

## Processing of Reject Products from Salt Works

H. Flachberger<sup>a</sup> and K. Krenn<sup>b</sup>

<sup>a</sup>MINTECH - Dipl. Ing. Dr. mont. H. Flachberger GesmbH,  
Peter Tunner-Straße 19, 8700 Leoben, Austria

<sup>b</sup>Österreichische Salinen AG,  
Wirerstraße 10, 4820 Bad Ischl, Austria

Vapor recompression is the thermal evaporation process used in Austria to produce sodium chloride from rock salt brines. Apart from the condensate, unavoidable reject products of this process route are the "brine purification mud" and the "mother liquor". In comparison with other European salt works, Salinen Austria GmbH of Österreichische Salinen AG is confronted with the highest mass percentage of reject products. This situation makes it difficult for the company to comply with the very stringent Austrian laws on environmental protection.

The paper provides a detailed description including a mass balance of the process used at the Ebensee plant of Salinen Austria GmbH. It also presents the results of investigations of how to convert the brine purification mud into a mineral fertiliser characterized by qualities that ensure its sale on a permanent basis. Moreover, the investigation into the utilisation of the mother liquor resulted in two tentative process routes capable of improving the salt quality.

### 1. INTRODUCTION

Due to the accessory salt content of rock salt brine, in the production of vacuum salt from rock salt brine all salt works have to cope with reject products such as "brine purification mud" and "mother liquor", which contain salt and/or solid matter. Throughout Europe, these reject products are either dumped (e.g. in underground excavations) or discharged into drainage ditches and/or the sea. As shown in *Figure 1* (see next page), a major part of the mother liquor remaining after evaporation can be re-used for brine purification, which, however, leads to a deterioration of the vacuum salt quality. It is, therefore, absolutely necessary to discharge the mother liquor to a certain extent in order to limit the accessory salt content which affects quality in a negative way, e.g. in relation to Br<sup>-</sup> and K<sup>+</sup>. Ebensee Salt Works of Salinen Austria GmbH, which are

located in the northern part of Salzkammergut, Austria, are in a particularly difficult situation because owing to geological conditions the rock salt brine to be processed has extremely high accessory salt contents and therefore also the highest share of reject products. Moreover, in view of the extremely stringent Austrian laws relating to water and/or regulations on the emission of waste water efforts must be continued to minimize the discharge in the process area "rock salt brine processing for the production of vacuum salt".

The present paper provides an introduction to salt production in Austria and describes Ebensee Salt Works and their use of the thermal preparation process. This is followed by a presentation of the results obtained by the author within the framework of a thesis<sup>1</sup> in his studies on how to minimise the discharge of reject products containing salt and/or solid matter at Ebensee Salt Works.

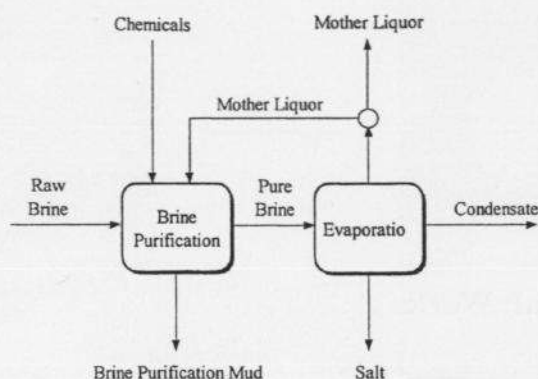


Figure 1. Simplified Diagram of the Process Area "Rock Salt Brine Processing for the Production of Vacuum Salt"

## 2. SALT PRODUCTION IN AUSTRIA

### 2.1 Österreichische Salinen AG

Österreichische Salinen AG, taken over in May 1997 by Salinen Beteiligungs GmbH, consists of the subsidiaries "Salinen Tourismus GmbH" (Salt Works Tourism Ltd. Liability Company), "Salinen Immobilien GmbH" (Salt Works Real Estate Ltd. Liability Company), and "Salinen Austria GmbH" (Salt Works Austria Ltd. Liability Company, abbreviated "SAG").

