OPERATION OF A DESALINATION PLANT

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Contents

Summary

In this chapter, all the steps, functional and operational, for the multi-stage desalination unit have been described. It incorporates the process description for each subsystem. The process descriptions are detailed in depth so that the reader can obtain some information about other matters that are related to and which I think are necessary to help understand the operation procedures.

System operation of the various plant components is given in operational steps aided by figures so that the operator will find it useful to trace the relation and gain more with respect to the interaction between process parameters and system components.

Attention is paid to the start-up procedures for the plant process as a whole, as well as individual items such as pumps, valves and steam ejectors, followed by the minimum load mode. Loading of the plant is enriched by several logic diagrams which are helpful to simplify and overcome the complexity of process parameters interaction.

Sections that explain how control schemes for each system function and describe the strong bonds between the operation of plant and its control schemes are included. It is important to give in-depth details of the control schemes and their influence on the plant

operation performance.

As far as applicable, process flow diagrams are given at the beginning of each section which explain in a simple manner the flow of various streams within the process and their functions. These are prerequisites for understanding the plant operation of MSF desalination process.

1. Introductory Remarks

1.1 Desalination and Sustainable Development

Desalination has already made a major contribution to quality of life in the most arid regions of the world, particularly the Arab region and North Africa. Without desalination, many of these regions would have remained uninhabited. With rising global demand, uneven distribution of fresh water and increasing population, Malthusian apocalypse would have already come true. Desalination technology is providing safe drinking water even to some ‘water rich’ nations where pollution reduced the quality of natural water. Thus as a means of augmenting fresh water supplies, desalination contributes significantly to global sustainability.

97% of the total global stock of water is saline and only 2.5% is fresh water. Approximately 70% of this global freshwater stock is locked up in polar icecaps and a major part of the remaining 30% lies in remote underground aquifers. In effect, only a miniscule fraction of fresh water (less than 1% of the total fresh water, or 0.007% of the total global stock) that is available in rivers, lakes and reservoirs is already accessible for direct human use. Further more, the spatial and temporal distribution of the freshwater stocks and flows is hugely uneven.

The desalination associations and institutions have a pivotal role to play here, encouraging the scientific and industrial communities to make efforts to meet world water requirements through environmentally sustainable technologies. One of the most commonly discussed issues in relation to military expenditure is the diversion of resources such expenditure may represent away from other, more productive areas such as health, education and human and economic development. Certainly, in a world where so many people lack access to the basic necessities of life, the nearly $1.5 trillion spent on the military worldwide(according to SIPRI figures for 2008) may well be considered an obscene amount by many people. The annual global expenditures for advertisement is currently a about US$482 billion(ZenithOptimedia, 2008).

Plant operation

The plant operation system in any utility involves four main parts interacting with each other. These are people, procedures, equipment and data. These four major elements interact and influence each other in a complex way. The first element, people, is perceptive and their response to any situation will greatly affect this process that is called plant operation system.

People: Managerial staff and operators that are responsible for operating the plant.

Enhancement of their skills is an essential target. It will help them in making good decisions and make them more productive.

The provision of the following will achieve this goal:

- Training.
- Data acquisition and monitoring system.

Training: Enhancement of the skills of the managerial staff and training the operators on how to operate the plants are key elements for achieving optimal plant operation and improving its performance. A very well trained operator will respond and act very quickly and efficiently to any transient conditions such as a load change or a disturbance. Timely action will reduce the risk of unsafe operation that could cause a trip or damage part of the plant equipment. Hence improving the response time of the operator when handling an emergency condition will help to keep the plant on-line and increase its availability.

Data acquisition and monitoring system: The data acquisition and monitoring system helps the operator to run the plant to achieve the maximum effect. It also provides tools for the managerial staff to gradually introduce measures aimed at further improvement in the operation of the plant. For example:

- It enables the operator to act safely and timely if there is a disturbance. The system provides the operator with guidance messages; in case of a disturbance, the alarm message will guide the operator directly to the related display specifying the location of the disturbance.
- Optimization of the time needed for start up, shut down and load changes; the system provides guidance in a form that is easily assimilated with and acted upon.
- Reduce the number of trips and the risk of unsafe operation; it reduces the response time of the operator and helps him to keep the unit on line. This will increase the plant availability and reduce the replacement cost.
- It gives the operator the possibility to exercise certain control functions by supplying the means of observing and changing the main control loop parameters; it makes it easier to identify optimum settings and assist the operator in operating close to constraints, thus minimizing the effect of over-design.
- Acquisition of all information required to be printed and operator action logs that contain all the operators' actions.
- Long-term data that could be used for identifying slowly changing plant conditions; from these data the maintenance engineer should be able to draw conclusions in regard to the condition of the plant performance.

