# BX06 - Industrial experimental study on desulfurization of high-sulfur bauxite under coal mines

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**Abstract**

The high-sulfur bauxite under the coal mines in Henan Province was used as raw material. The grinding fineness, pH value and collector dosage on its desulfurization performance, and industrial flotation desulfurization process were studied. The best flotation desulfurization conditions were grinding fineness of 75 %, pH of 8.5, and collector of 600 g/t. "One coarse, one cleaning and one sweep" closed-circuit flotation was established as the industrial flotation desulfurization process. After the closed-circuit test, the sulfur content of aluminum concentrate with the yield of 93 % was 0.23%, and the sulfur removal rate was 83.16 %, and the sulfur content of tailings (sulfur concentrate) was 15.09 %.

**Key words**: High-sulfur bauxite under coal mines, flotation, desulfurization.

## 1. Introduction

The bauxite resources in China are relatively necessitous compared to huge consumption. With the rapid development of the world's alumina production industry, over 50 % of the world's alumina production capacity is concentrated in China. So, in the face of the soaring demand for bauxite resources, China will bear huge pressure [1 - 6]. According to the U.S. Geological Survey's annual reserves and production data, China's bauxite resources have a static recoverable life of only 14 years, far behind the global 102 years [7 - 8]. In order to ensure the further development of China's alumina production industry, it has become very urgent to explore and find new areas of bauxite. In recent years, many fine bauxite deposits have been found in North China coalfields. In Henan Province, from 300 meters to 500 meters below the coal seam, bauxite reserves of 300 million tons can be found [9 - 10], however, this part of bauxite has high sulfur content and cannot be directly used in alumina production. Therefore, solving the problem of high sulfur in coal seam bauxite will be of great significance for expanding the source of bauxite and ensuring the safety of the Chinese aluminum industry.

## 2. Raw Ore

### 2.1 Multi-Element Analysis

The ore samples used in the laboratory represented the high-sulfur bauxite under the coal mines in Henan Province. The chemical composition of the ore sample was analyzed. A typical result is shown in Table 1.

**Table 1. The main chemical components (%).**

| element | $Al_2O_3$ | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $K_2O$ | $Na_2O$ |
|---|---|---|---|---|---|---|
| content | 63.46 | 12.35 | 2.46 | 2.96 | 1.10 | 0.025 |
| **element** | **CaO** | **MgO** | **S** | **C** | **LOI** | |
| content | 0.81 | 0.25 | 1.21 | 1.80 | 13.40 | |

It can be seen from Table 1 that aluminum in the ore exists in the form of alumina with a high content of about 64 %, silica content was relatively low at 12.35 %, and the alumina-silica ratio was 5.14. However, the ore contain elevated sulfur, reaching 1.21 %, which belongs to a high-sulfur bauxite ore. Desulfurization experiments needed to be conducted on the ore sample to see if it could become useful for processing.

## 2.2. Process Mineralogy

### 2.2.1. Mineral Composition

The mineral composition of the raw ore is shown in Table 2. The valence analysis of sulfur is shown in Table 3. The X-ray diffraction analysis is shown in Figure 1.

**Table 2. Analysis results of phase composition (%).**

| Phase | Diaspore | Pyroxene | Kaolinite | Chlorite | Illite |
|---|---|---|---|---|---|
| content | 65.00 | 5.5 | 5.0 | 3.0 | 10.5 |
| **Phase** | **Pyrite** | **Calcite** | **Anatase** | **Rutile** | **Quartz** |
| content | 2.4 | 1.4 | 2.0 | 1.0 | 1 |

**Table 3. Valence analysis results of sulfur (%).**

| Total sulfur | Sulfur content in sulfate | $S^{2-}$ |
|---|---|---|
| 1.21 | 0.07 | 1.14 |

It can be seen from Table 2 and Figure 1, the diaspore is the main aluminum mineral, and the sulfur existed mainly in the form of pyrite. In order to obtain a low-grade sulfur product, flotation desulfurization experiments needed to be performed. Studies had shown that bauxite with 2 % sulfur can be desulfurized by flotation to obtain concentrates with sulfur content below 0.41% [11].

The flotation desulfurization process of the high-sulfur bauxite was based on the flotation differences among pyrite, diaspore, and aluminosilicate minerals. Xanthate was used to remove pyrite from bauxite via reverse flotation.