### 2.2 Process Route of Vacuum Salt Production

#### 2.2.1 Production of Rock Salt Brine

At present, rock salt brine is produced at the salt works located at Altaussee (approx. 40 %), Hallstatt (approx. 30 %) and at the Bad Ischl brine field (approx. 30 %). The exploitation of the salt-containing geological formation called Haselgebirge is carried out by solution mining (borehole wells) from the surface and underground. The other part is produced at pump wells. Out of an annual output of about 2.5 million m<sup>3</sup> rock salt brine approximately 0.7 million m<sup>3</sup> are supplied directly to the Ebensee factory of Solvay Österreich AG for the production of sodium carbonate.

#### 2.2.2 Conveyance of Rock Salt Brine

The rock salt brine produced by the application of mining methods is transported through pipelines from the production site to the processing works.

#### 2.2.3 Processing of Rock Salt Brine into Vacuum Salt

At Ebensee Salt Works the vacuum salt is produced by evaporation of the brine using the vapor recompression process after the chemical brine purification according to the Schweizerhalle process.

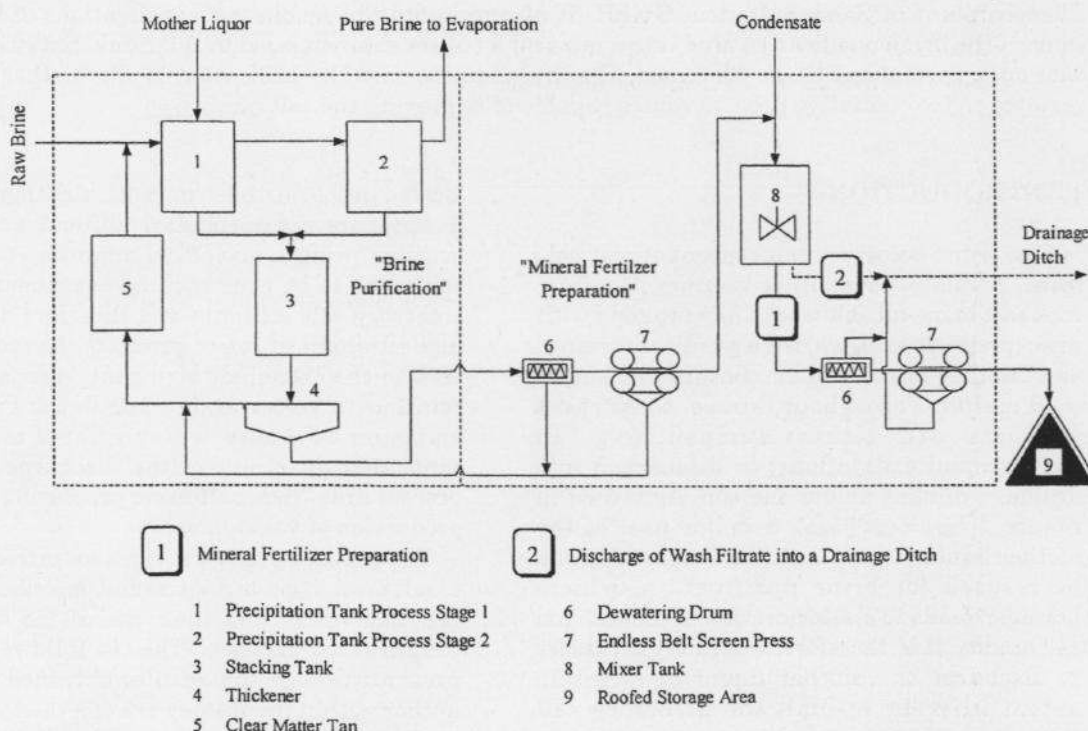


Figure 2. Simplified Graph: Brine Purification with Subsequent Mineral Fertilizer Preparation at Ebensee Salt Works

### 2.2.3.1 Brine Purification and Aftertreatment of Precipitation Products

Figure 2 (see preceding page) shows the brine purification process route used at Ebensee Salt Works and the subsequent steps of preparation of the brine purification mud.

The precipitation products are collected in a stacking tank (content of solid matter approx. 10 %) and thickened in a thickener until the content of the solid matter amounts to 20 %–30 %. The thickener overflow is redirected to process stage 1 of brine purification, while the thickener underflow has to pass a brine removal stage consisting of a dewatering drum and an endless belt screen press (Figure 3), which results in a compact filter cake with about 60 % of solid matter.

