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AIR GAP MEMBRANE DISTILLATION: AN EFFICIENT DESALINATION TECHNOLOGY

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Revised Proposal — Today, one of society's most serious issues is the lack of healthy drinking water. Although there is a plentiful amount of water available in the oceans, much of it contains substances that make it undrinkable. To resolve this problem, engineers have been researching to find an optimal technology that efficiently desalinates, or removes salts and minerals from seawater. As a result of their research, a process known as membrane distillation was developed. Membrane distillation is defined as the process in which thermal energy is added to a microporous membrane to separate water vapor from salts, minerals, and other substances [1]. In order to efficiently use thermal energy, an air gap membrane distillation system was created. Air gap membrane distillation systems are systems in which a microporous, or semipermeable, membrane and a condensing surface separated by an air gap are used to desalinate water [2]. In this paper, air-gap membrane distillation systems will be analyzed to show their significant contributions to the efficient desalination of seawater. Components of an air gap membrane distillation module include a hot water flow channel, cold water flow channel, hydrophobic porous membrane, and an air gas layer [3]. The system functions by collecting solar energy and applying it to its membrane distillation process. In its membrane distillation process, water converts to water vapor; this water vapor is relinquished of excess substances first through the microporous membrane and then additionally through an air gap. The air gap is implemented into the system in order to maintain the interior flow of heat and the efficiency of the system as a whole [2].

Air gap membrane distillation is a significant development in the engineering community because its use of solar energy is practical and beneficial. Systems that can run on solar energy are very important to society because many areas lack the other resources necessary to desalinate water. Also, once the air gap membrane distillation system is implemented, the cost of maintaining the energy needed to run the system is much lower than many other desalination technologies. For example, Memstill air gap membrane distillation systems operate at \$0.26 for every meter cubed of water compared to \$0.45 for meter cubed of water for other desalination technologies [4]. With air gap membrane distillation, money can be saved, society's energy consumption problem can be alleviated, and purified drinking water can be provided to

those in need. In this paper, a detailed analysis will be conducted of the application of air gap membrane distillation modules for water desalination. Air gap membrane distillation modules will be described not only by their benefits, but also by their needed areas of improvement. Improved modules, such as ones with a developed internal latent-heat-recovery, will be addressed.

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This article, from a professional, peer revised online journal about desalination, provides an ethical outlook on water resources engineering and engineering as a whole. The article outlines the how engineers should act with profession competence by prioritizing the public's needs. The information from this source will be used to explain how the use of air gap membrane distillation systems is an ethical approach to desalinating water.

Y. Chen, Y. Li, H. Chang. (2012). "Optimal design and control of solar driven air gap membrane distillation desalination systems." *Applied Energy*. (Online Article). <http://www.engineeringvillage.com/search/doc/abstract.url?pageType=quickSearch&searchtype=Quick&SEARCHID=0c3e1e2dM2bfaM4f36M9fd5Me565cbf6e42a&DOCINDEX=3&database=3&format=quickSearchAbstractFormat&dedupResultCount=&SEARCHID=0c3e1e2dM2bfaM4f36M9fd5Me565cbf6e42a> pp. 193-204

This article, from a professional, peer-reviewed online journal about applied energy, describes a study regarding the factors that affect the efficiency of solar driven air gap membrane distillation systems. The article details how the addition of a control structure into an air gap membrane distillation system minimizes energy consumption per unit distillate water flowrate. Information from this source will help us understand the factors necessary for optimal design and control.

A. Cipollina, M. Di Sparti, A. Tamburini, G. Micale. (2012). "Development of a Membrane Distillation module for solar energy seawater distillation." *Chemical Engineering Research and Design*. (Online Article). <http://www.engineeringvillage.com/search/doc/abstract.url?pageType=quickSearch&searchtype=Quick&SEARCHID=4aadf71eM6122M4089M8229Mdd9516de7ac0&DOCINDEX=1&database=3&format=quickSearchAbstractFormat&dedupResultCount=&SEARCHID=4aadf71eM6122M4089M8229Mdd9516de7ac0> pp. 2101-2121

This article, from a professional, peer-reviewed online journal about chemical engineering, details the development of a laboratory scale planar geometry, air gap membrane distillation unit. The article describes a study on the module's process performance and other parameters relevant to the use of solar energy. Information from this article will be used to show an example of an analysis conducted on an air gap membrane.

