge amount of energy by assisted the induction heating process.

2.3 TYPES OF DISTILLATION

Distillation is a physical method of assorting mixtures depending upon the difference in the boiling point of the component substances. The working principle of distillation is to heat a mixture at a specific temperature, collect the hot vapors and condense to separate the component substance. In simpler terms, a highly volatile compound is separated from a less-volatile or non-volatile compound by using distillation. As per evidences, the principle of distillation has been used since ancient times. It is believed that the ancient Arab chemists applied distillation for the first time to

separate perfumes. Today, it is one of the most popular techniques implemented for purification and separation of a mixture.

Following are the common types of distillation:

i. **Simple Distillation**

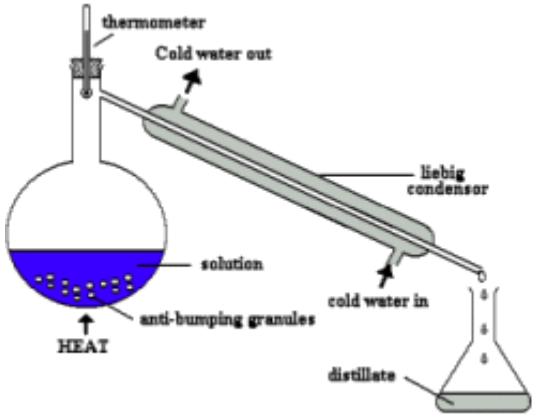

Figure 2.3a: Simple distillation diagram

Source: http://www.docbrown.info

Simple distillation is practiced for a mixture in which the boiling point of the components differs by at least 70 ℃. It is also followed for the mixtures contaminated with nonvolatile particles (solid or oil) and those that are nearly pure with less than 10 percent contamination. Double distillation is the process of repeating distillation on the collected liquid in order to enhance the purity of the separated compounds.

ii. **Fractional Distillation**

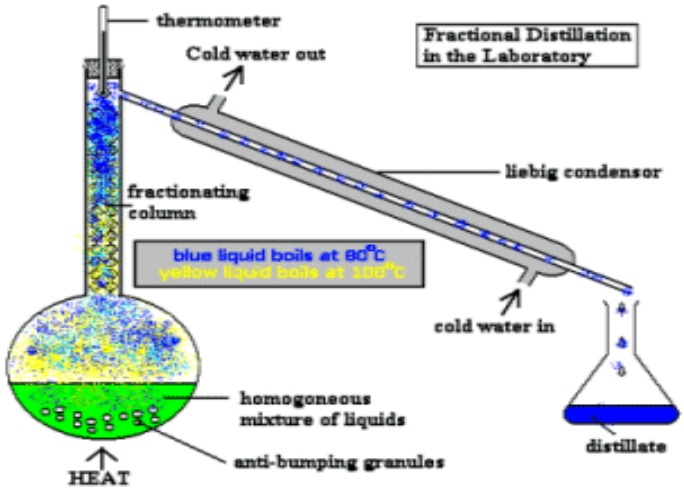

Figure 2.3b: Fractional distillation diagram

Source: http://www.docbrown.info

Those mixtures, in which the volatility of the components is nearly similar or differs by 25 ℃ (at 1 atmosphere pressure), cannot be separated by simple distillation. In such cases, fractional distillation is used whereby the constituents are separated by a fractionating column. In the fractionating column, the plates are arranged and the compound with the least boiling point is collected at the top while those with higher boiling point are present at the bottom. A series of compounds are separated simultaneously one after another. Fractional distillation is used for the alcohol purification and gasoline purification in petroleum refining industries.

iii. **Steam Distillation**

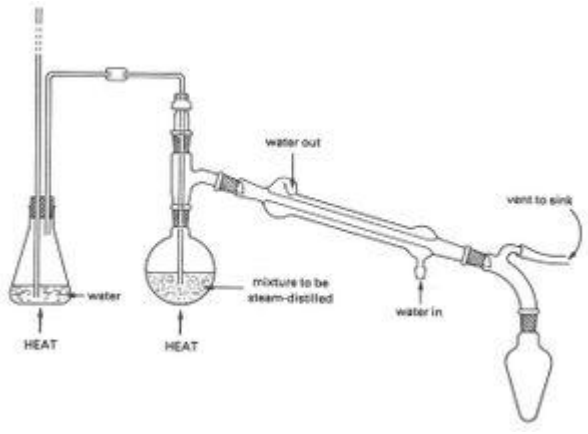

Figure 2.3c: Steam distillation diagram

Source: http://www.docbrown.info

Steam distillation is used for the purification of mixtures, in which the components are temperature or heat sensitive; for example, organic compounds. In the instrument setup, steam is introduced by heating water, which allows the compounds to boil at a lower temperature. This way, the temperature sensitive compounds are separated before decomposition. The vapors are collected and condensed in the same way as other distillation types. The resultant liquid consists of two phases, water and compound, which is then purified by using simple distillation. Steam distillation is practiced for the large-scale separation of essential oils and perfumes.