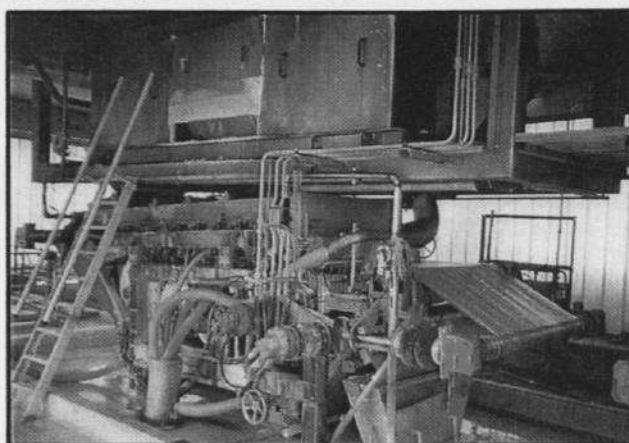


Figure 3. Brine Removal Stage: Dewatering Drum (at the Top), Endless Belt Screen Press

The filtrate brine of the brine removal stage is then fed into the thickener overflow, the filter cake is again elutriated by means of a condensate in a mixer tank to reduce the sodium chloride content. The suspension is discharged into a drainage ditch or processed into a mineral fertilizer. In case of mineral fertilizer production the thin turbid liquid passes a washing stage, which also consists of a dewatering drum and an endless belt screen press, and is again dewatered.

After washing, the filtrate (see Section 4.1.2) is drained off, the resulting compact filter cake is conveyed by means of a conveyor belt to a roofed storage area (Figure 4) where it is loaded onto a truck by means of a dipper shovel. The mineral fertilizer product is available on the market under the tradename "Biosalin". In order to separate the vacuum salt production completely from mineral fertilizer production, a leaching cavern is being prepared in the Bad Ischl brine field for the brine



Figure 4. Roofed Storage Area to Guard the Mineral Fertilizer against Rain

purification mud. Salinen Austria GmbH will have reduced the brine purification mud discharged into the Lake to zero by 2001.

### 2.2.3.2 Thermal Evaporation Process and Processing of Mother Liquor

Ebensee Salt Works use three evaporators, applying the vapor recompression method. The addition of the third evaporator in June 1999 led to an increase in the annual output of sodium chloride products from 500,000 tons to 750,000 tons.

In a flash evaporator per m<sup>3</sup> of flash evaporator feed an additional 50 kg of sodium chloride is removed from the mother liquor. In the course of the evaporation process, approx. 0.2 m<sup>3</sup> of mother liquor has to be discharged per m<sup>3</sup> of pure brine feed in order to keep the accessory salts from contaminating the vacuum salt product, which would lead to a deterioration of its quality. The mother liquor discharged from the flash evaporator at a temperature of 40 to 55 °C is collected in the mother liquor tank. A portion of about 83 % is returned to brine purification, while the remaining part is conveyed through pipelines to Ebensee-based Solvay Österreich AG, where it is partly used for sodium carbonate production.

### 2.2.3.3 Aftertreatment of Crystallized Material

The salt/brine mash discharged from the lower part of the evaporator is first cooled down to about 60 °C, using pure brine; subsequently, the brine is removed in four centrifuges until the remaining brine content is about 2 %. The filtrate is returned to the evaporator. The part of the production that is not directly conveyed to the storage hall (capacity 100,000 tons) by conveyor belt is thermally dried in two fluidized bed driers.