A. Cipollina, G. Micale. (2010). "Coupling sustainable energy with membrane distillation processes for seawater desalination." *Proceedings of the First International Nuclear Renewable Energy Conference*. (Online Article). <http://www.engineeringvillage.com/search/doc/abstract.url?pageType=quickSearch&searchtype=Quick&SEARCHID=94b00c5aM0212M460dM9242Mf11111feeec&DOCINDEX=1&database=3&format=quickSearchAbstractFormat&dedupResultCount=&SEARCHID=94b00c5aM0212M460dM9242Mf11111feeec> pp. 1-6

This article, a conference paper from the Proceedings of the First International Nuclear and Renewable Energy Conference, details how using solar energy for water desalination can be beneficial by saving money and energy. The article describes the general process for membrane distillation and the performance of solar powered membrane distillation systems. Information from this article will aid us in our general understanding of why solar powered membrane distillation is important to develop.

H. Fath. (1998). "Solar distillation: a promising alternative for water provision with free energy, simple technology and a clean environment." *Desalination*. (Online Article). <http://www.engineeringvillage.com/search/doc/abstract.url?pageType=quickSearch&searchtype=Quick&SEARCHID=834659aeM2de2M48a7M8b96Me45751323902&DOCINDEX=1&database=3&format=quickSearchAbstractFormat&dedupResultCount=&SEARCHID=834659aeM2de2M48a7M8b96Me45751323902> p. 1

This article, from a professional, peer-reviewed online journal about desalination, describes how solar distillation is a beneficial desalination technique that can be used to provide drinking water to those in need. The article defines solar distillation and details the types of stills available for this process. Information from this article will help us understand solar desalination configurations as a whole, along with the factors that make one module better than another.

H. Geng, H. Wu, P. Li, Q. He. (2013). "Study on a new air-gap membrane distillation module for desalination." *Desalination*. (Online Article). <http://www.engineeringvillage.com/search/doc/abstract.url?pageType=quickSearch&searchtype=Quick&SEARCHID=b5bec026Mbc27M4939M868dMf8e6afef6162&DOCINDEX=1&database=3&format=quickSearchAbstractFormat&dedupResultCount=&SEARCHID=b5bec026Mbc27M4939M868dMf8e6afef6162> pp. 29-38

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This article, from a professional, peer reviewed online journal about desalination, gives details about a new air gap membrane distillation module that has internal latent heat recovery. The article gives descriptions, statistics, and graphs that show the improved efficiency of the model. Information from this source will be used to explain how air gap membrane distillation systems can be improved in the future by recycling its energy.

E. Guillen-Buttieza, J. Blanco, G. Zaragoza. (2011). "Experimental analysis of an air-gap membrane distillation solar desalination pilot system." *Journal of Membrane Science*. (Online Article).
<http://www.engineeringvillage.com/search/doc/abstract.url?pageType=quickSearch&searchtype=Quick&SEARCHID=7b39f53dMf920M4768M8aacM8e61ea7ceea5&DOCINDEX=1&database=3&format=quickSearchAbstractFormat&dedupResultCount=&SEARCHID=7b39f53dMf920M4768M8aacM8e61ea7ceea5> pp. 386-396

This study, from a professional, peer-reviewed online journal about membrane science, details the success of an air gap membrane distillation system for the Medesol project. This study traces four months of experiments; during those experiments, the system was analyzed based on its production quantity, production quality, and thermal efficiency. Information from this source will be used to detail the specific system, along with the parameters that make the system's performance valuable.

G. Meindersma, C. Guijt, A. Haan. (2006). "Desalination and water recycling by air gap membrane distillation." *Desalination*. (Online Article).
<http://www.engineeringvillage.com/search/doc/abstract.url?pageType=quickSearch&searchtype=Quick&SEARCHID=56b5d6e8M8fe0M4ab6Ma7daMb6ebccdc35ec&DOCINDEX=1&database=3&format=quickSearchAbstractFormat&dedupResultCount=&SEARCHID=56b5d6e8M8fe0M4ab6Ma7daMb6ebccdc35ec> pp. 291-301

This article, from a professional, peer revised online journal about desalination, delineates how an air gap membrane distillation system functions to remove salts and minerals from water. The article gives detailed descriptions about how the heat transport and mass transport processes make the system a promising technology. Information from this article will help us detail the general description of an air gap membrane distillation unit along with statistics of its performance.