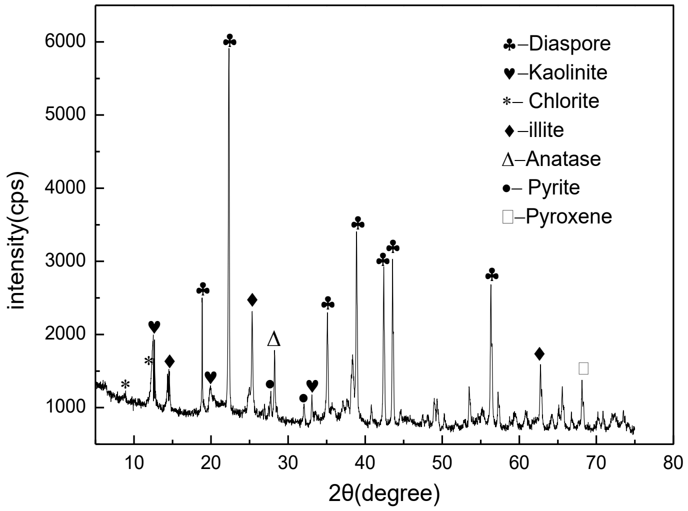


**Figure 1. XRD pattern of high-sulfur bauxite.**

### 2.2.2 The Scanning Analysis of Raw Ore Powder

Process mineralogy parameters such as the complexity of mineral inlays and the degree of dissociation can be determined by using QEMSCAN. The scanning was performed by QEMSCAN. The scanning picture of the mixed ore sample of the high sulfur bauxite under coal in industry test is shown in Figure 2.

Figure 2 shows that most of the particles with a particle size of 150 µm or above in the ore sample are complex and have strong inclusions. Enlarged image of three larger particles are shown in Figure 3. In the original ore sample, there was serious inclusion between the diaspore bauxite mineral and silicon mineral. This coarse mineral was generally floated out during the desilication flotation process and entered the high alumina material. However, the inclusion of silicon minerals affects the alumina content of the high alumina material, which is very unfavorable.