Table 1

Balance Sheet Relating to „Rock Salt Brine Processing for the Production of Vacuum Salt“

product		yield	grade, %							recovery, %						
		[m.-%]	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Br <sup>-</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>	H <sub>2</sub> O	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Br <sup>-</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>	H <sub>2</sub> O
output	salt	23,96	59,369	0,040	0,008	0,063	0,000	0,000	2,028	92,87	1,64	32,23	9,61	0,00	0,03	0,66
	brine purification mud	1,76	11,309	24,019	0,008	0,235	5,192	17,555	19,292	1,30	72,43	2,35	2,63	100,00	99,90	0,46
	mother liquor	4,20	14,942	3,384	0,084	3,078	0,000	0,001	68,820	4,10	24,37	60,85	82,22	0,00	0,02	3,94
	condensate	70,08	0,378	0,013	0,000	0,012	0,000	0,000	99,348	1,73	1,56	4,57	5,54	0,00	0,05	94,93
input	raw brine	99,45	15,398	0,587	0,006	0,158	0,092	0,088	73,750	100,00	100,00	100,00	100,00	100,00	28,16	100,00
	chemicals	0,55	0,000	0,000	0,000	0,000	0,000	40,484	0,000	0,00	0,00	0,00	0,00	0,00	71,84	0,00
feed		100,00	15,314	0,583	0,006	0,157	0,091	0,309	73,344	100,00	100,00	100,00	100,00	100,00	100,00	100,00

### 3. MATERIAL FLOW BALANCE IN THE PROCESS AREA „ROCK SALT BRINE PROCESSING FOR THE PRODUCTION OF VACUUM SALT“ AT EBENSEE SALT WORKS

Table 1 shows the mass balance of "Rock Salt Brine Processing for the Production of Vacuum Salt" based on the brine purification reports<sup>2</sup> of the Quality Management Laboratory of Ebensee Salt Works.

### 4. DETAILED DESCRIPTION OF THE CONDITIONS OF THE REJECT PRODUCTS OF THE VACUUM SALT PRODUCTION AT EBENSEE SALT WORKS CONTAINING SALT AND/OR SOLID MATERIAL

#### 4.1 Brine Purification Mud

##### 4.1.1 Brine Purification Mud after the Brine Removal Stage

The specific generation of precipitation products amounts to about 15 kg per m<sup>3</sup> rock salt brine and/or 50 to 55 kg per t of vacuum salt product. According to Table 2 the solid materials of the brine purification mud (calculation without water and salt) are composed of gypsum CaSO<sub>4</sub> · 2 H<sub>2</sub>O, calcite CaCO<sub>3</sub> and nemalite Mg(OH)<sub>2</sub> as well as a clay minerals rest and a share of portlandite Ca(OH)<sub>2</sub>. The brine remaining in the pressed filter cake after the brine removal stage is saturated with NaCl, gypsum and portlandite and essentially corresponds to the brine between process I and process II of brine purification. The specific remaining brine content

in the filter cake amounts to about 35 kg per ton of vacuum salt produced. The remaining brine saturated with sodium chloride, gypsum and portlandite is rather alkaline (ph-value: 12.5), the density is 1,205 kg/m<sup>3</sup>.

Table 2

Composition of the Brine Purification Mud at Ebensee Salt Works

component	grade, %	density, g/cm <sup>3</sup>
gypsum CaSO <sub>4</sub> · 2 H <sub>2</sub> O	58,8	2,35
calcite CaCO <sub>3</sub>	23,4	2,72
nemalite Mg(OH) <sub>2</sub>	16,8	2,40
clay minerals	1,0	2,75
Σ	100,0	2,45

#### 4.1.2 Filtrate after the Washing Stage

The interstices of the brine purification mud, approx. 60 % of which consists of solid matter, are saturated with brine, as described in Section 4.1.1.

A rough estimate of the sodium chloride content (approx. 10 %) makes it impossible to use the filter cake after the brine removal stage directly as a mineral fertilizer. Therefore, the interstitial liquid of the filter cake, which is saturated with sodium chloride, has to be diluted by means of sodium chloride-free water so the marginal value laid down in the mineral fertilizer specification (see Table 3 in Section 4.1.3) of < 1% sodium chloride in the filter cake can be met after the washing stage. This results in a specific amount of wash filtrate of approx. 6.5 m<sup>3</sup> per t of solid matter after brine removal and/or 0.32 – 0.36 m<sup>3</sup> of wash filtrate per ton

of vacuum salt produced<sup>3</sup>. The wash filtrate, which is saturated with gypsum and portlandite, is characterized by high alkalinity (ph value = 12.3 - 12.5). A neutralisation plant designed to neutralise the wash filtrate in the course of mineral fertilizer production is in the planning stage.

