

The Use of Computer Models in Solar Salt Field Process Control

E. Burnard

Dampier Salt (Operations) Pty Ltd, Dampier Division, P.O. Box 1619, Karratha, WA 6714, Australia

ABSTRACT

The Dampier salt field operation is based on continuous flow of brine through concentration ponds and crystallisers. This method of operation ensures the best salt quality and utilisation of brine. The ability to supply an adequate quantity of the correct density brine, to feed the salt crystalliser is one of the primary objectives in solar salt field concentration ponds operation and brine control. To optimize the use of brine, the Dampier salt field uses computer models with radio telemetric data collection and brine flow control. Details of the models and their use are described. Blending of brine streams can ensure that crystalliser brine demand is always met, without brine wastage. The ability to proportion blending is provided in the computer model.

INTRODUCTION

The salt field at Dampier has been operating since 1970. Over recent years the field has been producing at a nominal design level of 2.5 million ship tonnes per annum. Recent field expansion has increased the crystalliser production capacity to 3.5 million tonnes per annum, together with the ability to supply the necessary brine from extra concentration pond area and salt redissolution crystallisers. A diagram of the current Dampier salt field and its location are shown in Fig. 1.

The basic operating methods for the Dampier salt field have been described previously (McArthur, 1980). With the expanded field operation and the need to optimize brine supply to meet the exact salting point brine demand throughout the year, it was appropriate to revise the brine control strategy for the whole field.

Ensuring an adequate supply of quality brine to feed the salt crystallisers is one of the primary objectives in solar salt field operation. Insufficient brine affects crystalliser density and depth control and consequently salt quality and production. Brine at or above salting point density causes salting of brine pumps, whereas brine at significantly lower density contains excessive calcium, which is deposited as gypsum, with the crystallised salt product.

Computer models for the concentration ponds and crystallisers have provided the basis for the required brine control strategy. These models predict the brine transfer volume requirement between succes-

sive concentrating ponds and crystallisers, so that, with consideration of daily change and trends in weather conditions, the required brine densities and pond levels can be maintained.

Additionally, due to different seasonal and other weather conditions, there are different evaporation rates for the range of concentrating ponds and crystalliser brine densities. As a consequence the total crystalliser brine volume demand often differs from the brine volume available from the concentration ponds, if the required crystalliser feed density is to be maintained. The computer models can also permit more efficient utilisation of brine through the blending of a number of brine streams. Details of the computer models are described in this paper.

To fully utilise these computer control models, a radio telemetry system linked to a base computer is used as the platform collecting field data and monitoring and controlling brine pump status. A further advantage of the radio telemetry system is the central monitoring of the operation of the salt field, which is more than 100 km² in area.

STEADY STATE CONCENTRATING POND MODEL

The purpose of this model is to calculate the brine flow rates and densities at different brine transfer points under steady state conditions, given the following data: pond areas; seepage rates; flow rates and densities of additional brine feed streams; flow rates and densities of additional exit streams; evap-