Logs of management containing information on plant performance, availability and reliability.

Procedures: The operators will follow these rules and instructions when performing the plant operation. Some of these operations are:

- Preparation and re-start up check.

- Plant startup.
- Plant loading and maneuvering.
- Plant shut down.

A specialist who has operational expertise for a particular plant prepares and writes these procedures. Proper manuals will document these procedures that the operational staff will use them permanently through all phases of operations.

Equipment: It comprises of the following:

- The equipment that handles the desalination process.
- The control and instrumentation system which control and monitor the process.
- The electrical system.
- Common facilities that serve all individual units.

Data: Data such as pressure, temperature and flow rate are analogous in nature and used to describe the operational parameters of the fluids handled by the process. In the desalination process, this information is measured by sensors, modified into another form such as a 4-20 mA electrical signal or 3-15 psi (21-103 kPa) air pressure signal and then transmitted through a transmission system to the control room panel where their values are displayed.

In modern plant that incorporates the data acquisition and monitoring system, most of the data are handled digitally. The data acquisition system has microprocessors that deal with digital data only. Thus an analog to digital converter is required.

Data are usually processed for the following functions:

- On-line display to help the operator to monitor and control the actual process status.
- Storage for later inspection.
- Storage for statistical evaluation such as trend in process performance.
- Using the data as input variables for the process control system.

2. Evaporation Processes

2.1 Background Information

During the 1960s, and at the initial stage of the development of desalination technology, the attention of the process designers and their focus was on solving the various problems related to the process. The philosophy of the control system which controls and monitors the operation of the plant was structured to respond to both water demand and steam availability changes. Since then these efforts have resulted in a tremendous improvement of the process parameters and materials selection and has led to a continuous increase of plant capacity.

Experience acquired in more than 40 years of operation of MSF plant has increased the confidence in terms of design parameters and materials selection, which in turn led to an optimized situation on various aspects of the plant design. Some of these aspects can be summarized:

- Stainless steel is now the most frequent material used for the evaporator shell instead of the more expensive CuNi alloy
- Use of 1mm thick tubes compare with the standard thickness of 1.2 mm
- Extensive use of fiberglass pipe work for sea water and low temperature brine which replaces the more expensive carbon steel cladded with CuNi or painted pipes.
- Elimination of unused and redundant equipment
- Optimized mechanical design of the evaporator vessel which led to a reduced evaporator thickness
- Applied fouling factor of 0.15 m^2 k/kW instead of 0.2 m^2 k/kw which will yield the use of less heat transfer surface area per installed capacity. Plants that are using correct antiscale chemical dosing rate and proper sponge ball cleaning system are operating with fouling factor between 0.07 and 0.09. Operating records of large MSF plants such as Taweelah B in Abu Dhabi and jebel Ali K1 in Dubai indicated that these plants are operating at a constant fouling factors of 0.12 m^2 k/kw for a period of time that exceed two years. (Dr. R. Borsani, IDA 2002, Bahrain)
- Also the ever-increasing water demand in the arid areas of the middle east region and the continuous need for more fresh water in these areas where fresh water is considered scarce and that the increase in unit size yields two major savings in the specific installation cost and the operational cost

This paved the way for new generation of MSF plant capacity that satisfies and meets these new design parameters and plant materials selection and that a plant size of 17.5 migd has become feasible. The shuweihat plant in Abu Dhabi emirate comprises of six units of 16.8/17.5 migd each (R.Borsani, IDA 2002, "*MSF Desalination Units over 15 MIGD is becoming a Reality and Start a New Age for the Old Technology*", See annex 1 Case study). This has exceeded the size of Jebel Ali K II (3 units x 13.33/15 migd) by 2.7 migd per unit.

An electronic control system normally monitors and controls the desalination process and its structure will achieve certain objectives. One of the most important objectives that influence the plant operation is the optimization of the process control. It is aimed at reducing the energy and chemicals' consumption over a wide range of plant operability (65-120 per cent).

Two factors necessitate a more sophisticated automation for the plant operation:

(a) The plant capacity has increased to over 10 migd and its performance ratio to 8:1 in the last decades.
(b) The technological improvements that have occurred for the individual equipment such as pumps and chemical dosing systems.

2.2 Improvement

Along with this situation, the design of the control loops that control and monitor the various process loops were exposed to these changes and have kept a constant pace with these enhancements.

Similarly, the improvements in plant operation procedures of the desalination process, which was initially of a simplified nature, has passed several transitional periods. These new techniques have considered the development of the control system and the present level of sophistication that the automation has reached.

