Desalination process design

Water is one of the vital resources needed for the survival of human, but around the world the availability of this product is getting reduced. This is as a result of the increase in human wants like irrigation, industrial uses and human consumption for the increase is the human population. (Gleick, P. H. 1994). Water covers 70. 9% of the Earth’s surface, the ocean which represents the largest majority of that has an average of 5. 5% (by weight) of dissolved salt which makes it inadequate for human consumption which the remain 3% of fresh water is inadequate to meet up with the need of the world population. (Hummel, D., T. Kluge, S. Liehr, M. Hachelaf 2006)

The world’s water consumption is increasing every 20 years, in addition to twice the population growth. It is estimated that by the year 2025 water requirement will surpass supply by 56%, due to persistent regional droughts, shifting of the population to urban coastal cities, and water needed for industrial growth. The supply of fresh water is on the decrease. Water demand for food, industry and people is on the rise.

The issues surrounding the inadequate quality and quantity of water is due to the cost and availability of the product. This has brought about the need for research into ways to get water from the ocean by the reduction of the salt in the ocean water, this process is called desalination. Desalination process is the removal of soluble salts and ions from water to make it suitable for human use. (Hamed, Osman A. (2005).

The different types of water- makers in circulation produces about 2 to 150 litres per hour when operational depending on the brand. Designs are made for boat, ships, yachts and submarines. The principle of reverse osmosis is

employed to achieve these goal, where water is passed through a membranes with a high pressure pump to allow pure water passes through the membranes and the salt water left behind. Water-makers sustain consumers on ocean-going vessels to be self-determining of shore-based water supplies, which are important in remote parts of the world, provide safe water when shore-based water is of uncertain quality and their compact and portable design makes it transferable to a life raft in an emergency. These designs are operated by external power like batteries or manual operation in an emergency.

The objective of this project is to analysis the different parts in the water-maker and try to create a better design. This design should create 5 – 10 litres/hour of operation, a dual power operation (automatic and manual pump), finding a way to reduce the replacement of the membranes, make the product more efficient, reliable and effective. The aim of producing an optimized design without changing the design drastically, reducing the risk of failure of critical components occurring by improving the reliability of the design and developing ability to apply advanced CAD tools in support of design activity.

CHAPTER TWO: LITERATURE REVIW

2. 0 Role of Seawater through desalination

Desalination implies the various means in which the removal of excess salt and other minerals from the water in order to make it suitable for human consumption. In a short form desalination is the removal of salt and other organic or inorganic minerals. (Hamed, Osman A. (2005). Through out the years various ways have been discovered to make seawater a means of

providing drinkable water through the use of boiling, evaporation, chemical reaction, sensitive material and ion manipulation in order to create clean water. The diagram below shows the steps that have been used to come to a final conclusion.

2. 1 Saline Water

In order to understand the process used, the minerals that make up the seawater has to be put in to perspective. Saline water is used to describe water that contains a considerable amount of total dissolved salt (TDS). The level of concentration is measured in parts per million (PPM) or milligram per litres (mg/l) or moles per litres (mole/litres) of salt content. The fact that the waters of the world are interlinked to one another does not mean that the salinity of the water is the same in all places.

This is due to the climate change in various regions, way of living of the region and water cycles. Seawater is roughly estimated to be between 35, 000 ppm, equivalent to 35 g/L which is the parameter used when deciding on the process to use for desalination. Here are our parameters for saline water:

- Fresh water – Less than 1, 000 ppm
- Slightly saline water – From 1, 000 ppm to 3, 000 ppm
- Moderately saline water – From 3, 000 ppm to 10, 000 ppm
- Highly saline water – From 10, 000 ppm to 35, 000 ppm

The boundary set by the World Health Organisation (WHO) which is the the amount necessary for human consumption is 500ppm as the maximum desirable concentration of total dissolved solids (TDS) in drinking water. Other living things like animals; birds may endure vaguely increased

concentration of up to 1000 ppm which in turn could be acceptable for human to sustanin them selves for a short period of time. (Porteous, (1983). Figure 2. 2 shows below is the allowable salinity requirement of various things.

2. 2 Desalination Processes

For saline water to become fresh water all the total dissolved substances must be removed. These are ions that make the saline water unsuitable for consumption which are Na+, (SO42-), Ca2+, Cl-, NH4, Fe2+, Fe3+, Mg2+, K+, CO32âˆ’ , OHâˆ’ , NO3âˆ’ , NO2âˆ’ , PO43, SO42âˆ’. Carrying out a purification process by desalination, the

Removal of large particles, which are visible to the naked eye like sand. Organic weed, metal fragments.

