

## Application of the Dry Process on Concentration of Boron Ores

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**ABSTRACT:** The subject of this study is a novel process: the Dry Process (DP) for the concentration of boron ores. The conditions of the concentration of boron ores by the dry process were determined in laboratory and pilot-scale tests. In addition to this, the necessary requirements to apply this process in the plant were investigated. In this process, three types of boron ore were used and they were compared at each step. Before the start of the tests, for determination properties of representative samples of feeds taken from the concentrators (tincal, colemanite and ulexite), particle sizes and the B<sub>2</sub>O<sub>3</sub> % distributions of feeds were investigated, and the B<sub>2</sub>O<sub>3</sub> grade of the samples was 23-32 % as the grades in the plants. In tests conducted in optimum conditions, concentrates with 43-60 % B<sub>2</sub>O<sub>3</sub>, tailings with 3-22 % B<sub>2</sub>O<sub>3</sub> and 70-96 % recoveries were obtained. In the currently operated plant, the concentrate grade is 32-38 % B<sub>2</sub>O<sub>3</sub>, recovery is 80 %, and the tailing grade is 14-16 % B<sub>2</sub>O<sub>3</sub>. The investigations showed that boron ores might be calcined. It was understood that higher quality and dry, cleaner products might be obtained.

### 1 INTRODUCTION

The following ores are exploited by Eti Holding: colemanite and ulexite in Bigadiç, Balıkesir; colemanite in Emet, Kütahya and Kestelek, Bursa; and tincal ore in Kirka, Eskişehir.

Although the evaluation of boron production technology in Turkey is limited in quantity, it is a very valuable mine for countries' economic resources, especially for export. Currently, in boron concentration plants in Turkey, concentrates are produced that fulfill the minimum requirements of the world market in terms of concentration processes. In these plants, only a concentrate ore with content from colemanite-ulexite ore of 32 % B<sub>2</sub>O<sub>3</sub> grade and tincal concentrate with a maximum 32 % B<sub>2</sub>O<sub>3</sub> content from tincal ore with a B<sub>2</sub>O<sub>3</sub> grade of 26 % have so far been produced.

### 2 PRELIMINARY RESEARCH

At the beginning of this research, all the boron ores had different ratios of crystal water. The occurrence of calcination events and the results of the heating process were investigated in a perlite mine operated in Cumaovası, İzmir (Eti Holding). For this purpose, interesting results of calcination were first produced by simple tests conducted on tincal ore (Aytekin et al., 1992). Calcination was

previously performed by preparing samples for the calcination and dry grinding processes rather than just obtaining concentrates for boron ores. However, it was found that there was no need for these processes when adopting wet grinding.

To date, research on the heating process done by different researchers (Aytekin et al., 1992a, b, c; Aytekin et al., 1993; Eric et al., 1982; Gundiler et al., 1972; Kaytaz et al., 1986; Sener et al., 1992) has been conducted on a pilot scale rather than as a laboratory test for the purpose of concentration. There have been several studies of the application of the calcination process instead of the wet process, which is used in ore production at present. These studies have mainly dealt with the beneficiation of rich tailings and concentrate beneficiation of low-grade ores produced at Kirka, Bigadiç and Emet. There is not a low market demand for these ores. Ores containing inherent crystal water lose it by heating, and as a result, calcination occurs. Due to this characteristic behaviour, the calcination process is applied to tincal, colemanite and ulexite ores (Akçıl, 1994).

### 3 MATERIAL

Boron samples (tincal, colemanite and ulexite) were taken from Eti Holding's Kirka and Bigadiç concentrator plant fine ore stocks with a weight of

250 kg for each ore.

The coarsest sample size was homogenized; this size was 40-50 mm. The tincal ore had an average content of 26 % B<sub>2</sub>O<sub>3</sub>, with different parts of the ore body having values of 24-29 % B<sub>2</sub>O<sub>3</sub>. Colemanite and ulexite had an average content of 32 % B<sub>2</sub>O<sub>3</sub>.

