Washing, Dewatering and Drying Salt

P.A. Stoffel
Escher Wyss Ltd.
Zurich, Switzerland

ABSTRACT

The three operations are partly connected, serve, however, different purposes, namely:

- *By washing it is intended to reach higher purity of the salt with corresponding better market price,*
- *By dewatering and drying, the salt is being prepared for subsequent storage or packing.*

The methods commonly adopted for the purpose of washing and dewatering differ widely. Whilst in the U.S. vacuum filters are still in the foreground, European practice almost exclusively uses push-type centrifugal separators.

For up-to-date drying, the fluid bed dryer seems now to dominate all over. There are, however, various types in operation, the performances of which differ considerably.

In order to enable a fair overall comparison, a description of plant according to European standards is given, together with performance figures. The trends of development of the push-type centrifuge are communicated and the possibility of a second stage washing is discussed. Furthermore, experience with a particular type of fluid bed dryer is stated.

The information submitted is a challenge for an investigation on comparative economics of U.S. and European practice.

INTRODUCTION

The final stages of every salt refining process are the washing, dewatering, and drying operations. They are usually followed by either immediate packing, bulk transport, or storage of the salt. Far from being secondary, they are well worth while attracting the attention of the salt manufacturer.

This paper is not intended to produce historical evidence nor to give a detailed comparison of a variety of methods applied up to now in this field. What it aims at, is to discuss the latest practice in Europe and to state the corresponding performance figures.

Although washing, dewatering, and drying of salt are at least partly connected operationally, they serve technologically completely different purposes, namely:

- *by washing* we endeavour to eliminate the maximum amount of impurities,
- *by dewatering and drying* we want to obtain a product which can *easily be handled* and which does not bake together when packed or stored.

It is the purity of the salt or more precisely the nature and proportion of its impurities that determines its market price and its field of consumption. For reasons of economy the chemical industry has to carefully optimize for each process so that the purchase cost of various qualities of salt can be enhanced by minimizing the cost of eliminating the impurities. The salt producer consequently has a vital interest to improve the quality of his product at the lowest possible cost in order to be more competitive.

The slurry of salt crystals and mother liquor we wish to consider may originate from the following sources:

- Evaporation, based on purified brine,

- Recrystallizer, based on crude salt,
- Evaporation, based on raw brine, operating with gypsum seeding.

PRELIMINARY ELIMINATION OF MOTHER LIQUOR

By introducing pure brine into the extraction or elutriation leg of the evaporators, two purposes can be fulfilled, namely a washing effect by displacement of the mother liquor, as well as a screening or separating effect, retaining the small particles in the evaporator body by the resulting upward flow. For the first two of the aforementioned processes, the displacement of the mother liquor is the most essential, whereas the gypsum seeding process is dependent upon the screening effect.

Test results prove that, provided the equipment is adequately designed, it is possible to displace up to 90% of the mother liquor by introduction of pure brine. This means that in the extracted salt slurry the major amount of impurities, originating from the mother liquor, is already eliminated.

Basically, the salt produced from purified brine as well as from the recrystallizer is purer than the product obtained from raw brine according to the widely used gypsum seeding process. The latter necessarily leaves a few nuclei of gypsum in the center of each salt crystal. Its impurities consist mainly of calcium sulfate, whereas in the former cases it is sodium sulfate.

With the aid of the following figures an attempt will be made to estimate the importance of the impurity. The first figure is focused on the center and shows the beautiful small gypsum nuclei in the middle of the crystal. Their volume amounts to about one twenty-thousandth of the surrounding cube. This particular crystal has therefore an inherent or permanent impurity of about 0.005%. For smaller crystals, it must be more important since the volume of the central seed-crystals remains about the same. However, it can safely be estimated that the average permanent impurity should not exceed 0.01 to 0.015%, provided we can produce sufficiently large crystals.

Figure 2 shows a salt crystal, focused on the surface, and you may detect a shining gypsum cube, as well as several smaller impurities adhering to it. Their total volume certainly exceeds the impurities shown before in the center.