#### 4.1.3 Mineral Fertilizer after the Washing Stage

Owing to a reduction of solid matter by about 4 % on account of the dissolution of gypsum, the specific amount of mineral fertilizer produced after the washing stage is about 14.4 kg of solid matter per m<sup>3</sup> of rock salt brine, which corresponds to 48 - 53 kg of solid matter per ton of vacuum salt produced<sup>3</sup>. An extract from the specification of the mineral fertilizer "Biosalin" is shown in Table 3.

Table 3  
Composition of the Mineral Fertilizer in line with the Specification for the Mineral Fertilizers

component	grade, %
CaO	22 - 25
MgO	8 - 9
S	7 - 8
CO <sub>2</sub>	7 - 9
Na	0,5 - 0,7
B	0,05
K	0,5
Fe	0,5
Mn	0,15
Zn	0,04
H <sub>2</sub> O	25 - 30

Table 4  
Mother Liquor Analysis for 1995 and 1997<sup>2</sup>

component	concentration			
	1995		1997	
	g/l	mmol/l	g/l	mmol/l
Na <sup>+</sup>	119,842	5212,800	119,749	5208,727
K <sup>+</sup>	38,415	982,592	42,766	1093,880
Mg <sup>2+</sup>	0,000	0,004	0,000	0,005
Ca <sup>2+</sup>	0,018	0,438	0,020	0,495
Sr <sup>2+</sup>	0,005	0,053	0,005	0,060
OH <sup>-</sup>	0,212	12,443	0,327	19,214
CO <sub>3</sub> <sup>2-</sup>	0,908	15,125	1,020	17,003
SO <sub>4</sub> <sup>2-</sup>	42,238	439,674	42,022	437,425
Cl <sup>-</sup>	186,504	5259,548	190,078	5360,338
Br <sup>-</sup>	1,051	13,151	1,080	13,520
H <sub>2</sub> O	859,020	47684	856,628	47551
density, kg/m <sup>3</sup>	1248,213		1253,695	
pH	11,8		11,7	

#### 4.2 Mother Liquor

The amount of mother liquor generated is about 50 kg/m<sup>3</sup> of rock salt brine, which corresponds to about 175 kg per ton of vacuum salt produced. Table 4 shows two mother liquor analyses for 1995 and 1997.

### 5. RESULTS OF THE INVESTIGATIONS AIMED AT THE MINIMIZATION OF DISCHARGES FROM EBENSEE SALT WORKS<sup>1</sup>

#### 5.1 General

The investigations carried out in connection with "Preparation of the Brine Purification Mud" were designed to ensure the almost complete utilization of the brine purification mud in the form of a mineral fertilizer featuring quality characteristics that would ensure the sale of the product. Furthermore, the studies also concentrated on further possibilities of processing the mineral fertilizer into products of a higher added value.

The investigations relating to "Preparation of the Mother Liquor" focused on an improvement of the vacuum salt quality by reducing the unavoidable accessory salt contents in relation to Br<sup>-</sup> and K<sup>+</sup> in the reused mother liquor on the one hand, and on the basic options for the production of a potassium product on the other.

#### 5.2 Investigations into the Preparation of Brine Purification Mud

One of the major requirements to be met by a mineral fertilizer is that it must be possible to spread the fertilizer easily, i.e. the moisture content must not exceed a certain critical limit. In recent years the average moisture value was 31.4 %. However, in a series of investigations it turned out that the product could be handled without problems only when the permissible moisture content did not exceed 28 %.

To mark the filtration characteristics of the brine purification mud suspended in brine and/or condensate, suction (vacuum) filtration experiments were conducted in the laboratory. The samples, which constituted a brine slurry, were characterized by a specific filtration resistance  $r_k$  around 50  $\mu\text{m}^2$  on the average with freak values up to  $r_k$  180  $\mu\text{m}^2$ , which are probably due to fluctuations in the process control of brine purification. By using Magnafloc 333 as a flocculent, the specific filtration resistance was reduced to about half. A temperature increase of

20°C to 40°C raises the filtration resistance by about 20 %, whereas a temperature reduction of 20°C to 10°C did not change the filtration resistance.