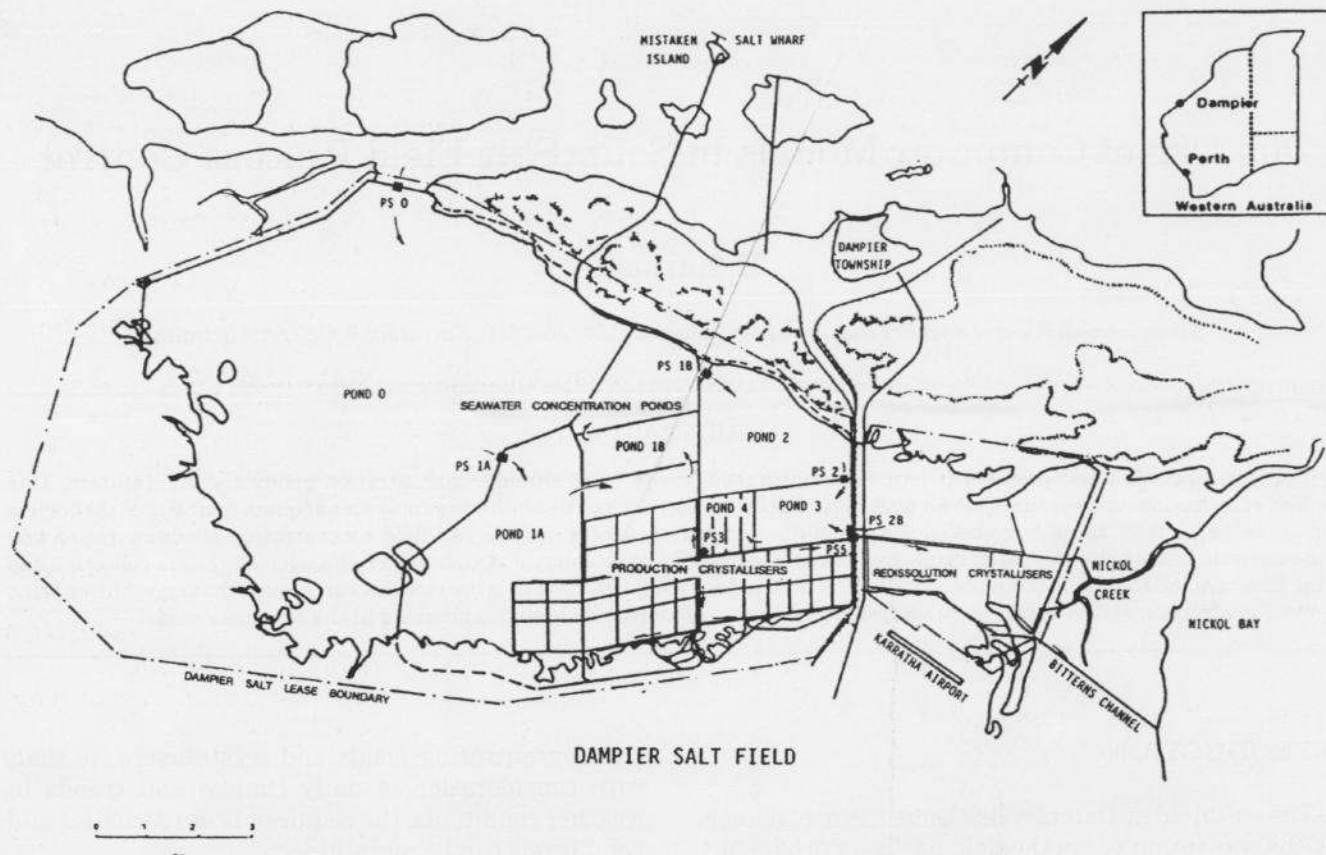


Fig. 1. Schematic diagram of Dampier salt field layout and location map of Western Australia.

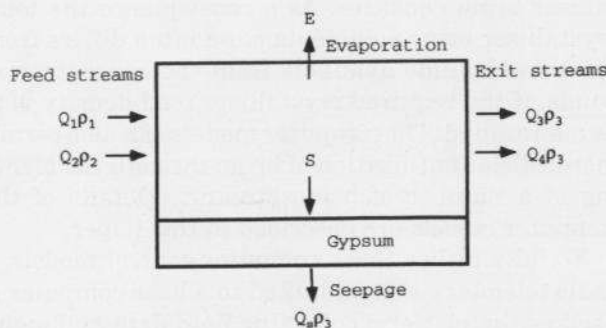


Fig. 2. Concentrating pond mass balance.

oration data (as monthly averages, immediate past evaporation data or derived from current meteorological information); initial input and final brine discharge densities

Derivation of the working equations

In order to reach the brine salting point, seawater is concentrated through a number of ponds, which are connected in series. As evaporation is the only mechanism acting to concentrate the seawater, there is a corresponding increase in brine density as

the brine flows to the final concentration pond.

The following steady state, one dimensional model, takes into account the precipitation of gypsum and uses magnesium ion, which is discharged in the bitterns from the final crystalliser, as a tracer in order to solve the mass balance (Fig. 2).