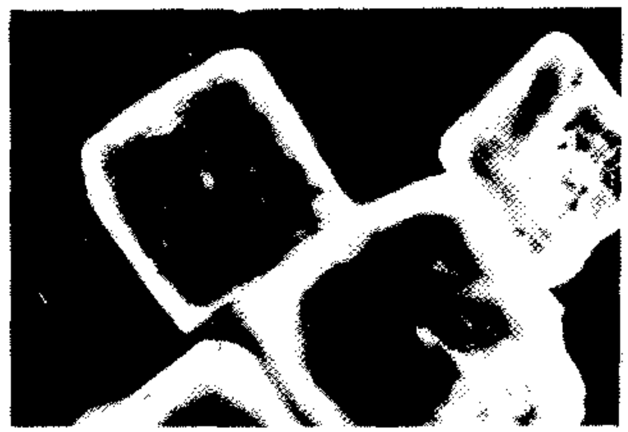

Figure 2.

The purpose of *washing* is to eliminate as far as possible these surface impurities, illustrated once more by Figure 3. Owing to the fact that, apart

Figure 1.

Figure 3.

from the center nuclei and the surface impurities, the cubes show on the whole a very pure structure. There is a good chance that the final purity is not far from 99.99%. In practice, values of 99.985 have been obtained.

LAYOUT

Figure 4 shows the schematic layout of a refining plant according to European practice.

After countercurrent washing in the elutriation leg of the evaporator, the slurry is extracted, then concentrated to 60–70% in a thickener, now shown, and subsequently fed to the centrifugal separator. After dewatering in the separator, the salt is fed by gravity to a channel-type fluid-bed dryer and cooler, from which it leaves on a conveyor belt for the package or storage section.

WASHING PERFORMANCE

The contribution of the different process stages towards higher purity of the product has been investigated and the following results related to the gypsum seeding type of plant can be reported:

- Purity after extraction from evaporator 99.81%
- Purity after thickening and dewatering, but without washing 99.95%
- Purity after thickening and dewatering, with washing during dewatering 99.98%
- Elimination of impurities, owing to thickening and centrifuging 0.14%
- Elimination of impurities, owing to thickening, centrifuging, and washing 0.17%
- Washing alone eliminates 0.03%

At first sight, one might conclude that the washing effect of the centrifugal separator is ineffective and hardly worthwhile. However, if one takes into