Removal clean water from the solution leaving salt solution which is called brine behind which has a here salt concentration.

Removal of the dissolved ions from the clean water.

2. 2. 1 Distillation

Distillation is a one of the oldest used technique used in the separating mixtures due to the difference in the properties of the mixture. To separate a mixture of liquids, the liquid can be heated to a temperature higher than the temperature of the mixture, which has different boiling points, into the gas phase. The gas is then condensed into liquid form and collected. This process can be repeated in order to collect as much end product as possible. For example, fresh water can be obtained from seawater (water that contains

salts), this can be achieved, seawater (saline water) is heated to a high temperature which makes the water in it evaporate and it is later condensed and collected as pure water (Sarton, George (1975). The salts in the seawater remain behind. In order to achieved the desired result the changes in temperature and/or pressure id observed. All desalination processes involve three liquid streams: the saline feedwater (brackish water or seawater), low-salinity product water, and very saline concentrate (brine or reject water).

Using the idea behind the distillation process above researcher have created three different process using there are three types of distillation processes used in desalination

- 2. 2. 1. 1 Multi-stage flash distillation (MSF)

Multi-stage flash distillation (MSF) is a type of water distillation of seawater is one that distills water by flashing. Flashing is described as increasing the temperature and pressure of the feed water in the stages. The Multi-stage flash distillation unit has a sequence of chambers called stages, which have heat exchangers and condenser collector. (Buros, O. K. 1987)

From the diagram Figure 2. 2, the Multi-stage flash distillation is divided into many stages depending on the nature of the plant in question. The seawater that is saline in nature is introduced which is referred to as feed water through each stage via the heat exchangers. This is done to increase the temperature of the feed water before it proceeds to the heating chamber. The temperature of the feed water is increase in order to reduce cost of heating and increase the temperature of the feed water higher than

required. In the heater, an amount of additional heat is added to raise the temperature of the liquid to steam (Camilleri, F. 1979). After the heater, the water flows through the pipes to the first stage, which have ever-lower pressure and temperature. During the course of flow the feed water is then called brine water because of the higher concentration of salt. As the brine travels through each stage, the temperature is reduced and the stem evaporates coming in contact with the heat exchangers. The steam cools and condenses against the heat exchanger tubes, thereby heating the feed water as described earlier (Chan, P. K. and K. W. Chan 1989)

Due to the increasing temperature, scale formation and corrosion is formed. This is one of the disadvantages of this system because it reduces heat conductivity of the system. Depending on the stages involved the temperature can varies from 120°C as maximum. The condenser feed water is called distillate, which is collected at the trays in each stage and passed out for collection. In the last stage the brine is recycled, this is done to increase the temperature of the feed water and excess is rejected back into the sea (Cant, R. V. 1980a). The brine and condensate still carry a small amount of heat that is lost from the system when they are discharged. The heat that was added in the heater makes up for this loss. A multi-stage flash distillation plant generates over 80 percent of all desalinated water in the world.

- 2. 2. 1. 2 Multiple-effect distillation (MED| ME)

Multiple-effect distillation (MED) is a numerous effects. In each phase, the feed water is heated through the passage of steam in tubes. When this

happens, some of the feed water evaporates due to the difference in temperature. The tube are continuous to the last stage in the unit, which carries on heating and evaporating water as it goes along each stage. This system is efficient because energy lost from each stage is used in the next stage. (Crerar, A. J., R. E. Low, and C. L. Pritchard 1987). The evaporated gas is cooler using a heat exchangers and collect as distillate.

- 2. 2. 1. 3 Vapor-compression (VC)

Vapor compression desalination is another form of distillation where saline water is heated up or evaporated by using compressed vapour. When vapour is compressed, it increases the pressure and temperature of the vapour in turn. This temperature and pressure can be used to heat up feed water. The effect of compressing water vapor can be done by two methods.(Dabbagh, T. A. & A. Al-Saqabi 1989)

The first method is done by using a steam ejector unit that compresses vapour. The unit is called Ejector or Thermo Compressor. The vapour steam produced is used as the heat.

The second method is done by using a mechanical device called mechanical vapour compression (MVC).

