The nickel-alloy avaruite found in chrysolite asbestos ore tailings is concentrated by magnetically separating the asbestos ore tailings to obtain a magnetically attracted, nickel-enriched fraction. The nickel-enriched fraction is mechanically impacted, preferably by ball milling, to increase the maximum dimension of the avaruite particles and to fracture the other more easily ground material in the tailings, mainly magnetite and serpentine rock, into smaller particles. After the maximum dimension of the avaruite particles has been increased, they can be efficiently size-separated from the smaller particles of fractured magnetite and serpentine.

10 Claims, 1 Drawing Figure
SEPARATION OF NICKEL FROM ASBESTOS ORE

BACKGROUND OF THE INVENTION

This invention relates to a physical process for obtaining a concentrated nickel-containing product from chrysotile asbestos ore. More particularly, the invention relates to a physical process for concentrating the awaruite particles (FeNi₄) that are found in asbestos ore in low weight percentages.

Nickel is present in small amounts in some asbestos ores in the form of awaruite, a metallic alloy with iron (FeNi₄). For example, the concentration of nickel in tailings from asbestos ore milling operations may be about 0.2 percent by weight. In general, granular fractions obtained from asbestos-milling operations tend to contain more nickel than fibrous materials and sinter underseizes. It should be noted, however, that the nickel content of asbestos ore found within specific locations within the same mine can vary widely.

Nearly the entire nickel content of chrysotile asbestos ore is in the form of particles of awaruite which are intimately associated with other materials including the fibrous chrysotile asbestos and serpentine rock. Small quantities of magnetite are also usually found in the ore.

The awaruite is magnetic and can, like the magnetite, be magnetically concentrated from the screen undersize material resulting from milling asbestos ore. However, much serpentine rock remains with the magnetically separated material, which precludes successful smelting operations and economical chemical recovery methods.

In the past, efforts were made to develop processes to recover the nickel from asbestos tailings, but the residual asbestos fiber and the large amount of serpentine rock associated with the awaruite in the tailings has prevented the inexpensive concentration of the nickel. No process has previously been developed that has proved commercially feasible.

OBJECTS OF THE INVENTION

A principal object of the present invention is to provide a commercially practicable process for recovering nickel from asbestos ore tailings, that is a process which produces nickel having a value greater than the cost incurred in practicing the process.

It is another object of the invention to provide a process that produces a highly concentrated nickel-containing product that can be readily used in steelmaking processes.

Still another object of the invention is to provide an economical mechanical process for concentrating the awaruite present in asbestos ore.

Additional objects and advantages of the invention will be set forth in part in the description which follows or will be obvious from the description, or may be learned by the practice of the invention.

SUMMARY OF THE INVENTION

The invention provides a process for concentrating the nickel alloy awaruite found in asbestos ore tailings. Asbestos ore tailings, preferably granular mill fractions having a major portion of the asbestos fiber removed, are magnetically separated to obtain a magnetically attracted, nickel-enriched fraction and a waste fraction. The nickel-enriched fraction is mechanically impacted, for example by ball-milling, to take advantage of the discovery that awaruite has a much lower grindability rate than serpentine and magnetite. Such impacting increases maximum dimensions of the awaruite particles because of its malleability and fractures the remaining more easily ground materials into smaller particles. Subsequently, the increased dimension, awaruite particles are separated by size from the smaller particles of unwanted materials to recover an awaruite-rich product.

Preferably, the nickel-enriched fraction is mechanically impacted by ball-milling while dry, and the increased-dimension awaruite is separated from smaller particles of unwanted materials by wet screening.

The process of the invention permits efficient recovery of nickel from asbestos ore tailings. It has been known for years that certain asbestos ore tailings contain nickel but the problems in economically recovering the nickel have previously been thought to be insurmountable. The present invention offers the first economically feasible process for recovering nickel from asbestos ore tailings. While the percentage of nickel present in the asbestos ore tailings is small, the commercial utilization of the process will permit recovery of large amounts of nickel per year, since vast quantities of asbestos ore tailings are readily available every year.

DESCRIPTION OF THE DRAWING

The drawing is a photomicrograph of awaruite particles which have been separated from asbestos ore tailings in accordance with the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

The process of this invention is useful for concentrating particles of awaruite (FeNi₄) found in asbestos ore, and in the tailings resulting from asbestos ore-milling procedures. While the process can be used to concentrate awaruite from extremely low concentrations of awaruite in the starting material, it is desirable to select asbestos ore tailings that possess as high a percentage of nickel as is readily available. Generally, in selecting the desirable asbestos ore tailings for use as starting materials, granular fractions are preferred because they possess somewhat higher nickel contents than fibrous materials and sinter underseizes.