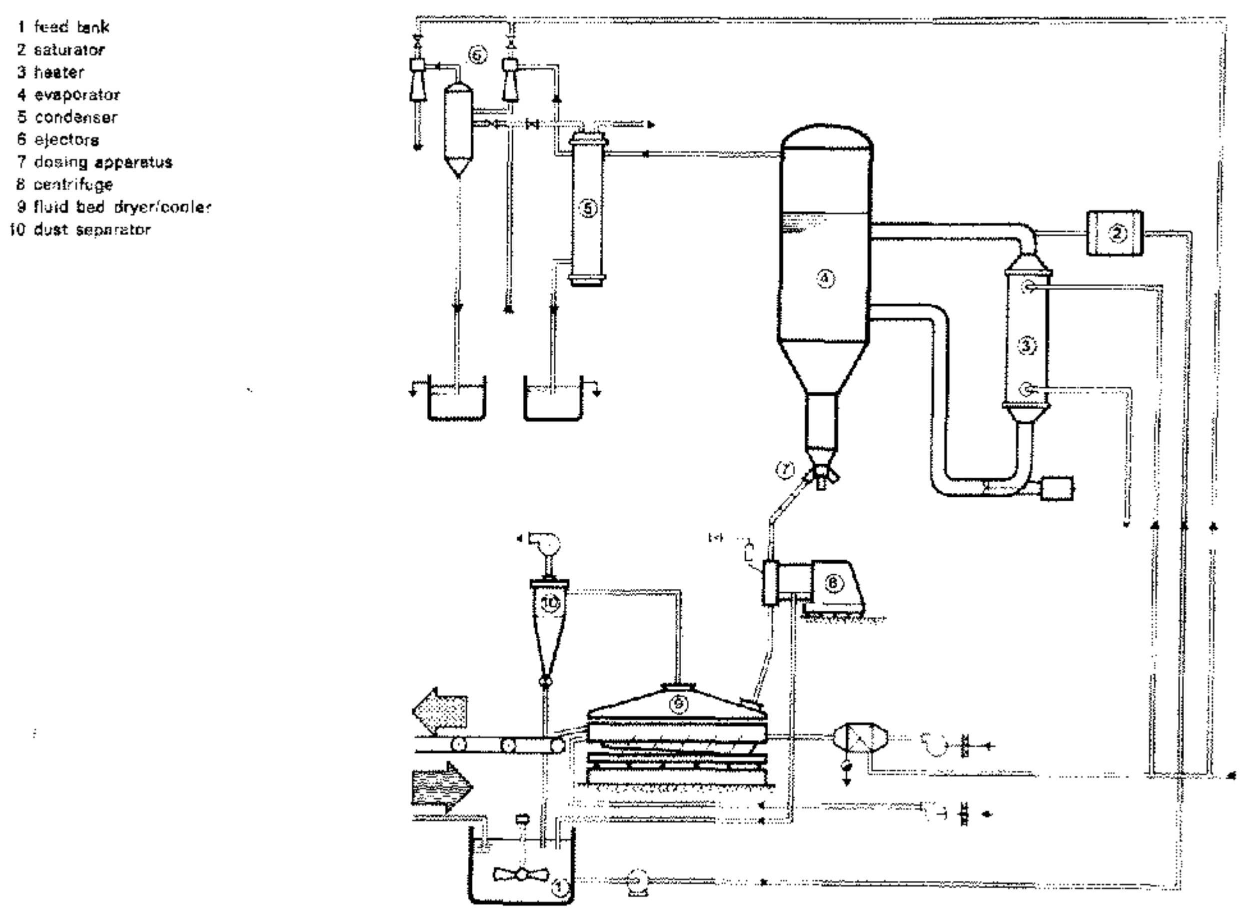

Figure 4.

account that the total of impurities after extraction from the evaporator amounts to 0.19% and that by washing we eliminate 0.03%, or 16% of it, the result is far from being negligible. Emphasis must be given to the fact that the 0.03% is the most difficult to eliminate, and that it can be done very elegantly at practically no cost. It may depend precisely on the success of this washing operation whether or not the salt is suitable for a certain process.

In the case of salt produced from pure brine, the purity after extraction from the evaporator amounts to some 99.90%. Thickening and dewatering brings it up to 99.97% and higher. Tests with washing on the centrifugal separator indicated that another 0.01% of the impurities could be eliminated. With salt from the recrystallizer, I can report a purity of 99.99% can be obtained regularly in industrial operation.

Since in these cases the impurity without washing is already very high, there may be no reason to revert to this operation. But in case of necessity, it can be done with very little effort, its effectiveness must, however, be very limited.

Attention must be drawn to the fact that investigations proved that the salt from the gypsum seed process shows less inclusions of mother liquor in the crystals than the salt originating from the two other sources under consideration. This may be of importance for the suitability of quality for certain processes, because it means the presence of very small amounts of water.

When carrying out the various tests, special care has to be given to the uniformity of the methods of analysis. It has been noticed that analyses carried out according to different methods do not fully coincide and can be misleading. The Atomic Absorption Spectrophotometer method appears to give very reliable results.

DEWATERING

From the point of view of dewatering, the multi-stage, push-type centrifuge, as shown in Figure 5, has been the most efficient. Its great advantage is that the remaining moisture of the salt can be reduced to 2–2.5% in one operation. This is already sufficient for many purposes and, by adding some anti-caking agent, the salt can be stored without further processing. Attention must be drawn to the fact that the performance of push-type centrifugal separators has now reached a very high level. With a small machine of only 20" diameter throughputs of over 20 t/hour can be obtained. Furthermore, the concentration of several rotors in one stator leads to a most economical solution as far as investment and space requirements are concerned.