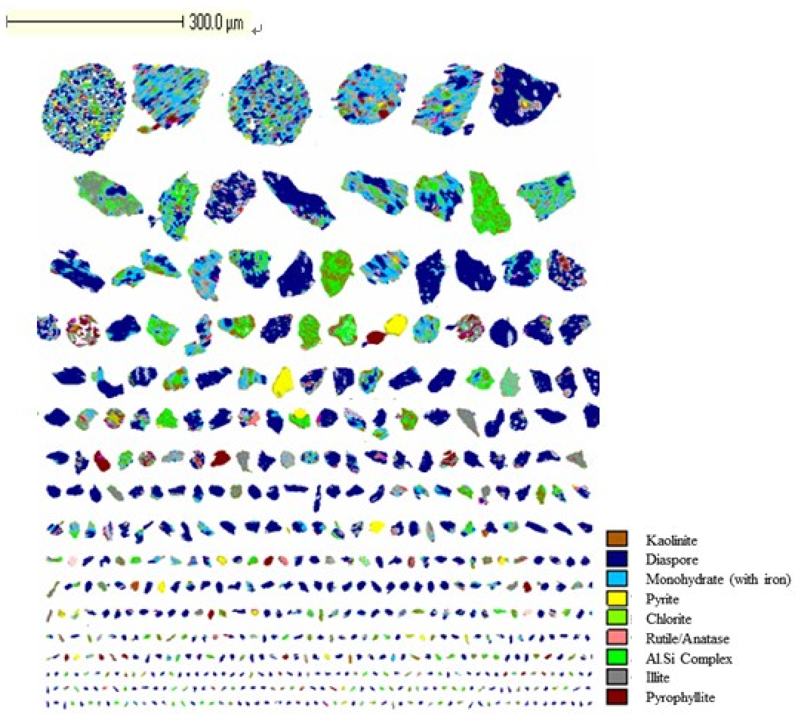


**Figure 2. The scanning chart of mixed ore samples of the high-sulfur bauxite under the coal mines.**

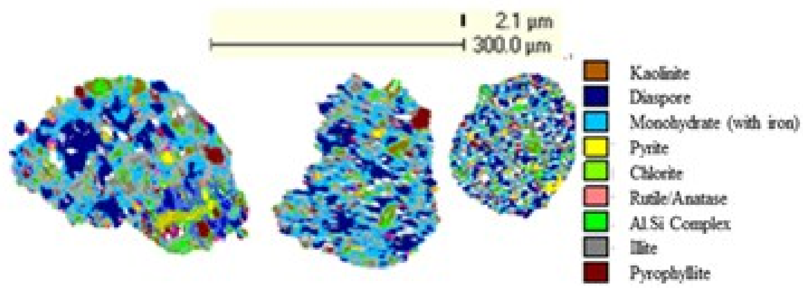


**Figure 3. Coarse-grained ore particles in raw ore samples.**

## 3. Experiment Equipment and Methods

The main equipment used in the experiment included ball mill and a flotation machine. The effects of various flotation conditions on the desulfurization flotation of mixed ore samples were investigated. Using 500 g ore samples, the test variables were: grinding fines, pH and collecting agent dosage. An internal "one coarse" flotation test was performed in a 1.5 L XFD single-tank flotation machine. The experimental process is shown in Figure 4.

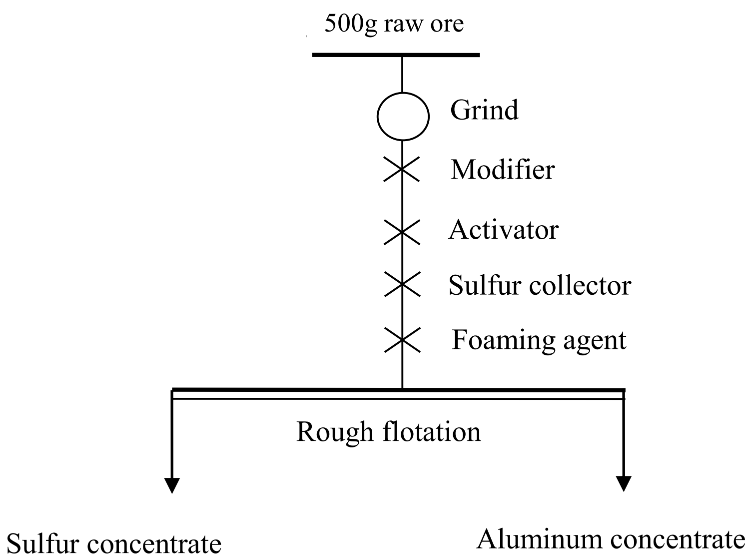


**Figure 4. Flow chart of flotation process.**

## 4. Experimental results

### 4.1 Desulfurization Flotation Optimization Test in Laboratory

#### 4.1.1 Impact of Grinding Fineness on Desulfurization Process

Fixed test conditions: the amount of collector is 650 g/t, and the pH is 5. The desulfurization flotation effect of mixed ore samples under different grinding fineness were investigated and analyzed. The fineness of grinding in Figure 5 refers to the proportion of -0.074 mm grain size. Under the selected grinding fineness conditions, qualified aluminum concentrates could be obtained from high-sulfur bauxite. The yield of aluminum concentrates was over 66 %, and the sulfur content was less than 0.4 %. According to the grade of aluminum concentrate and considering the grinding characteristics of high-sulfur bauxite ore, the energy consumption of grinding was relatively high. Therefore, the grinding fineness of 75%-80 % below -0.074mm was suitable for desulfurization flotation.