Notation

- A = pond area, m^2
- C = salt concentration, kg/m^3
- D = concentration of tie component (Mg), kg/m^3
- E = mass of water evaporated, kg
- E_R = evaporation ratio, dimensionless
- F = monthly evaporation factor, dimensionless
- F_{we} = fresh water evaporated, m/s
- Q_i = flow rate, m^3/s
- Q_s = seepage, m^3/s
- R = rainfall, m/s
- S = mass of calcium sulphate precipitated, kg (and/or other precipitated salts)
- Q_i = density of brine, kg/m^3
- Q_w = density of water, kg/m^3

The following steps are used in setting up the mass balance:

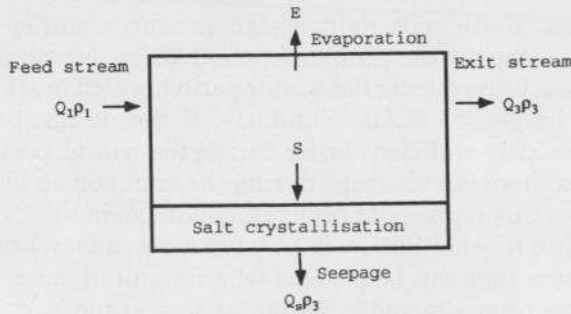


Fig. 3. Crystalliser mass balance.

(a) Total mass balance

$$S = Q_1 \rho_1 + Q_2 \rho_2 - Q_3 (\rho_3 + \rho_s) - E \quad (1)$$

where $E = (E_R \times F \times F_{we} - R) A Q_w$ in which the evaporation ratio (E_R) is obtained from the following empirical relationship, derived from Bonython (1966) and collected data.

$$E_R = -3.374 + 9.064 \times 10^{-3} Q_i - 4.697 \times 10^{-6} Q_i^2$$

(b) Total salts mass balance

$$S = C_1 Q_1 + C_2 Q_2 - C_3 (Q_3 + Q_4 + Q_s) \quad (2)$$

with an empirical relationship between the total salt concentration and the brine density, derived from the data of Baseggio, 1974.

$$C_i = -3065.318 + 2.216 Q_i + \frac{848944.6}{Q_i}$$

(c) From the tie component (Mg) mass balance

$$Q_3 = \frac{(D_1 Q_1 + D_2 Q_2 - D_3 Q_4 - D_3 Q_s)}{D_3} \quad (3)$$

with $D_i = -23.009 - 0.0372 Q_i + 6.022 \times 10^{-5} Q_i^2$ also being derived from Baseggio, 1974.

Solution procedure

Starting from the first brine concentration pond, there are:

- unknowns = $Q_1, Q_3, \rho_3, E, C, D$
- knowns = Q_2, Q_4, Q_s, ρ_1
- number of equations = 6

With six equations and six unknowns, a solution is possible, with several ways of solving the equations. The method used in this work is outlined below:

- (a) For a given Q_1 value, assume a value for Q_3 (as a first iteration, $Q_3 = Q_{feed}$ plus a small increment)
- (b) Calculate Q_3 from equation (3)
- (c) Calculate S from equation (1), i.e.: S_1
- (d) Calculate S from equation (2), i.e.: S_2
- (e) Steps (b) to (d) are repeated with an incremen-

tal change in Q_3 , until $|S_1 - S_2| < \text{accuracy condition}$ is achieved.

The exit flow rate and density become the feed flow rate and density for the next pond in the series. Steps (a) to (e) are then repeated for each subsequent pond.

For the final pond, the exit density is then compared with the target exit density. If the difference is outside the accuracy required, Q_1 in step (a), for the first pond is changed. By varying the first pond feed rate, it is then possible to satisfy the exit density requirement.

STEADY STATE CRYSTALLISER MODEL

When the brine has reached, or nearly reached, the salting point in the final concentration pond it is discharged into groups of crystallisers. At Dampier, each group consists of three crystallisers linked in series. The mass balance calculations are identical to the ones performed for the brine concentration ponds, with the only difference being that salt (NaCl) is now the major precipitating component.

With the aid of the following diagram, the mass balances can be described (Fig. 3).

Overall mass balance

$$S = Q_1 \rho_1 - Q_2 \rho_2 - Q_s \rho_2 - E \quad (1a)$$

with $E = [E_R \times F \times F_{we} - R] A Q_w$

$$\text{and } E_R = 0.7458 \exp \left[\frac{(\ln(Q_i/1000) - 0.1663)^2}{-0.0205} \right]$$

Salt (NaCl) mass balance

$$S = C_1 Q_1 - C_2 Q_2 - C_2 Q_s \quad (2a)$$

with C_i derived from Baseggio, 1974.

$$C_i = 347.7545 \exp \left[\frac{(\ln(Q_i/1000) - 0.1521)^2}{-0.0079} \right]$$

From the tie component (Mg) mass balance

$$Q_2 = \frac{(D_1 Q_1 - D_2 Q_s)}{D_2} \quad (3a)$$

with D_i derived from Baseggio, 1974.