2.3 Start up Procedures

The start up procedure of desalination plant, from cold condition to nominal load, consists of a series of checks and operations. It can be grouped into the following six main phases:

- The general checks and settings of the common facilities and systems.
- Pre-start up checks and filling of lines.
- Warming up of steam lines.
- Raising of vacuum.
- The operations of valves and pumps.
- Loading of the evaporator from minimum to nominal.

Automatic or manual start ups will perform these series of steps and actions depending on the control and instrumentation system which controls and monitors these actions.

2.4 Semi-Automatic Start up

Currently the plant operation is classified as an operation which can be achieved by either a semi-automatic system or a full automatic system. The semi-automatic plant operation procedures are combinations of some manual operations and automatic start up sequence. The manual checks and operations are performed to guarantee the safety of the plant and the individual equipment. These manual steps will supply the permissive signals to the automatic start up sequence that will be initiated by pressing the push button of the functional group control station. Once the start up sequence is initiated, the operation steps will progress automatically one by one. The instrumentation and control system, according to the permissive signals from the process or the protection built into the equipment, performs the various steps of the start up sequence and supplies the operator with the information relevant to the position of the sequence and to the checks or manual operations he must do prior to the initiation of the next sequence. The semi-automatic start up will continue in the same fashion until the plant reaches the minimum distillate production. The degree of automation of this system allows the automatic operation of the plant when it is fully in operation with the possibility of changing the distillate product. It could be achieved by activating the plant loading procedure on the distiller unit coordinator (DUC).

2.5 Fully Automatic Start up

The fully automatic start up basically performs the same sequential steps as in the semi-automatic startup. However the initiation of this sequence is performed at a higher level and, once initiated, it progresses automatically step by step proceeding from one functional group to the next one.

A controversial aspect is whether to start up the plant on full automatic operation from a cold condition or to limit the automation to the start up from a hot condition. The full automatic start up from the cold condition requires the installation of many sensors that need continuous maintenance to ensure their satisfactory operation. An attempt is likely to turn into a semi-automatic mode as a consequence of the non-availability of any permissive signal from the numerous sensors provided in this system. However the start up sequence from a hot condition (i.e. to resume the normal operation of the plant after a trip or a shutdown for a short duration) on full automatic mode will progress automatically without manual intervention until the start up procedures are completed and the pre-set plant condition is attained.

2.6 Plant Loading

The operation of the plant loading involves a close coordination of the various activities between the power and steam generation plant and the desalination plant. A request for a change in the distillate production rate is influenced by the steam plant capability, by whether such a steam increment can be met, and by the proper response of the control scheme of the distiller for generating the set points of the top brine temperature (TBT) and the brine recirculation flow for the required distillate output. The change in steam consumption in response to a load change of the distiller will affect the power generation. To perform these procedures manually, they require close cooperation with the power plant in a stepwise sequence to protect the boiler from a possible trip. On the contrary, the automation of these steps will ease the problems related to plant loading and the system will not be exposed to critical situations. This practice necessitates an intensive data transfer between the boiler and the distiller. Also the implementation of this mode of control involves the incorporation of the major process parameters of the power plant into the top brine temperature control scheme.

2.7 Future Plant Operation

The plant operation is no longer mere operation procedures that are prepared to enable the operator to start up and shut down the various systems of the plant. The purpose of this section is also to help the operator to understand that the future plant operation in which all plant elements that are shown on the monitor will be directly accessible by virtual operation and that the automation functions can be activated for operation by selecting the function with a mouse click.

The future systems such as centralized visualization and man and machine interface that are characterized by innovative hardware concepts and object oriented software structures will allow the connection of all different types of displays to design an operation philosophy which will be handled by the operator comfortably for each situation and ensure safe plant operation under all conditions.

3. Multi-stage Flash Desalination Process

3.1 Introduction

This section introduces the functional and operational description of the Multi-stage flash process. The process is divided into systems that are described in sequential order that indicates the relation between them.

A typical seawater desalination process consists of the following:

- Seawater supply system.
- Seawater recirculation system.
- Feed water system.
- Brine blow down system.
- Vacuum system.
- Brine recirculation system.
- Condensate flow from brine heater system.
- Distillate system.

Seawater, brine, and the distillate are treated by using various chemicals. Dosing systems are provided to control the dosing rates of these chemicals. Chemical dosing systems that are commonly used for desalination process are as follows:

- Hypochlorite dosing system.
- Anti-foam dosing system.
- Anti-scale dosing system.
- Sodium sulfite dosing system.

The flow of information, when describing each of the above mentioned systems, shall respect the main purpose of this section. It maintains the logical sequence of the individual steps and exposing the interrelationship between these systems.

Emphasis shall be given to the following:

- Description of the process that is handled by each particular system.
- Functional and operational description of the system.
- Functional description and a diagram of the related control loops and their variables.

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