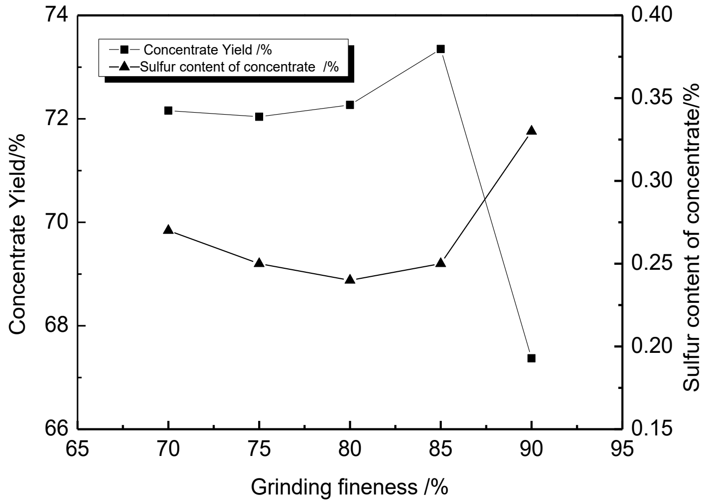


**Figure 5. Effect of grinding fineness on desulfurization flotation of ore samples.**

### 4.1.2 Influence of pH Value on Desulfurization Performance

The surface acidity and alkalinity of the high-sulfur bauxite were neutral; hence the flotation pH would not only affect the desulfurization effect, but also the backwater utilization of the entire system. Therefore, the effect of pH on the flotation desulfurization was studied. The grinding fineness of 75 % was below -0.075mm was fixed, and the amount of collector was 350 g/t. A roughing reverse desulfurization flotation test was conducted. The test process diagram is shown in Figure 4 and the results are shown in Figure 6.

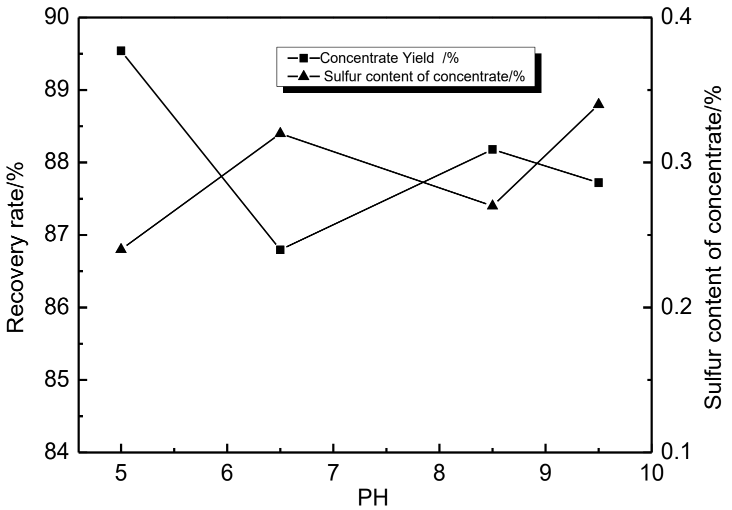


**Figure 6. Effect of pH on desulfurization flotation of mineral samples.**

It can be concluded from Figure. 6 that the flotation pH values were 5.0 and 8.5, the yield of aluminum concentrate was high, and the sulfur content in the concentrate was below 0.3 %, which confirmed a suitable desulfurization performance. The yield of aluminum concentrate was the highest after desulfurization at pH of 5.0. According to the phenomenon in the flotation process, it can be judged that under this condition, the removal of pyrite was more efficient. Therefore, when the pH value was 5.0, the effect of desulfurization flotation was the best. However, considering the influence of the pH value of desulfurization on desiliconization by flotation during the desulfurization and desiliconization flotation of bauxite at the same time, and the effect of the acidic system on the subsequent alumina production process, it is more appropriate to choose pH of 8.5.

#### 4.1.3 Collector Dosage Experiment

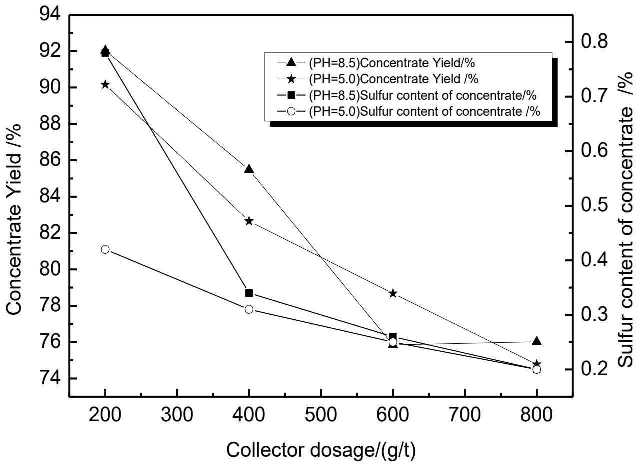


**Figure 7. Effect of collector dosage used in desulfurization flotation.**

The main function of collector was to adsorb on the surface of the pyrite, so that the target mineral could float out during the flotation process. So, the amount of collector used had a very important impact on various parameters of flotation. The desulfurization flotation collector used in the experiment was BKS-1, and the grinding fineness is 75 % below 0.075mm. The effect of the amount of collector on the flotation desulfurization under various pH conditions was studied and analyzed. The results were shown in Figure 7.