In comparison with the samples suspended in brine the samples suspended in condensate have a higher specific filtration resistance with a mean value around  $120 \mu\text{m}^2$ . Practical work and experimental results in the dewatering laboratory of Andritz AG Machine and Equipment Factory confirmed these results concerning the difference between the filtration behavior of brine suspended and condensate suspended brine purification mud. It was also found that the intensity of stirring has a pronounced influence on filtration resistance.

Thorough investigations conducted at Ebensee Salt Works finally revealed the measures required to keep the moisture content of the final product under the critical limit of 28 %. Filtration experiments in the dewatering laboratory of Andritz AG Machine and Equipment Factory confirmed the experiences gained at Ebensee Salt Works with regard to useful improvements. The experiments also showed that it was expedient to revamp the washing stage endless belt screen press by substituting a high load resistant press felt for the polyamid press screen. The options for the production of granulated mineral fertilizer products with added value were also examined.

### 5.3 Studies relating to the Preparation of Mother Liquor

At present, a portion of about 17 % of the mother liquor discharged from the evaporator has to be drained off from the balance area "Processing of Rock Salt Brine". The remaining 83 % may be re-used for brine purification. However, this re-use results in an increased accessory salt content of the pure brine and thus a certain deterioration of the quality of the vacuum salt product.

Table 5

Balance Sheet Covering the Process Area „Cooling of Mother Liquor, Subsequent Evaporation and Renewed Cooling, Material Flows Discharged in the Course of the Mirabilite Process“

product	yield [m.-%]	grade, %					recovery, %				
		Cl <sup>-</sup>	K <sup>+</sup>	Br <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>	Cl <sup>-</sup>	K <sup>+</sup>	Br <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>
vapour	52,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
crystallized residue a	23,37	47,108	7,330	0,188	12,898	32,475	70,81	47,00	41,75	87,72	78,31
crystallized residue b	1,57	47,897	48,276	0,000	0,982	2,845	4,84	20,80	0,00	0,45	0,46
retarded mother liquor	22,87	16,549	5,130	0,268	1,778	8,996	24,35	32,20	58,25	11,84	21,23
mother liquor feed	100,00	15,54	3,64	0,11	3,44	9,69	100,00	100,00	100,00	100,00	100,00

The experimental studies carried out in the laboratory have pointed in two directions of how a quality improvement of the vacuum salt product could be achieved. There are two alternative methods described in the following under the heading of aphthitalite process and mirabilite process. Both of them would require a change of the current process configuration (see Figure 1).

#### 5.3.1 Aphthitalite Process

Figure 5 shows the diagrammatic flow sheet of the aphthitalite process. In this process, the mother liquor, which passed the main stage of evaporation,

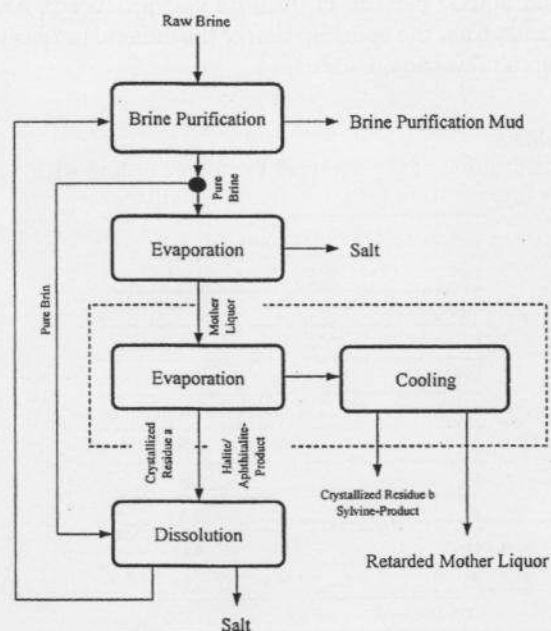


Figure 5. Aphthitalite Process for the Preparation of Mother Liquor for Results Relating to the Process Area Marked in Broken Lines (see Table 5)



has to pass another evaporation stage at 90°C, which is beyond the apththalite saturation limit. This evaporation process has to be broken off as soon as 80 % of the  $\text{SO}_4^{2-}$  recovery has been crystallized in the form of apththalite ( $\text{Na}_2\text{SO}_4 \cdot 3\text{K}_2\text{SO}_4$ ).