When investigating the washing effect on the centrifugal separator, a test series showed that the optimum was reached when 6 to 7% water of total solids was introduced. The final moisture thereby increases by about 0.5%.

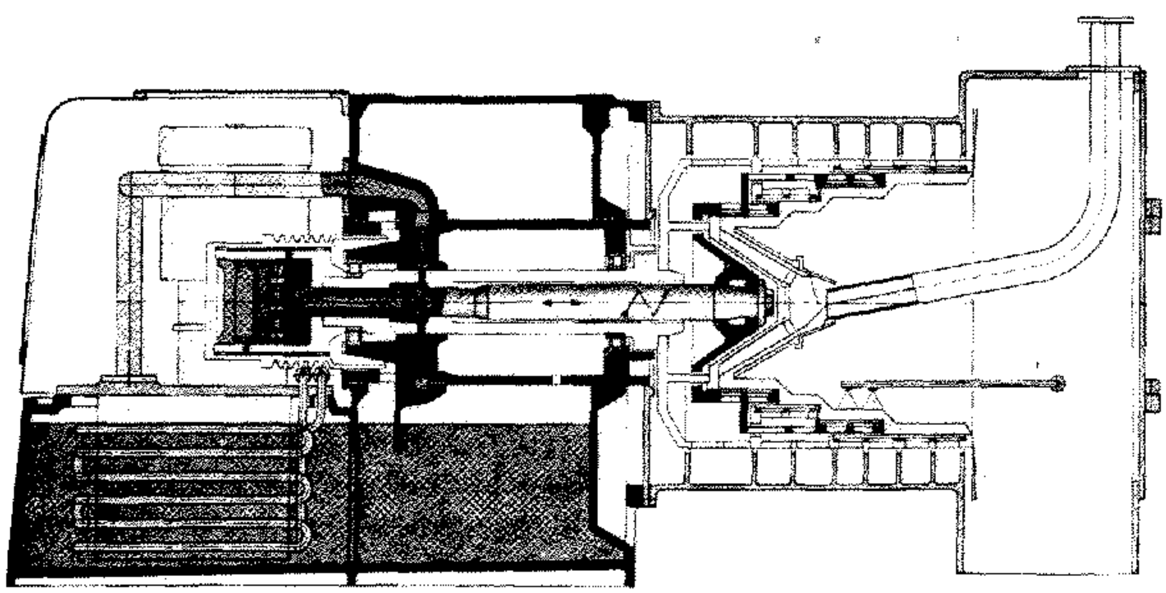

Figure 5.