It can be seen in Figure 7 that with the collector amount increasing, the yield of aluminum concentrate decreased rapidly, but the sulfur content in aluminum concentrate also gradually decreased. Under the same desulfurization index, the amount of collector in alkaline environment was more than that in acidic environment. In summary, the best flotation conditions for flotation desulfurization of mixed ore sample are grinding fineness of 75 %, under weak acidic conditions, the amount of flotation desulfurization collector of 400 g/t and under weak alkaline conditions, with the amount of collector dosage of was 600 g/t.

### 4.2 Industrial Test of Flotation Desulfurization

The industrial test for flotation desulfurization used a novel non-drive flotation device. All equipment was automatically controlled to provide a reliable basis for industrialized design. The industrial test process is shown in Figure 8, and the processing capacity is 1.5 t/h.

Optimizing the test results according to the process parameters of desulfurization by flotation in the laboratory, the effects of the collector amount, grinding fineness and other conditions on the desulfurization effect of industrial tests were investigated.

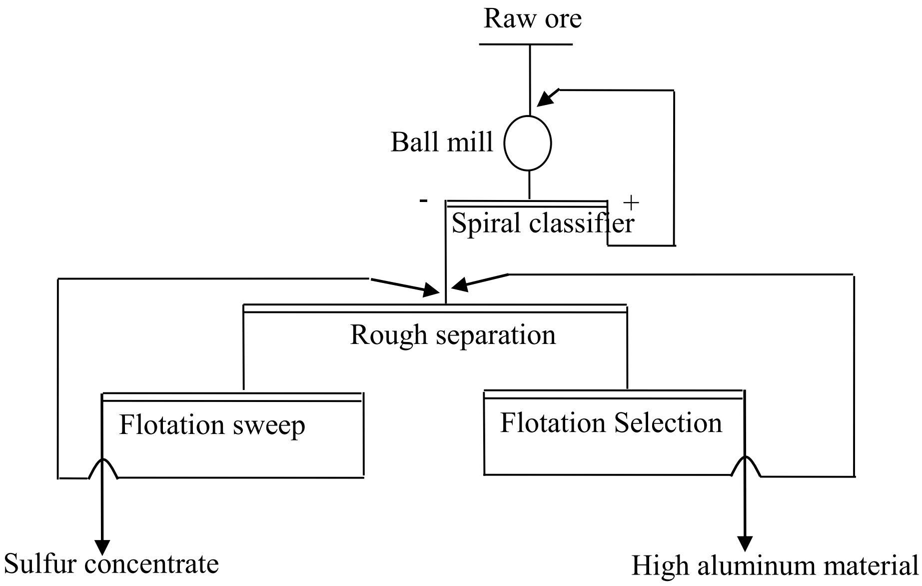


**Figure 8. Industrial flow chart of flotation desulfurization of high-sulfur bauxite.**

### 4.2.1 Grinding Fineness Test

The effect of various grinding fineness on the desulfurization effect of flotation was studied. The results are shown in Table 4. When conducting the debugging test of grinding fineness, the amount of fixed collector used was 1000 g/t, and the pH was 8-9.

**Table 4. Flotation index under different fineness conditions.**

| Grinding fineness (-200 mesh)/% | Aluminum concentrate | | Tailings | | S removal rate, % |
|---|---|---|---|---|---|
| | S, % | Yield, % | S, % | Yield, % | |
| 86-93 | 0.22 | 92.13 | 11.79 | 7.87 | 82.06 |
| | 0.26 | 90.31 | 10.37 | 9.69 | 81.06 |
| | 0.29 | 88.51 | 9.86 | 11.49 | 81.53 |
| 81-86 | 0.23 | 91.45 | 12.39 | 8.55 | 83.44 |
| | 0.22 | 90.38 | 11.86 | 9.62 | 85.16 |
| | 0.21 | 92.88 | 13.27 | 7.12 | 82.89 |
| 74-78 | 0.20 | 92.54 | 14.40 | 7.46 | 85.31 |
| | 0.17 | 93.43 | 15.39 | 6.57 | 86.42 |
| | 0.19 | 92.76 | 13.87 | 7.24 | 85.06 |
| Average index | 0.22 | 91.60 | 12.58 | 8.40 | 83.66 |