iv. **Vacuum Distillation**

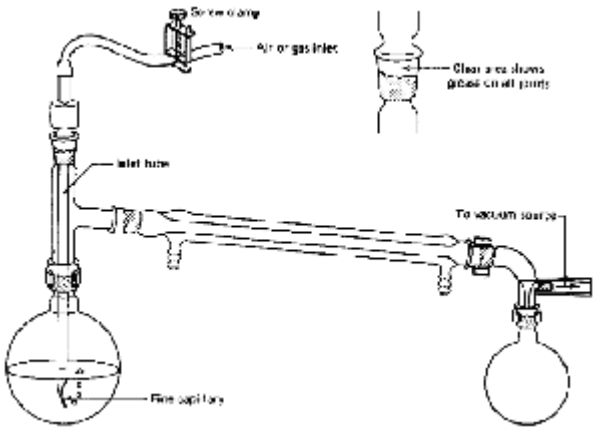

Figure 2.3d: Vacuum distillation diagram

Source: http://www.docbrown.info

Vacuum distillation is a special method of separating compounds at pressure lower than the standard atmospheric pressure. Under this condition, the compounds boil below their normal boiling temperature. Hence, vacuum distillation is best suited for separation of compounds with higher boiling points (more than 200 ℃), which tend to decompose at their boiling temperature. Vacuum distillation can be conducted without heating the mixture, as usually followed in other distillation types. For the separation of some aromatic compounds, vacuum distillation is used along with steam distillation.

v. **Short Path Distillation**

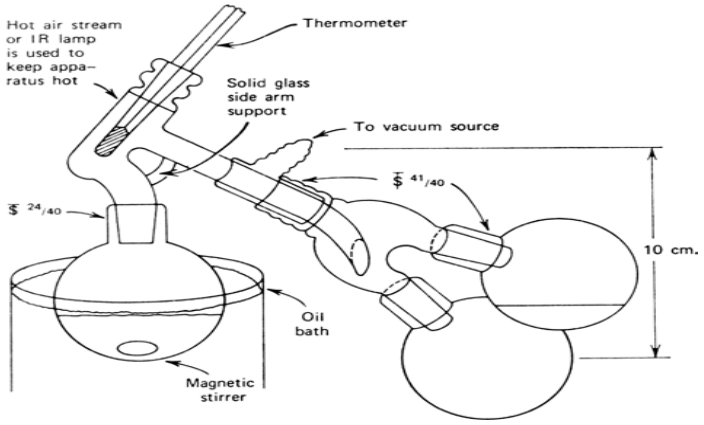

Figure 2.3e: Short path distillation diagram

Source: www.docbrown.info

Thermal sensitive compounds can also be separated by following short path distillation. In this technique, the separated compounds are condensed immediately without traveling the condenser. The condenser is configured in a vertical manner between the heating flask and the collecting flask. Similar to vacuum type, the pressure is maintained below the atmospheric pressure. Short path distillation is used for the separation of organic compounds with high molecular weight, especially in the pharmaceutical industries.

2.4 WATER DISTILLATION PRINCIPLES

Every element can exist in three states: as a liquid, solid and vapor, which mostly depend on its temperature. This applies to water, too. So, water can be found as ice, water and steam. If water is cooled down below 0 degrees Celsius (32 Fahrenheit), it becomes ice, and if heated above 100 degrees Celsius (212 Fahrenheit), it becomes steam. The temperature, at which a substance changes it state from liquid to vapor is called a boiling point, and it is different for different substances. This difference can be used to separate substances, and as such can be used for water purification.

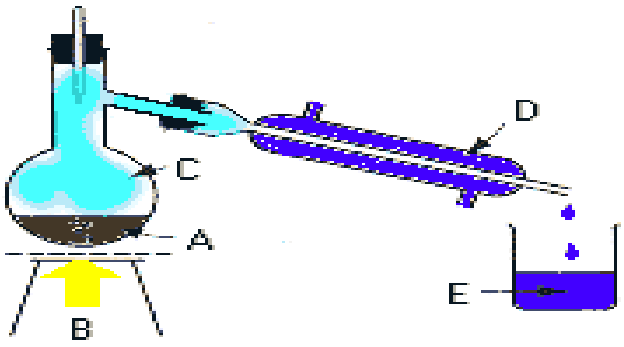

Figure 2.4a: Simple water distillation process

Source: www.i4at.org/surv/distill.htm

The process is relatively simple:

A: The dirty water/ reservoir water is heated

B: (Heat sources) heated to the boiling point and thus vaporizes

C: (Becomes steam), while other substances remain in solid state, in boiler. Steam is then directed into a cooler

D: (Condenser) where it cools down and returns to liquid water

E: (Distilled water) purified of additional substances found in it before distillation.