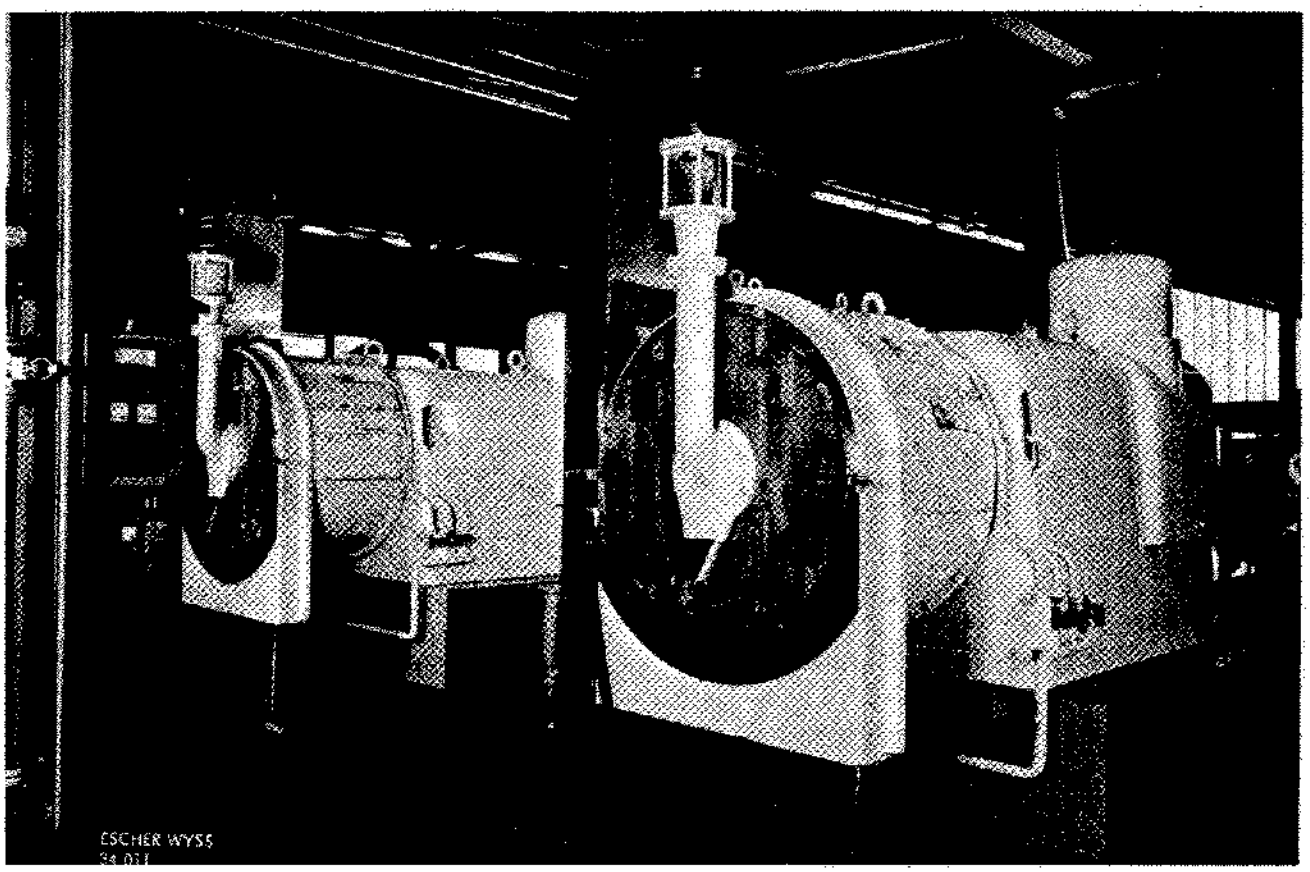

Figure 6.

Figure 6 shows two machines installed at the Swiss Rhine Salt Works.

It is certain that the efficiency of the washing is at least partly due to the multi-stage design of the centrifuge. In fact, when dropping from the first to the second stage, the salt cake is opened up and offers not only better penetration to the liquid, but also improved evacuation of the impurities. A small loss of salt is, of course, involved in the washing with water but it can be recovered with the backflowing mother liquor.

The advantage of an additional stage of washing after de-hydration to further enhance the purity of the salt has been investigated. The salt evacuated from the centrifuge was mixed with saturated pure brine and the resulting slurry, after thickening, again fed to a second centrifugal separator. On this machine washing was equally applied. The result of this test was, however, negative and we must conclude that the additional impurities evacuated were probably less in proportion, than the amount of pure salt dissolved by the operation.

DRYING

The production of table salt and certain salt qualities for the chemical process industry, requires further drying after dewatering. Rotary kilns or hot air dryers have frequently been adopted in the past, but nowadays there is unanimity that the answer to the problem is the fluid-bed dryer. Figure 7

TYPE OF DRYER	HEAT CONSUMPTION/POUND OF DRY SALT
FLASH DRYER (COCURRENT FLOW)	125 - 135 BTU/lb
ROTARY DRYER (COUNTERCURRENT FLOW)	80 - 90 BTU/lb
FLUIDBED DRYER (CROSS FLOW)	40 - 50 BTU/lb

Initial humidity 2,8 weight %

Final humidity 0,05 - 0,1 weight %

Figure 7.

shows the comparative heat consumption of the three basic types of such equipment.

