Desalination and Water Purification, 1

Desalination Processes and Multistage Flash Distillation Practice

Arshad Hassan Khan

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Arshad Hassan Khan

Planning, Engineer, Water and Electricity Department, Abu Dhabi, United Arab Emirates

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Preface

Desalination is not a subject that is of interest to everyone. However, for those who are interested, the interest is intense and will continue on into the forseeable future. To cater to the needs of those associated with desalination, a few books have been published in the past decade or so. However, with a couple of exceptions, most of these books are academically oriented. Also, the most dominant process (MSF) was not covered as extensively as it should have been. Therefore, a need was felt to write a book that would overcome these shortcomings.

This book is primarily based on the MSF process. Other desalination processes have also been included in order to generate widespread interest. In this book, the neglected practical engineering aspects, rather than academic considerations, predominate. However, theory has not been neglected. MSF plant operation is covered in depth. Many other topics that are ignored in the available books have been included.

This book is divided into four parts:

Part I describes the different processes used for desalination and discusses the important variables in process selection. This part will be of interest to technical as well as non-technical personnel in water utilities.

Part II is based on the MSF process and is the most important part of the book. It deals with various aspects such as design, tendering, erection, commissioning, operation, maintenance and plant management. This part will appeal to engineers (of all disciplines) and operators in MSF plants. It can be used by water utility employees being trained to purchase, operate and maintain MSF distillers.

Part III deals with very important aspects of distillation (chemistry, scaling, corrosion and materials of construction), which significantly affect plant life and costs. Both theory (which is applicable to all types of distillation plants) and practical information specific to the MSF process are presented. This part will appeal to personnel working in all types of distillation plants and to corrosion engineers and chemists in particular. It is advisable that it be read before Part II, because scaling and corrosion control are critical factors in plant operation and should therefore precede Chapters 16-18.

Part IV deals with pumps, which are among the most important plant components. It contains theory as well as detailed practical information. This part will be useful for engineers and operators in both desalination and power plants. It will also be of interest to technical personnel in the process industries.

Parts II and III together can be considered to be a mini reference book for the MSF process. The material covered is adequate for it to be adopted as a text for training, especially by countries of the Arab world. Desalination technology students will also find it very useful.

This book is the result of my working in the UAE during its period of phenomenal growth. For this, credit should be given to Mr. Salim Faraj Al Tamimi. His efforts were instrumental in making me decide to stay on and work in Abu Dhabi, where I gained the invaluable experience which has made it possible for me to write this book.

Working in the Water and Electricity Department (WED) at a time when its massive expansion plans were being implemented has been a unique experience. For this, I have to thank Mr. Darwish M.K. Fareigh, Director General, Power and Desalination Plants, who encouraged me to join WED. Mr. Fareigh, an extremely dedicated and hard-working man, has always encouraged his subordinates to be productive. His deputy, Mr. Bushara Makkawi, contributed in moulding my thoughts and attitude to work. His characteristic comments led me to consider various options for doing something challenging and constructive in my spare time. The result is this book.

Encouragement from Mr. Mahmoud Kamel Ahmed, as well as my colleagues, was always forthcoming and is highly appreciated. I would also like to express my gratitude to Sidem (for permitting the use of Sidem diagrams) and to Sasakura, Aqua Chem, Ionics and Weir Westgarth (for being very cooperative in providing information).

I would like to thank Klein, Schanzlin & Becker (KSB), Dr. J.C. Drake and Dr. W.T. Hanbury for reviewing portions of the manuscript. I would also like to thank all those who helped in preparing the drawings and typing the manuscript. Finally, the contribution of my family, particularly my children whom I often neglected, is acknowledged.

Arshad Hassan Khan

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PART I

DESALINATION PROCESSES

CHAPTER 1

NEED FOR DESALINATION

01 INTRODUCTION

Water is the most important chemical compound for the use of mankind. It has an essential role in all organic life due to its solvent properties. It is a precondition for improvement in health standards. Water is closely associated with the progress man has made. Upon its availability depends the growth of a village, a city or a country. Since times immemorial, man has realized its importance. Therefore, his settlements often grew up near water sources (springs, lakes and rivers). To control these sources, he often went to war. With the passage of time, the importance of water has not diminished. In modern times, it is a very important ingredient for agricultural and industrial growth. It is also required for supporting growing urban populations which require adequate supplies of drinking water.

02 WATER SOURCES

Most of the available water is either present as seawater or as icebergs in the polar regions. 97% of all the earth's water is in the oceans and about 2% in glaciers and ice caps. The rest is available in lakes, rivers and underground. Nature itself provides most of the required fresh water by the solar distillation process. Solar energy evaporates water from the oceans. This condenses into clouds. Water is then returned to earth in the form of snow or rain. Rivers carry it back to the oceans.

03 WATER QUALITY

Water is the universal solvent. Chemical materials dissolve in it to such an extent that it often becomes unsuitable for human consumption. Besides various chemicals, natural waters also contain pollutants from coastal cities. The concentration of the dissolved substances determines whether water can be used for drinking. The salinity (concentration) standards are not the same in all countries. In some dry areas, water of 3,000-4,000 ppm salinity is used for drinking. The WHO standard specifies the maximum permissible concentration for human consumption at 500 ppm. The maximim limit for chloride ions is 250 ppm.