#### 4 METHOD

Colemanite and ulexite ores calcine by losing crystal water during the heating process under specific conditions. However, tincal ore behaves in a different manner. When tincal ore is treated with a heating process, popping occurs and a porous surface is observed. As a result of ore processing, clay minerals agglomerate in different sizes and colors emerge, while gangue minerals are calcined and become hard. The more compacted part, which is made of clayey product and gangue minerals, gives a coarse-size product when squeezed under rollers, while softer parts, which are rich in B<sub>2</sub>O<sub>3</sub>, give a finer-size product. These two different products are classified by separation and concentrate is obtained.

#### 5 EQUIPMENT USED

All die tests were conducted with the characteristics of a revolving preheating calcination furnace (originally designed by Aytekin, 1992).

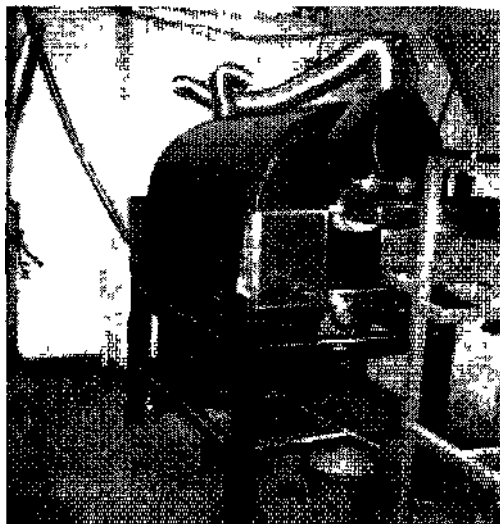


Figure 1. Revolving preheating calcination furnace

The furnace consists of a cylindrical ceramic tube, which is used for moving the materials in pieces inside the furnace and for heating with rotation. This tube has a special position, either balancing its position angle or balancing its rotating velocity. Feeding is done with a vibration feeder. The tube conveying materials into the calcination furnace contains two temperature areas. The first part is 80 cm away from the feeding point of the material. This part, at the same time, is the first drying and calcination temperature point area. The second part is only 40 cm away. In this part, the material loses crystal water and calcination also takes place. A portable thermometer on the control panel is used for measuring the inner furnace temperature.

#### 6 MAIN RESEARCH

The main parameters listed below, in addition to other secondary parameters, were investigated during the calcination tests:

- preheating and calcination temperatures,
- heating and calcination times,
- particle size of the feed.

As a result of the loss of crystal water in the structure of the boron ore under temperature, it calcined. Its expansion properties were determined and systematic calcination tests were conducted. The concentration treatment was completed by the separation of the large particle impurities which remained, such as clay, dolomite and calcite. The white mass should be subjected to further treatment such as screening or air separating. The parameters of calcination temperature, calcination time, particle size and the quantity of feeding, which affected the recovery obtained with this method, were investigated by doing different series of tests for the optimum calcination conditions of Kirka tincal ore and Bigadiç colemanite-ulexite ores.

Various parameters were tested for separation of the expanded ore from solidified clay together with other gangue minerals after the calcination process, and as a result, the comminution of the end products on top of a uniform rubber plate by roller was preferred. Sieving was used to separate the boron concentrate and tailings. Boron powder is easily separated from solidified clay and gangue minerals after the comminution process. After the tests, the optimum conditions were determined from the results of chemical analysis.

#### 7 APPLICATION OF DRY PROCESS ON BORON ORES

It was found that it was possible to concentrate the tincal ore\* by the dry process (DP). The optimum

conditions were determined for the concentration of tincal ore by this process. Thus, systematic tests were carried out to determine the calcination temperature, time and particle size of the used ore. According to the results obtained in the tests, the sample was divided into different seven particle sizes: 50-25 mm, 25-12.5 mm, 12.5-9.51 mm, 9.51-4.76 mm, 4.76-3 mm, 3-1 mm, and -1 mm.