$$D_i = 1343.733 - \left[\frac{1606.796}{Q_i/1000} \right]$$

Because there are three crystallisers in series, application of the above mass balances to each crystalliser in turn gives, after a little manipulation, six simultaneous equations with six unknowns; $D_2, D_3, Q_1, Q_2, Q_3, Q_{exit}$, where: $D_2, D_3 = \text{concentration of tie}$

component leaving the first and second crystalliser, respectively; Q_i = volume flow rate entering the i th crystalliser; Q_{exit} = volume flow rate leaving the 3rd crystalliser and discharged as bitterns.

The solution procedure developed for the concentrating ponds is adapted to the solution of the crystalliser mass balance equations.

COMPUTER CONTROL OF FIELD OPERATION

The overall objective of the salt field control is to ensure that brine of the required density and quantity is always available at the crystalliser feed channel to meet the crystalliser requirements.

The computer models of the concentration ponds and crystalliser mass balances have been linked to a proprietary software control package (WIZCON). It is this Supervisory Control and Data Acquisition (SCADA) system, that provides the real time control of all the brine flows through the field. The SCADA system communicates with the remote data collection and pump sites via radio telemetry. At each site resides a remote telemetry unit, the essence of which is a transceiver linked to a PLC. Instruments are wired to these PLCs, which in turn are interrogated by the SCADA system.

As can be seen from the model schematic diagrams, all the material streams represent measurable quantities. With the appropriate sensors and instrumentation, these physical quantities are measured and their values transmitted via radio telemetry, to a central radio base station, which is linked to the computer, on which the SCADA system resides. Each transfer point is polled at a given rate and the values at each location logged and manipulated by the SCADA system, ultimately performing a mass balance closure for the entire field. The radio link permits brine flow control to be achieved through automated switching, within pre-set limits.

The SCADA system is also being utilised to monitor meteorological conditions such as solar heat flux, wind parameters, evaporation, etc., which enables instantaneous values of, say, evaporation to be used, rather than monthly average or previous day values.

Improved accuracy and timing of input data of the field operating parameters give greater confidence in the mass balance closures.

BLENDING OF BRINE STREAMS

As mentioned previously, the ability always to meet the crystalliser demand for quality feed brine may not be possible due to changes in relative evaporation between concentration ponds and crystal-

lisers. If the salt field design produces sufficient brine during the summer period there is usually excess brine during the winter period, which must be discharged to waste. Similarly, if the design produces only sufficient brine during the winter period then there is a shortage during the summer. In both cases this represents poor brine management.

The ideal situation is to have a secondary brine stream that can be utilised when required, such as brine from the redissolution of low grade salt by seawater.

The Dampier field expansion includes the provision for secondary brine blending into Pond 3. The blending of the two streams is achieved by Ratio Control with recognition of the delay time period and evaporation between the blending pond and entry into the crystalliser feed channel.

The computer control of the pumps transferring brine to the blending pond essentially automates the supply of brine to meet crystalliser feed brine demand.

CONCLUSIONS

The salt field expansion and use of computer control allowed a change in brine production strategy in that crystalliser salting point brine demand can be predicted from the crystalliser computer model and the required brine volume prepared in an upstream pond, by the blending of the main and supplementary brine streams.

ACKNOWLEDGMENTS

The author would like to thank Dr. Goldwyn Hart for assistance in the preparation of this paper. The Management of Dampier Salt (Operations) Pty Ltd is also acknowledged for making the time available for the preparation of this paper and for permission to publish this information.

REFERENCES

- Baseggio, G., 1974. The composition of seawater and its concentrates. In: A.H. Coogan (Editor) Fourth Symposium on Salt. Northern Ohio Geol. Soc., Cleveland, Ohio, pp. 351-358.
- Bonython, C.W., 1966. Factors determining the rate of solar evaporation in the production of salt. In: J.L. Rau (Editor), Second Symposium on Salt., Vol. 2. Northern Ohio Geol. Soc., Cleveland, Ohio, pp. 152-167.
- McArthur, J.N., 1980. An approach to process and quality control relevant to solar salt field operations in the north-west of Western Australia. In: A.H. Coogan and L. Hauber (Editors), Fifth Symposium on Salt. Northern Ohio Geol. Soc., Cleveland, Ohio, pp. 325-334.