DESIGN DATA FOR NON-CONDENSABLE GAS RELEASE RATES IN FLASH CHAMBERS

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Summary

In MSF plants the gases which are molecularly dissolved in seawater and do not react chemically such as oxygen, nitrogen, and argon are almost completely released in the deaerator or, if no deaerator is provided, during flash evaporation in the first two stages. Their physical desorption rates can be predicted quite reliably. In contrast to that, uncertainty exists in the coupling of the chemical reaction kinetics with the mass transfer and in the rate-determining steps during the release process of carbon dioxide and, thus, in the prediction of the total CO_2 release rates and the distribution of these between the individual distiller stages. Due to this uncertainty and the complexity of the problem, the design data of different MSF plant manufacturers for CO_2 release vary tremendously.

The design assumptions regarding O_2, N_2, and Ar release as well as the different approaches employed by MSF plant manufacturers and other experts to determine the CO_2 release rates for the dimensioning of the design venting rates or for simulation purposes are described. Furthermore, a new experimental approach for measuring CO_2 release in the individual stages of MSF distillers and a selection of the measurement

results are presented. The design assumptions regarding the ratio of vapor to non-condensable gases at the vent extraction points in the cooling sections of the condensers are summarized.

1. Introduction

The dimensioning of the design venting rates in multistage flash (MSF) distillers must take into account the extraction of the non-condensable (NC) gases released from the flashing brine, essentially carbon dioxide (CO_2), oxygen (O_2), nitrogen (N_2), and argon (Ar) and the leakage of air as well as the ratio of vapor to NC gases at the vent extraction points in the cooling sections of the condensers. Furthermore, the release profile of the gases in the distiller, i.e. the distribution of the release rates between the individual stages, must be considered.

Concerning the total release rates and the distribution of these between the stages, a differentiation must be made between the release of the gases which are molecularly dissolved in seawater without reacting such as O_2, N_2, and Ar and those which react chemically in seawater such as CO_2. The main features of the O_2, N_2, Ar, and CO_2 release processes in desalination distillers are described in Analysis, Approaches, and Models for the Release of Carbon Dioxide, Nitrogen, Oxygen, and Argon in Evaporators (See: Analysis, Approaches, and Models for the Release of Carbon Dioxide, Nitrogen, Oxygen, and Argon in Evaporators).

In the following, the design assumptions about the release of O_2, N_2, Ar, and CO_2 and the ratio of vapor to NC gases in the cooling sections of the condensers are summarized. Furthermore, measurement results of CO_2 release in the individual stages of MSF distillers are presented and compared with the different approaches to CO_2 release computation.

2. Design Assumptions Regarding the Release of O_2, N_2, and Ar

MSF distillers with brine recirculation are usually equipped with a deaerator. O_2, N_2, and Ar are almost completely removed from the make-up flow in the deaerator. The deaerators are normally specified to provide a dissolved oxygen concentration in the make-up flow leaving the deaerator lower than 20 p.p.b. (Oldfield and Todd 1987).

MSF once-through distillers are not equipped with a separate deaerator. The O_2, N_2, and Ar content entering the distiller with the feedwater is considered to be almost completely released in the first three stages, actually more than 95 per cent in stage 1 and the rest in stages 2 and 3 (Genthner et al. 1997).

3. Design Assumptions Regarding the Total CO_2 Release

The release of CO_2 in MSF distillers is a complex process involving chemical reactions and their kinetics and phase equilibria at the brine/vapor interface as well as mass transfer processes. Thus, the CO_2 release is affected by various physicochemical, thermal and hydrodynamic parameters.

(a) The prevailing pressures and temperatures.
(b) The vapor release mechanisms.
(c) The brine residence time.
(d) Turbulence and agitation of the brine.
(e) The ionic strength of the brine.
(f) The pH value and the distribution of the carbonic acid species bicarbonate HCO_3^-, carbonate CO_3^{2-}, and dissolved CO_2 in the brine at the entrance of the first flash chamber.