There are many different makes of fluid-bed dryers on the market and they certainly fulfil the purpose of reducing the residual moisture to anything between 0.1 and 0.01%.

The kind of fluid-bed dryer now being used in Europe is of the channel-type with a vibrating platform, as shown in Figure 8. Its first sections are fed with hot air for the drying action. The final sections can be fed with cold air in order to cool the salt down to the temperatures necessary for storage. Owing to the clear flow of the salt and its simplicity, this dryer has given excellent performance. The heating and cooling effects are demonstrated by the graph in Figure 9. The full line shows the progress of drying as a function of the advance of the salt in the vibrating channel. The dotted line in the middle indicates its temperature.

Such a dryer, as shown in Figure 10, surprised its owner by the following behavior:

The purity of the outflowing salt proved to be slightly higher than the salt fed to the dryer. This

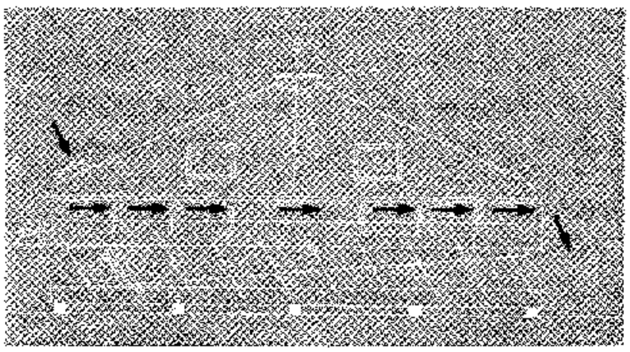

Figure 8.

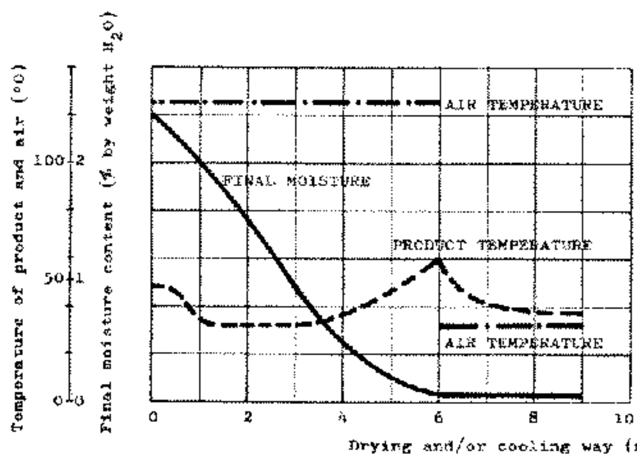

Figure 9.