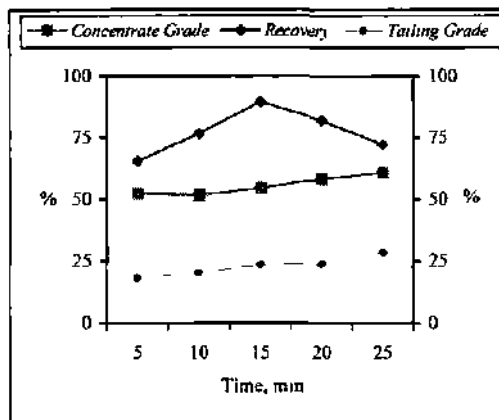


Figure 2 Change in grade and recovery of calcined tincal concentrates according to different parameters

The concentrate grade and recovery obtained as a result of the calcination tests done on ore which was divided into different particle sizes at different times (5-25 mm.) and temperatures (300°C-500°C) were compared with regard to each parameter.

First, tests carried out at the optimum temperature, which had been found to be the most suitable calcination temperature beforehand, were evaluated. When the ore was smaller than 9.51 mm with a calcination time of 15 minutes, it was observed that the concentrate recovery was the highest. After this value, a small decrease was observed. For 15 minutes of calcination, the concentrate grade was 46-56 % B<sub>2</sub>O<sub>3</sub> with 87-95 % recovery and the tailing grade was 3-13 % B<sub>2</sub>O<sub>3</sub>.

Calcination tests were conducted on Bigadiç colemanite ore in order to find the optimum calcination conditions in the same manner as for the concentration of tincal ore by the dry process. The optimum conditions in terms of concentrate grade, recovery and tailing grade were found to be a calcination temperature of 500°C, a calcination time of 20 minutes and a particle size of less than 12.5 mm.

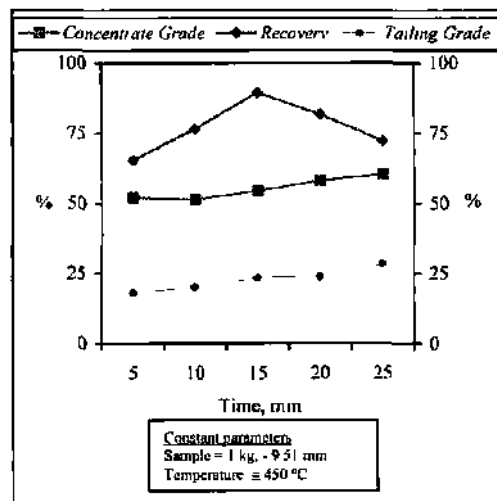


Figure 3 Change in grade and recovery of calcined colemanite concentrates according to different parameters

The results of tests in optimum conditions showed that calcination recovery was 92-94 %, the concentrate grade was 48-51 % BiO<sub>3</sub> and the tailing grade was 9-11 % B<sub>2</sub>O<sub>3</sub>. The concentrate recovery of the Bigadiç concentrator was 80 %, the concentrate grade was 42 % B<sub>2</sub>O<sub>3</sub> and the tailing grade was 16 % B<sub>2</sub>O<sub>3</sub>. Concentration by the calcination tests increased the concentrate recovery by 16 % and the concentrate grade by 19 %, and decreased the tailing grade by 37%.

Calcination tests were conducted on Bigadiç ulexite ore in order to find the optimum calcination conditions. As a result of the tests, it was observed that the 25-1-mm particle size fraction was the optimum fraction, and the grade and recovery of ulexite concentrate from this fraction constituted the highest values. At the end of the tests, it was determined that the optimum calcination temperature and calcination time were 450°C and 25 minutes, respectively. In the tests carried out at the optimum calcination temperature, it was observed that the water in the chemical composition of the ulexite ore was not completely evaporated, and the surface of the ulexite ore was covered with a block glassy layer over this temperature.