Distillation is an effective process and more important, it can be done with a lot of improvisation. The water can be heated with whatever is at hand: fire, electricity, or whatever. Distillation will remove from water almost anything, even heavy metals, poisons, bacteria and viruses. However, it does not remove substances that have boiling points at a lower temperature than water. Some of these substances are oils, petroleum, alcohol and similar substances, which in most cases don't mix with water. Distilled water can be used directly and does not need to be boiled again.

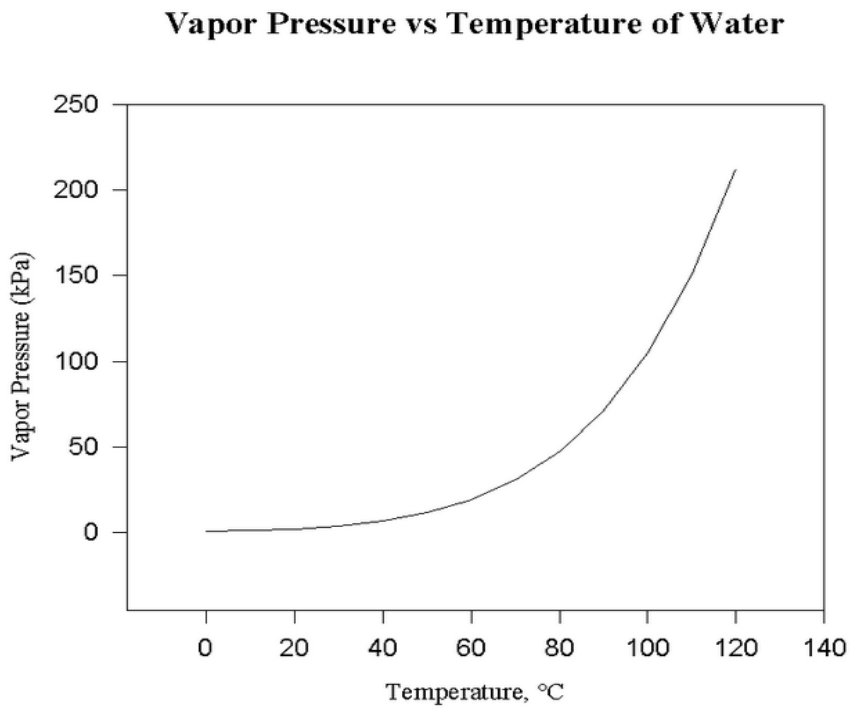

Figure 2.4b: Vapor pressure dependence on temperature for water

Source: www.umsl.edu

At equilibrium, the process of vaporization is compensated by an equal amount of condensation. Incidentally, if vaporization is an endothermic process (i.e. heat is absorbed), condensation must be an exothermic process (i.e. heat is liberated). Now consider how vapor pressure varies with temperature. Figure 2.4 illustrates that vapor pressure is a very sensitive function of temperature. It does not increase linearly but in fact increases

exponentially with temperature. A useful "rule of thumb" is that the vapor pressure of a substance roughly doubles for every increase in 10 ℃. If we follow the temperature dependence of vapor pressure for a substance like water left out in an open container, we would find that the equilibrium vapor pressure of water would increase until it reached 1 atmosphere or 101325 Pa (101.3 kPa, 760 mmHg). At this temperature and pressure, the water would begin to boil and would continue to do so until all of the water distilled or boiled off. It is not possible to achieve a vapor pressure greater than 1 atmosphere in a container left open to the atmosphere. Of course, if we put a lid on the container, the vapor pressure of water or any other substance for that matter would continue to rise with temperature until the container ruptured. Elevation of the boiling point with increase in external pressure is the principle behind the use of a pressure cooker. (Source from www.umsl.edu)

2.5 ADVANTAGES OF DISTILLATION PROCESS

i. Easily and efficiently removes toxic chemicals, heavy metals, bacteria, viruses, parasites such as cryptosporidium, and other contaminants that are harmful to our health.
ii. Distillation also removes pathogens in the water, mostly by killing and leaving them behind when the water vapor evaporates. If the water is boiled, or heated just short of boiling, pathogens would also be killed.
iii. A good distillation unit produces very pure water. This is one of the few practical ways to remove nitrates, chloride, and other salts that carbon filtration cannot remove.
iv. As long as the distiller is kept clean and is working properly the high quality of treated water will be very consistent regardless of the incoming water - no drop in quality over time.
v. More effective than reverse osmosis systems in contaminant reduction, even with high levels of pollution.