TABLE 1.1
Water purity limits

Substance	Maximum concentration (ppm) WHO standards	Optimum concentration (ppm) USPHS requirements
Carbon dioxide	20	
Carbonates (Na & K)	150	
Chlorides	250	250
Chlorine (free)	1	0
Copper	3	
Detergents	1	
Fluorides	1.5	0.5
Iron	0.3	0
Lead	0.1	0
Magnesium	125	125
Nitrates	10	
Phenols	0.001	
Sulfates	250	250
Zinc	15	0
NaCl (maximum)	250	
Total dissolved salts	550	500

04 WATER DEMANDS

The four most important uses of water are:

1. Drinking
2. Domestic
3. Agricultural
4. Industrial

Man's food chain from soil to stomach requires large volumes of water. The minimum requirements have been estimated at 1.1 m^3 per day, assuming man can live on bread alone. The actual amount varies and depends on the standard of living. In the USA for example, the per capita consumption of water is 6.6 m^3 per day. This figure includes industrial and agricultural use.

05 CAUSES OF WATER SHORTAGE

The annual precipitation on earth is adequate for the needs of the earth's population. However, its distribution is not uniform. In many parts of the world (especially the Middle East), which have limited or no water resources, rainfall is almost non existant.

Nature has blessed earth with large bodies of water. These account for approximately 75% of the earth's total surface area. Unfortunately, this water is not uniformly distributed. Also, most of it is unfit for human consumption without treatment. Another factor, which compounds the water shortage problem, is the important population growth factor. In the past fifty years, the world's population has more than doubled. This rapid growth is more pronounced in the water shortage areas. It is increasingly taxing the limited water resources available. There are many other factors which have also contributed to the growing water shortage. They are rising standard of living, urban growth, industrialization, expansion of irrigation agriculture, pollution of natural water reserves (by industrial waste and sewage), cultural development and political awareness.

In some areas of the world (especially the Middle East), the value of mineral resources was suddenly realized and their large scale development was undertaken. Increased income was obtained from the sale of these minerals, especially from oil. The monetary returns enabled the governments of these countries, in particular the oil rich countries, to increase water supply far above what the local population had been used to.

Water shortages are not confined to the arid lands which comprise more than 60% of the earth's total surface. Even in countries where plenty of water is available, many supply and quality problems exist and some areas experience shortages.

06 SOLUTION TO THE WATER SHORTAGE PROBLEM

The demand for steady, economical supply of water is constantly increasing all around the world. Often it does not match the available supply. It does not seem possible that supply will equal demand in the near future. Therefore, sound water resources development and management is and will be a constant challenge. In many countries, water policy will have to be an essential ingredient of economic policy.

There are many solutions to the water problem. Alternatives include control of water consumption, conservation, improved distribution and storage, reclamation, purification and reuse, crops that use less water, tapping of new sources, etc. Desalination is seriously considered only when all the other possibilities have been ruled out for various reasons.

Seawater desalination plants have been constructed in many countries of the world, especially in the arid Middle East, only because there were no other available alternatives. The objective of desalination is to provide water with salinity below 500 ppm. The major problems associated with desalination have been very high capital and operating costs. Over the past several years, the cost of desalting has gone down but it is still quite high. It still cannot compete with the cost of natural fresh water, which has the advantage that it requires minimum treatment to make it potable.

07 DESALINATION HISTORY

The possibility of obtaining fresh water from seawater has been known to mankind for thousands of years. The earliest reference is found in the Bible. Aristotle (2,400 years ago), had realized that water could be obtained by distillation. Alexander of Afrodisias wrote a commentary on Aristotle's Meteorlogica. In it he described distillation as a means of obtaining fresh water from the sea. Other references include descriptions by Pliny, Arab and Byzantine philosophers as well as Renaissance writers [41].

The first modern desalination systems were used 200 years ago on ships. They provided drinking water while at sea. Various commercial distillation processes were developed only in the last 100 years. All these systems were based on the thermal distillation process. The most popular was the submerged tube design. Land based plants also came into use gradually. The first one was installed more than 100 years ago in Aden.

In the early 1930's, several small seawater desalination systems were installed in the Middle East, where oil had been recently discovered. These plants had low efficiency and high maintenance. However, the advantage of water availability in hitherto completely dry areas was brought home and the desalination industry was founded. In the late 1940's, development of oil in the Arabian Gulf gave a push to the desalination industry. The growth rate ever since then has been spectacular.

Upto the 1950's, the largest desalination unit ever built had an output of less than 0.5 mgd. The worldwide capacity was about 2.2 mgd. In 1960, all the land based desalination plants in the world had a combined daily output of barely 8.33 mgd. By 1970, the figure had jumped to 220 mgd. In 1977, it was in region of 833 mgd. By 1980, worldwide desalination capacity was 1.6 bgd.

A study made by Flour, for the Office of Water Research and Technology, showed the anticipated minimum United States desalted water demand in the year 2000 at 29 bgd (130 m^3/d) and an overseas demand of 5.45 bgd. This represents an average growth rate of 18%. Unit sizes have also been growing. In the early sixties, a 1 mgd unit size was considered quite large. Nowadays, most of the unit sizes are in the 5 mgd range. The size of the largest MSF unit is 8 mgd. The massive Al Jubail 2 complex (in Saudi Arabia) is the