According to these results, the grades and recoveries of the calcined product obtained in the tests carried out in optimum conditions were within the ranges of 43-44 % B<sub>3</sub>O<sub>3</sub> and 94-95 %, respectively. In the currently operated plant, the concentrate grade is 36-38 % B<sub>2</sub>O<sub>3</sub>, concentrate recovery is 80 % and the tailing grade is 14-16 % B<sub>2</sub>O<sub>3</sub>.

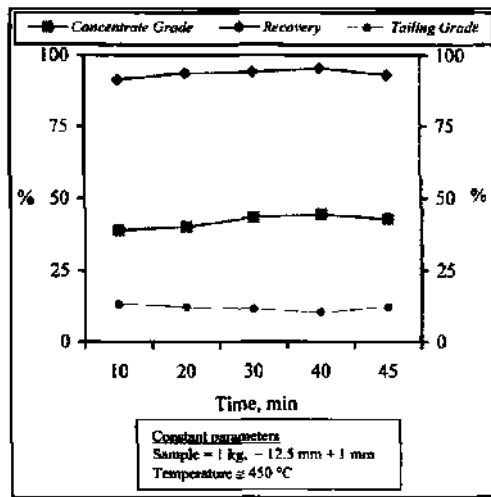


Figure 4. Change in grade and recovery of calcined ulexite concentrates according to different parameters.

## 8 CONCLUSIONS

During the concentration of boron ores by the dry process, a specially designed preheated calcination furnace was used. At the end of the tests carried out with this furnace, the optimum calcination conditions were found in terms of calcination temperature, calcination time and feed fraction. For classification, a screening method was chosen. For calcine, a 0.2-mm sieve was found to be suitable. In this classification process, undersize parts were taken as concentrate and oversize parts as tailing.

In the plant, which is located at Kırka, a concentrate with a grade of 32-34 % B<sub>2</sub>O<sub>3</sub>, at a recovery of 82-84 % and tailing grade of 14 % B<sub>2</sub>O<sub>3</sub> is produced. The grade of the concentrate which we obtained in optimum calcination conditions in the laboratory was 46-60 % B<sub>2</sub>O<sub>3</sub> at a recovery of 70-95 % and the tailing grade was 3-13 % B<sub>2</sub>O<sub>3</sub>.

In the tests conducted on colemanite ore in optimum conditions, 80 % of the original sample was over 4.76 mm and had a grade of 32.33 % B<sub>2</sub>O<sub>3</sub>. Coarse particle fractions had concentrated B<sup>+</sup>. The part over 12.5 mm had a grade of 43 % B<sub>2</sub>O<sub>3</sub>. This grade was the sample grade of the Bigadiç concentrator and this sample was used as the concentrate. In optimum calcination conditions, the grade of colemanite concentrate was 31-51 % B<sub>2</sub>O<sub>3</sub> at a recovery of 62-94 % and the tailing grade was 11-32 % B<sub>2</sub>O<sub>3</sub>. In addition to the concentration process used in the Bigadiç concentrator to determine the concentration of colemanite by the dry process, laboratory studies were carried out. Finally, instead of a concentrator plant, a dry process plant was used.

In the tests done in optimum conditions, ulexite concentrates with grades of 38-44 %, tailings with

grades of 10-13 % B<sub>2</sub>O<sub>3</sub> and 91-95 % recovery were obtained. In the currently operated plant, the concentrate grade is 36-38 % B<sub>2</sub>O<sub>3</sub>, concentrate recovery is 80 % and the tailing grade is 14-16 % B<sub>2</sub>O<sub>3</sub>.

The investigations showed that boron ores might be calcined. Final products of concentration with the calcination of boron ores are better than the product of currently operated plants. For this reason, it is concluded that it is more suitable to set up a plant operated with concentration by the dry process. The production of boron derivatives from the concentrate products obtained by the dry process is easier and cheaper technologically. In addition, with this process, the problems of tailing, storing and dewatering can be eliminated.

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