2. 2. 2 Ion exchange

Ion exchange is an swapping of ions amongst two electrolytes. Ion exchangers are either cation exchangers that exchange positively (Na+, K+, Ca2+, Mg2+) charged ions (cations) or anion exchangers that exchange negatively (OHâˆ’, Clâˆ’, SO42âˆ’ , PO43âˆ’charged ions (anions). (Delyannis, E. E. 1987)

The feed water that is fed in to the unit has ion that makes the water saline so by removing this type of ions these ion can be removed making the distillate. This process is not used, as a commercial process due to the specification require for the electrode. This is mostly used for water that are hard due to regional problems. It is used mostly in situations where there are ions present in the feed water.(Delyannis, E. E. 1987)

2. 2. 3 Membrane processes

Membrane process is a desalination process where there is a barrier separating the feed water and distillate. Membrane processing is a method that permits concentration and separation without the use of heat. The membrane are physical material with tiny porous that allows water through it, leaving behind saline water.(Gomkale, S. D. and R. L. Datta 1973). To achieve this pressure is applied to force the distillate through the membrane There are four types of membrane separations

2. 2. 3. 1 Electrodialysis reversal (EDR)

EDR desalination has been used since the early 1960s. Feedwater passes concurrently through a cell. Electric current is passed through a panel in the cell to attract saline ions like nitrates and sulfates (Hall, W. A. 1980).

Reverse osmosis (RO)

Osmosis involves advancement of a solvent through a semi-permeable membrane into a solution of elevated solute concentration, which results in the balance of the concentrations of solute on either sides of the membrane (Haynie, Donald T. 2001). Semi-permeable membranes are slender film of

fabric which permit some things to pass through them nevertheless avoid other elements from transient through. Semi-permeable membranes could permit small molecules like Oxygen, water, Carbon Dioxide, Ammonia, Glucose, amino-acids to pass through but prevent larger molecules like Sucrose, Starch, protein from pass through. a region of higher concentration is a region that has higher water contain while a region of low concentration is a region with less water concentration (Warner, Jill D. Wright (1997).

Below is a beaker filled with salt water on one side and pure water on the other, which is separated with semi-permeable membranes. Originally, the level of the salt-water mixture and the pure water are equal, but after a while, something unanticipated happens. The pure water rose, the rise is attributed to “ osmotic pressure.”(Borg, Frank 2003)

Reverse osmosis is a separation procedure using pressure to drive a solvent in a semi permeable membrane that hold on to the solute on one side but permit the solvent to go through.

- Conventional filters; only removes relatively coarse suspended particles
- Microfiltration; will separate finer particles and bacteria (down to approximately 1 micron size)
- Ultrafiltration; will separate much finer suspended matter (including colloids) plus some large dissolved molecules and smaller micro-biological species
- Nanofiltration; will remove organic substances plus moderate retention for univalent salt

- Reverse Osmosis; Finest of the filters and separates ionic salts from water stream

There are two main membrane used in reverse osmosis

Spiral wound: using a sheet produces this membrane, which consist of polyester base, polysulfone layer and polyamide layer. Each of the layers is used to separate ions and salt.

From the figure 2. 10, this sheet is the membrane responsible for the separation process as shown above. The membrane is then combined with a sheet of feed channel spacer, which provide turbulence and creates a space between sheets to allow uniform flow of the water across the sheet(Leitner, G. F. 1989). Other corresponding sheets are glued together depending on the diameter required. The sheets are then rolled around hollow tube called the collecting tube, which is used to channel the distilled water.

Hollow fibre tube: the hollow tube is a tinny fibre, which was discovered in the 1800s by some group of clothing manufacturers (Lucas, M. 1987). The material was developed to be able to be used as a fabric foe sewing clothes but during the research of the product they discovered the potential of the strands of the material because of this unique discovery this fibre is only manufactured in five companies in the world making it expensive and hardly accessible (Lawand, T. A. 1987). The strands of the fibre consist of Antifouling polyethersulfone (PES) composition, which allows water to pass from the external to the internal holes of the fibre. The wall thickness of the fibre ranges from 50 microns to 150 microns as shown in Figure 2. 10, this is to allow easy passage of water and reduce to rate of blockage.

The fibre is bundled together with a hollow pipe running through the middle of the bundle; the thickness of the bundle depends on the diameter required (Lucas, M. 1987).

As it flows rapidly through the bundle and over the fibres, some of the water penetrates the fibres, flows down the bore and is collected in the tube sheet end of the vessel. The remainder of the water carries concentrated salts to the concentrate port of the vessel.

2. 2. 4 Freezing

Freezing is a desalination process that uses the freezing point of water as a separation process. The saline water is cooled to a temperature from 0 0C to -2 0C, at this temperature only pure water would freeze while the impurities remain liquid. The ice formed, which is the distillate, is collected and cooled (Manson, J. 1993). This process is hardly used because of the energy required in a large scale and the time required for the freezing to take place. This process is mostly used for small-scale manufacture or in cold places like the North Pole where cooling can be easily reached. (S. Manor 1987).