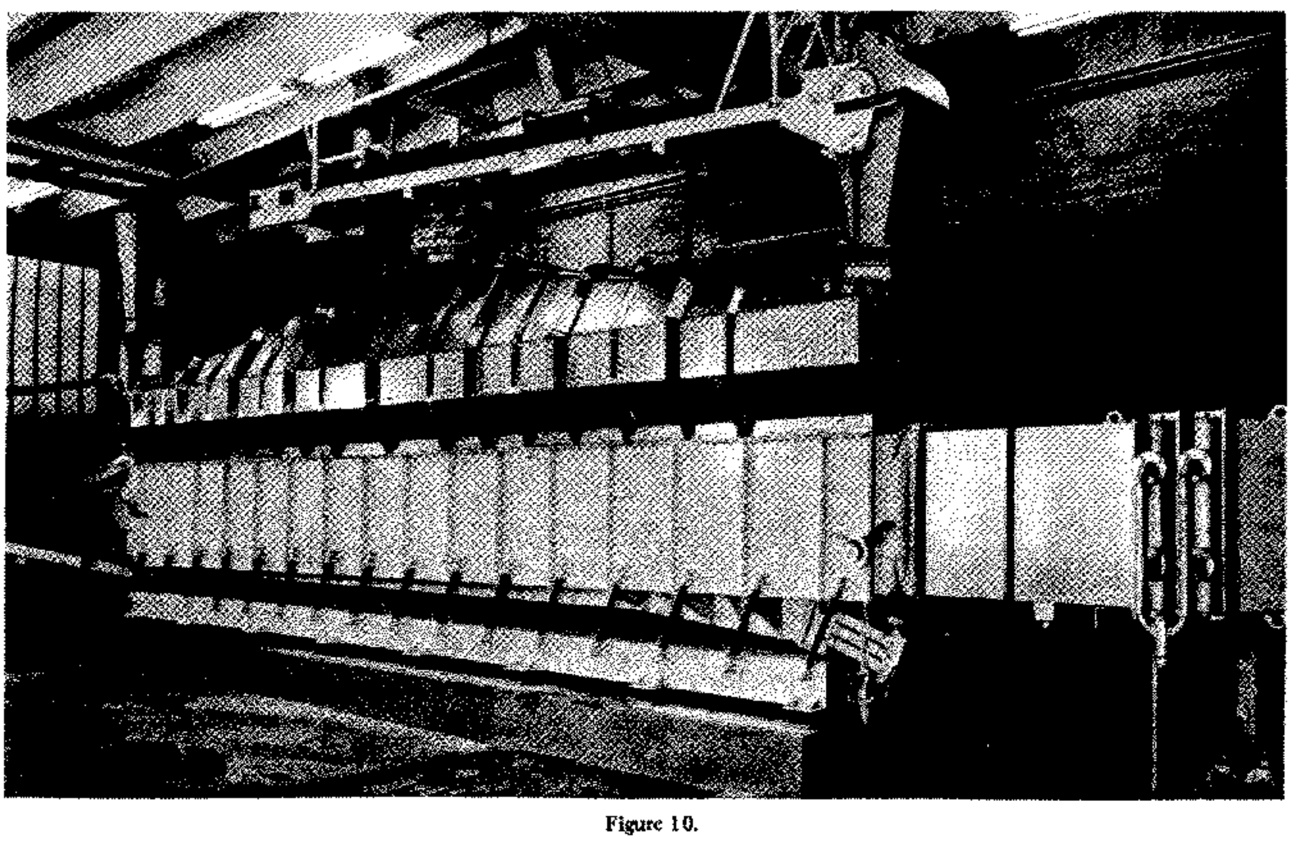

Figure 10.

was unexpected but can be explained as follows: –During fluidizing with hot air, a further "washing" effect must take place. In fact, due to elimination of the remaining moisture and to a certain friction between the salt crystals, small impurities, left on the surface of the crystals, free themselves and are carried away by the air stream. The salt dust recovered from the cyclone separators showed, in fact, a much higher impurity content than the feed and thus confirmed the phenomena.

CONSUMPTION AND INVESTMENT

As far as the comparative consumptions are concerned, the following figures may be of interest.

These figures have been communicated by manufacturers currently operating this equipment, however, they are not the average of a systematic investigation. Nevertheless, they are meant to express the basic difference of economy. The investment for the European version does not exceed 60 to 70% of the layout with vacuum filter, followed by a fluid-bed cooler.

CONCLUSION

In spite of the different purposes, washing and drying of salt are closely connected operations. Depending on the initial quality of the evaporator salt, purity can be improved by subsequent washing during centrifugation and further, to a small extent, by the final drying operation. The frequently quoted 99.99% purity can be obtained under certain favorable conditions.

Low investment and low energy consumption with consequent attractive economy characterize the combination of multi-stage, push-type centrifugal separator with fluid-bed dryer and cooler. Its wide and successful application in salt refining plants all over Europe may be a stimulant to the solution of traditional problems elsewhere.

Vacuum filter	12	kWh/t (metric)	of salt
Cooler	8.3	kWh/t (metric)	of salt
Total	20.3	kWh/t (metric)	of salt
Centrifugal separator	1.6	kWh/t (metric)	of salt
Fluid-bed dryer and cooler	3.6	kWh/t (metric)	of salt
Total	5.2	kWh/t (metric)	of salt
Plus:			
Waste steam consumed for drying	145	lbs/t	of salt