Reactions with other seawater components, particularly calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions.

Reactions with other chemicals dosed to the brine, e.g. anti-scale additives.

In practice, different approaches are employed by MSF plant manufacturers and other experts to determine the CO_2 release rates for the dimensioning of the design venting rates or for simulation purposes (Glade and Genthner 1995). These approaches are based on simple reaction models and sparse experimental data.

The phenomena occurring during the reaction and release process and the relative importance of the influencing parameters are treated quite controversially in the different models for CO_2 release computation. In fact, most of the approaches for predicting CO_2 release only consider the HCO_3^- content in the seawater and the top brine temperature as the determining parameters for CO_2 release and neglect mass transfer resistances. Consequently, most of the approaches for predicting CO_2 release in MSF distillers provide, in a first step, a calculation basis for the total amount of CO_2 which is released in all distiller stages. In a second step the total amount of CO_2 is distributed roughly between the individual stages. In the following, examples of design practice for estimating total CO_2 release are described.

3.1. Decomposition of the Bicarbonate Ions

In design practice, one example of predicting the total CO_2 release rate is to convert a certain fraction of the bicarbonate HCO_3^- ions in the make-up flow to gaseous CO_2 that is released in the evaporator.

It is assumed that the reaction

$$2\,HCO_3^- \Leftrightarrow CO_2 + CO_3^{2-} + H_2O \qquad (1)$$

occurs when CO_2 is released from the evaporating brine. The reaction

$$CO_3^{2-} + H_2O \Leftrightarrow CO_2 + 2\,OH^- \qquad (2)$$

is assumed not to occur (See: Analysis, Approaches, and Models for the Release of Carbon Dioxide, Nitrogen, Oxygen, and Argon in Evaporators).

On the basis of reaction (1) the total CO_2 release rate in the distiller is predicted as

$$\dot{m}_{\mathrm{CO_2,R}} = f(T_0)\frac{[\mathrm{HCO_3^-}]_{\mathrm{mu}}}{2}\cdot M_{\mathrm{CO_2}}\cdot \dot{m}_{\mathrm{mu}} \qquad (3)$$

with

$\dot{m}_{\mathrm{CO_2,R}}$

as the CO_2 release rate,

$[\mathrm{HCO_3^-}]_{\mathrm{mu}}$

the molality of HCO_3^- in the make-up flow,

$M_{\mathrm{CO_2}}$

the molar mass of

$\mathrm{CO_2}$, $\dot{m}_{\mathrm{mu}}$

the make-up flow rate, and $f(T_O)$ the HCO_3^- decomposition factor depending on the top brine temperature T_O.