Preferably, the starting materials comprise tailings obtained after asbestos ore has been fiberized and screened. Preferably, only the undersize material from the screening operation is utilized, but sometimes it may be advantageous to further crush and process oversized fractions also.

If the starting material for the process contains a significant amount of asbestos fiber, it is desirable to fiberize this material and remove it before proceeding to the magnetic separation step described below. Magnetic separation is hindered by the presence of fibrous material which tends to bind the awaruite and serpentine particles together, or to trap small magnetic particles. A screening with aspirating step, in some instances combined with air separation, aids in putting the feed in the optimum granular, fiber-free condition. Preferably, the feed particle size is between 10 and 100 mesh prior to the magnetic separation step and the feed contains a minimum of fiber.

In accordance with the invention, the finely divided asbestos tailings are magnetically separated to obtain a magnetically attracted, nickel-enriched fraction. This magnetic separation can be accomplished by commercially available equipment such as described on pages 1091-1093 of Chemical Engineering Handbook, by John H. Perry, third Edition, McGraw-Hill. Typical of such equipment is an enclosed belt-type magnetic separator manufactured by Eriez Manufacturing Co. and a high-intensity induced roll magnetic separator manufactured by Carapco Manufacturing, Inc.

In one test, the awaruite content in the nickel-enriched fraction was found to be highest in +100-mesh particles.

In accordance with the invention, the nickel-enriched fraction is subjected to mechanical impact to increase the maximum dimension of the awaruite particles and to fracture the remaining materials, mainly serpentine rock, into smaller particles. It has been discovered that the awaruite is more malleable than the other major components of the nickel-enriched fraction, serpentine and magnetite, and that the softer awaruite particles do not accumulate an undesirable amount of small-gauge particles during the process. When mechanically impacted, such as during ball-milling, the awaruite flattens and thereby enlarges in two dimensions. At the same time, the magnetite and serpentine tend to shatter into smaller pieces, with the small pieces of magnetite and serpentine tending to form particles that are physically distinct from the awaruite particles.
Typically, a large portion of the awaruite particles is over 325-mesh in size after completion of the mechanical impacting step, while almost all of the physically distinct particles of magnetite and serpentine are smaller than 325-mesh. Preferably, the nickel-enriched fraction is mechanically impacted by ball or pebble-milling. The presence of fiber in the nickel-enriched fraction tends to decrease the efficiency of the milling by becoming more voluminous during processing and thus contributing a cushioning action which dampens the impact of the milling process on the serpentinite or maghemite and is so undesirable that a dry-processing step to remove fiber is advantageous if such an operation was not performed prior to effecting the magnetic separation.

The exact milling procedure to be used for any given nickel-enriched fraction, depends on the particle sizes present in the charge, and the amount of fiber present in the nickel-enriched fraction. While ball or pebble-milling produces presently preferred results, other procedures can be used to mechanically impact the nickel-enriched fraction including hammer milling and centrifugal impact milling.

In accordance with the invention, the increased dimension awaruite particles are separated from the smaller particles of magnetite and serpentine by a size separation procedure, such as screening, or air-separation, or a combination of air-separation and screening. Preferably, because of the large quantities of material which usually must be size-separated, it is desirable to perform an air separation step to reduce the quantity of material to be subjected to the final size-separation operation. The air-separation can be carried out on a large scale at high-feed rates.

It has been found that air separators which rely on cyclones to make the cut are successful. For example, in one test procedure a heavy fraction was recovered which contained 60 percent by weight of the material charged to the air separator and 90 percent by weight of the nickel. The light or dust fraction was found to contain almost no recoverable nickel, that is nickel that would be recovered in an efficient final wet-screening step.

The preferred final size separation step comprises wet screening on a very fine mesh screen, for example, a 65 to 400 mesh screen, with a 325-mesh screen presently considered optimum. This wet-screening step removes most of the serpentinite and magnetite and leaves the awaruite particles as the oversize fraction. Dry-screening and air-screening procedures can be utilized in the final separation step, but possess problems because the material tends to agglomerate.