After the separation of the mother liquor the multimaterial mix is washed with pure brine, apththalite is dissolved, with the sodium chloride product remaining as a residue. The solution, which is now rich in sulphate ions, but poor with regard to potassium and bromine, is re-used for brine purification where it is used in calcium precipitation. The material flows exiting from the balance area "Evaporation of the Mother Liquor and Cooling" are summarized in Table 5 (see preceding page). Table 6 shows the improvement of the content ratios of  $[\text{K}^+]/[\text{SO}_4^{2-}]$  and  $[\text{Br}^-]/[\text{SO}_4^{2-}]$ , when the dissolved apththalite product is substituted for the mother liquor re-used at present. (Note: The figures relate to the start-up state at the beginning of the lye re-use).

Table 6

Content Ratios of  $[\text{K}^+]/[\text{SO}_4^{2-}]$  and  $[\text{Br}^-]/[\text{SO}_4^{2-}]$  with the Present System of Mother Liquor Re-Use in Comparison with the Improvement to be Expected from the Use of the Dissolved Apththalite Product

	content ratio	
	$[\text{K}^+]/[\text{SO}_4^{2-}]$	$[\text{Br}^-]/[\text{SO}_4^{2-}]$
mother liquor reused in present (Source: Table 1)	$909 \cdot 10^{-3}$	$25,9 \cdot 10^{-3}$
Dissolved apththalite-product in exchange for the mother liquor reused in present (Source: Table 5)	$568 \cdot 10^{-3}$	$14,7 \cdot 10^{-3}$

When the remaining solution is cooled down after the evaporation process of the mother liquor the crystallized residue is a sylvine product slightly contaminated with apththalite (crystallized residue in Figure 5 and Table 5, see preceding page).

### 5.3.2 Mirabilite Process

Figure 6 illustrates the flow sheet of the mirabilite process. With this type of process, the mother liquor discharged from the main evaporation stages is to be cooled down to 0°C – minus 5°C, in the course of which about 70 % (mean value from 3 test series) of the  $\text{SO}_4^{2-}$  contained in the mother liquor is crystallized in the form of mirabilite ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ). After separation from the solution the mirabilite product may be dissolved in pure brine and used in brine purification.

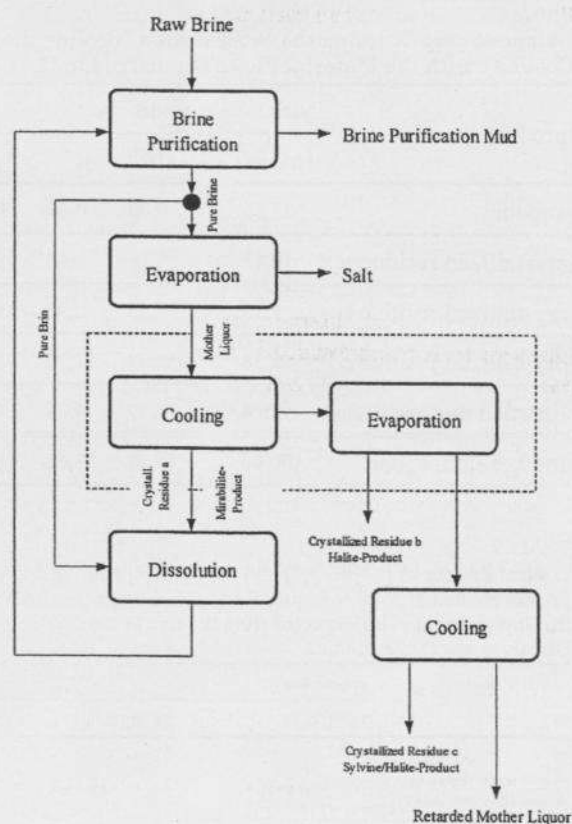


Figure 6. Mirabilite Process for the Preparation of Mother Liquor For Results Relating to the Process Area Marked in Broken Lines (see Table 7, next page)

By cooling the mother liquor down to -5°C you get a mirabilite product with a mass of about 10 % and a content of  $\text{SO}_4^{2-}$  ions of about 77 %. Only about 11 % of the  $\text{K}^+$  recovery and about 3 % of the  $\text{Br}^-$  recovery were carried over into the mirabilite product. According to a calculation by means of the ChemSage computer programme a cooling temperature of about 1°C might lead to a further reduction of the  $\text{K}^+$  burden. The material flow balance of the process area shown in Figure 6 is shown in Table 7 (see next page).