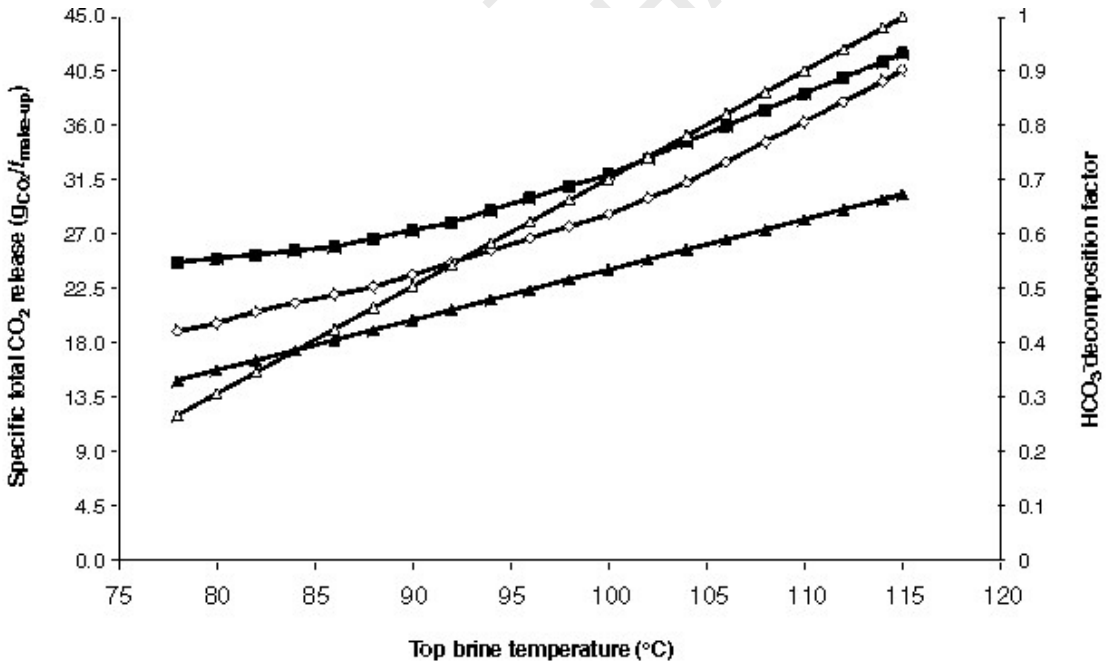

Figure 1. Range of design estimates of four different manufacturers for the total CO_2 release relative to the make-up flow (scale on the left-hand side) and the HCO_3^- decomposition factor $f(T_0)$ (scale on the right-hand side) as a function of top brine temperature (Ludwig and Hetschel 1990). The scale on the l.h.s. for the specific total CO_2 release is based on a HCO_3^- concentration of 125 mg kg^{-1} in the make-up flow.

The decomposed HCO_3^- fraction $f(T_0)$ is assumed to depend on the top brine temperature. The range of various design estimates for the total CO_2 release based on reaction (1) and Eq. (3) is shown in Figure 1. The curves in Figure 1 were derived from data provided by four manufacturers of MSF plants (Ludwig and Hetschel 1990). They show that considerable uncertainty exists about the degree of influence of the top brine temperature on the total release of CO_2. However, there is an observable trend of increasing CO_2 release with rising top brine temperature.

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Bibliography and Suggestions for further study

Genthner K, Wangnick K, Bodendieck F and Al-Gobaisi D M K (1997) The next size generation of MSF evaporators: 100 000 m^3/d. Part I. *IDA World Congress on Desalination and Water Reuse* (Proceedings of the IDA World Congress, Madrid, 1997), Vol. 1 (ed. Centro de Estudios y Experimentacion de Obras Publicas), pp. 271-293. Madrid: Ministerio de Fomento Centro de Publicaciones.

Glade H and Genthner K (1995) The problem of predicting CO_2 releases in MSF distillers. *IDA World Congress on Desalination and Water Sciences* (Proceedings of the IDA World Congress, Abu Dhabi, 1995), Vol. 2 (ed. Darwish M K Al-Gobaisi), pp. 365-386. Abu Dhabi: Abu Dhabi Printing and Publishing Co.

Glade H and Genthner K (1999) Measurements of the CO_2 release rates in the individual stages of MSF distillers. *IDA World Congress on Desalination and Water Reuse* (Proceeedings on CD of the IDA World Congress, San Diego, 1999), Vol. 1 (ed. International Desalination Association), pp. 361-373. CD Mastering: DesalCo Limited.

Ludwig H and Hetschel M (1990) Treatment of distillates and permeates from sea water desalination plants to make potable water. *Saline Water Processing* (ed. H G Heitmann), pp. 287-308. Weinheim: VCH Verlagsgesellschaft.

Oldfield J W and Todd B (1987) Vapour side corrosion in MSF plants. *Desalination* **66**, 171-184.

Water Consultants International (1997) *CO_2 Release and Scaling Potential in Abu Dhabi Desalination Plants*, Unpublished Report. Fort Lauderdale, Florida.

Watson Desalination Consultants (1979) *Technology Review and Handbook: High Temperature Scale Inhibitors for Sea Water Distillation, A Multi-client Study*. Barnett St. Manassas, VA, USA.