It can be seen from Table 4 that when the fineness of grinding is in the range of 74 -93 %, the proportion of sulfur in aluminum concentrate is distributed between 0.17 % and 0.29 %, and the yield of flotation aluminum concentrate was above 88%. This shows that this industrial test does not have too high requirements for grinding fineness, and flotation tests in a wide range of grinding fineness can obtain qualified flotation indexes. While continuing to increase the fineness of grinding, the sulfur content of aluminum concentrate gradually increased, and the sulfur content of tailings gradually decreased. A at the same time the sulfur removal rate of the raw ore also decreased. Considering factors such as the beneficiation cost, the optimum grinding fineness (-200 mesh) of the high-sulfur bauxite the flotation desulfurization industrial test under coal was determined to be 74-78 %.

#### 4.2.2 Collector Dosage Test

The collector dosage test examined three conditions of 600 g/t, 1000 g/t, and 1400 g/t, and the addition ratio of rough flotation: flotation selection was 4: 1. Other dosages are activator of 50 g/t and foaming agent of 400 g/t, and the pH is 8-9. It is table 6 for the average index of different collectors.

**Table 5. Average index of collector usage for industrial test.**

| Collector dosage, g/t | Aluminum concentrate | | Tailings | | S removal rate % |
|---|---|---|---|---|---|
| | S % | Yield % | S % | Yield % | |
| 600 | 0.32 | 94.51 | 17.15 | 5.49 | 75.42 |
| 1000 | 0.21 | 93.00 | 15.04 | 7.00 | 84.54 |
| 1400 | 0.16 | 89.01 | 9.65 | 10.99 | 88.14 |

From the results in Table 5, the amount of collector used at 600 to 1400 g/ t can achieve appropriate flotation desulfurization indexes. The sulfur content of the aluminum concentrates obtained is less than 0.35 %, and the yield of concentrates reaches 88.0 % or more. With the increasing use of collectors, the yield of flotation concentrates decreases, while the sulfur content of concentrates gradually decreases. When the amount of collector used reaches 600 g/t, the sulfur content of the concentrate is still above 0.3 %; when the amount of collector used reach 1000 g/t, the average proportion of sulfur in the flotation concentrate is 0.21 %. Taking all desulfurization indexes of industrial tests into consideration, the amount of collector used should be 1000 g/t when the industrial test for flotation desulfurization of high-sulfur bauxite under coal started stably. Large amount of collector used in this industrial test may be related to the higher carbon content in industrial ore samples.

After steady industrial tests, another test was carried out according to the flotation desulfurization process of once roughing, once selecting and once sweep cleaning. When the sulfur content was 1.21 %, the obtained aluminum concentrate contained 0.23 % sulfur, the concentrate yield was 93 % with the sulfur removal rate of 83.16 %, and the tailings (sulfur concentrate) had a sulfur content of 15.09 %.

## 5. Conclusions

The useful minerals in the mixed ore samples in the industrial test were mainly bauxite. The sulfur-containing minerals are mainly pyrite, and the average S content of the ore was 1.21 %. According to the optimized experimental results of process parameters of desulfurization flotation, the most suitable process conditions in the laboratory for desulfurization of high-sulfur bauxite under coal were that the feed fineness after grinding is 75%. In weak acidic conditions, the amount of flotation desulfurization collector was 400 g/t; in weak alkaline conditions, the amount of desulfurization flotation collector was 600 g/t.

The optimal conditions for industrial flotation of high-sulfur bauxite under coal were as follows: the feed fineness after grinding was 74-78 %, flotation reagent was added in stages, and the total amount of collector used was 1000 g/t. The industrial desulfurization flotation process adopts "one coarse, one fine, one sweep" flotation, and the process of returning the middle ore to the rough flotation can obtain the aluminum concentrate with sulfur content of 0.23 %, and the concentrate yield of 93 %. The sulfur removal rate was 83.16 %, and the sulfur content of the tailings (sulfur concentrate) was 15.09 %.

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