Table 8 (see next page) illustrates the improvement of the content ratios of  $[\text{K}^+]/[\text{SO}_4^{2-}]$  and  $[\text{Br}^-]/[\text{SO}_4^{2-}]$  when the dissolved mirabilite product is used as a replacement for the mother liquor re-used at present. (Note: The figures refer to the start-up at the beginning of the lye re-use).

After evaporation of the solution remaining after the mother liquor has been cooled down it could be possible to produce a rather pure halite product (crystallized residue b in Figure 6 and Table 7).

Table 7

Balance Sheet Covering the Process Area "Cooling the Mother Liquor, Subsequent Evaporation and Renewed Cooling", with the Material Flows Discharged in the Course of the Mirabilite Process

product	yield [m.-%]	grade, %					recovery, %				
		Cl <sup>-</sup>	K <sup>+</sup>	Br <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>	Cl <sup>-</sup>	K <sup>+</sup>	Br <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Na <sup>+</sup>
vapour	23,86	0,00	0,00	0,00	0,00	0,00	0,0	0,0	0,0	0,0	0,0
crystallized residue a	10,45	7,16	3,66	0,02	25,80	14,97	4,8	10,6	2,4	76,5	16,0
crystallized residue b	7,35	60,53	0,75	0,16	0,00	38,66	28,5	1,5	10,5	0,0	29,1
crystallized residue c	2,58	52,50	31,76	0,23	0,04	15,45	8,7	22,6	5,4	0,0	4,1
retarded mother liquor	55,76	16,19	4,24	0,16	1,48	8,90	58,0	65,3	81,7	23,4	50,8
mother liquor feed	100,00	15,58	3,62	0,11	3,52	9,77	100,0	100,0	100,0	100,0	100,0

Table 8

Content Rations of [K<sup>+</sup>]/[SO<sub>4</sub><sup>2-</sup>] and [Br<sup>-</sup>]/[SO<sub>4</sub><sup>2-</sup>] with the Present System of Mother Liquor Re-Use in Comparison with the Improvement to be Expected from the Use of the Dissolved Mirabilite Product

	content ratio	
	[K <sup>+</sup> ]/[SO <sub>4</sub> <sup>2-</sup> ]	[Br <sup>-</sup> ]/[SO <sub>4</sub> <sup>2-</sup> ]
mother liquor reused in present (Source: Table 1)	909 · 10 <sup>-3</sup>	25,9 · 10 <sup>-3</sup>
Dissolved mirabilite-product in exchange for the mother liquor reused in present (Source: Table 7)	142 · 10 <sup>-3</sup>	0,78 · 10 <sup>-3</sup>

As a result of the subsequent cooling of the remaining solution we got a halite/sylvine mix (crystallized residue c in Figure 6, page 7 and Table 7) with a very low mass issue.

The realization of a mother liquor preparation plant would require investments in the amount of ATS 50 million. The advantages of such a plant are on the one hand a better utilization of the raw material brine for salt production, on the other hand a reduction of discharges from the process area "Rock Salt Brine Processing for the Production of Vacuum Salt".

## References

- <sup>1</sup> H. Flachberger: Processing of Rock Salt Raw Brines with Particular Consideration of Side Products from Salt Works. Thesis (1999), Department of Mineral Processing, The University of Leoben
- <sup>2</sup> H. Schwaiger: Brine Purification Reports 1995 and 1997, Quality Management Laboratory of Ebensee Salt Works
- <sup>3</sup> H.J. Steiner: Studie über Abwasserfragen im Bereich der Aufbereitung von Salzmineralen. Unveröffentlichte Studie für die Salinen Austria GmbH, (1997), Department of Mineral Processing, The University of Leoben