For a clearer understanding of the invention, specific examples of it are set forth below. These examples are illustrative and are not to be understood as limiting the scope and underlying principles of the invention in any way.

All percentages listed in the specification and claims are weight percentages unless otherwise noted. All screen sizes are U.S. Standard unless otherwise noted.

**EXAMPLE I**

The undersized material (0.23% Ni) from an ore screening operation using a screen of 26 mesh in a Quebec Chrysotile asbestos mill is passed through a magnetic separator. A magnetic concentrate containing 0.42 percent by weight of nickel is recovered. Analysis of the materials resulting from the magnetic separation operation is shown below in Table I:

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Recovery (percent)</th>
<th>Ni (percent)</th>
<th>Percent of total Ni in fraction</th>
<th>Total pounds Ni per ton of feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>100</td>
<td>0.23</td>
<td>100</td>
<td>4.6</td>
</tr>
<tr>
<td>Magnetic</td>
<td>17</td>
<td>0.42</td>
<td>30</td>
<td>1.4</td>
</tr>
<tr>
<td>Non-magnetic</td>
<td>83</td>
<td>0.19</td>
<td>70</td>
<td>3.2</td>
</tr>
</tbody>
</table>

The magnetic separation concentrated 30 percent of the nickel originally present into a nickel-enriched fraction comprising 17 percent by weight of the original sample. The nickel-enriched fraction is then passed through a centrifugal impact mill manufactured by Entoleter, Inc. to subdivide or open the residual fiber bundles, making them more bulky and easier to subsequently separate and remove.

After this operation the nickel-enriched portion is subjected to a screening and air-separating operation to simulate standard asbestos recovery techniques in which the bulky fiber tends to stratify above the granular material on a shaking screen where it can be removed by suction.

The screening and air-separating procedure produces a more concentrated fraction containing 0.70 percent by weight nickel. This 0.70 percent nickel fraction is ball milled in a small mill for 16 hours to produce flat, platelike particles of awaruite and to fracture the magnetite and serpentine rock remaining in the processed material. The ball-milling operation is carried out dry.

After the ball-milling operation, the milled material is sent to a mechanical air separator which separates the material into a heavy fraction that amounts to 15 percent by weight of the material charged to the separator and contains 95 percent of the recoverable nickel. Subsequently, the air-separated material is subjected to a wet-screening operation using a 325-mesh screen. About 1 pound of material per ton of charged feed is recovered and this material contains about 50 percent nickel. The awaruite particles present in the product of this example are in the form of substantially flat shiny platelets, and have the general shape illustrated in FIG. 1 of the drawings.

**EXAMPLE II**

Asbestos ore tailings comprising ~28-mesh screen undersized materials are magnetically concentrated to contain about 0.35% Ni and 50 percent serpentinite rock. Further concentration of the nickel is accomplished by micropulverizing the material to liberate more awaruite particles and then screening the material on a nest of increasing mesh screens. The magnetite and awaruite seem to concentrate in the finer fractions produced by micropulverizing. A nickel-enriched portion of ~200-mesh concentrate is obtained by magnetically separating the pan fraction from the screening operation.

The serpentinite content of the magnetically attracted fraction is reduced to about 30 percent by the magnetic separation and the nickel percentage is raised to about 3.5 percent.

This material containing 3.5 percent by weight of nickel is ball-milled while dry for about 72 hours and subsequently wet-screened through a 325-mesh screen. Microscopic examination of the plus fraction showed that the particles are platelike and silver-colored, and have the general shape shown in FIG. 1. Spectrographic analysis confirms that the particles are almost completely awaruite. The actual nickel content of this plus fraction is 60 percent, and the calculated composition is 79 percent awaruite, 8 percent magnetite, and 8 percent serpentinite. This procedure produced a recovery of 0.4 percent of the original ~28-mesh tailings.

It is believed that the particles present in the plus fraction are all basically awaruite particles. A small amount of fine gangue is apparently driven into the soft awaruite particles, however, to give a slightly impure product.

**EXAMPLE III**

In this example, ~66-mesh undersize asbestos ore tailings which would have had any large, heavy, awaruite particles already screened out, is used at the feed material. It is more fibrous and has a lower magnetic content that the feed material of Examples I and II. This material is processed in accordance with the procedure of Example I except that no air separation step is utilized between the ball-milling and the wet-screening. The ground concentrate is directly wet-screened to give an awaruite recovery amounting to 0.07 lbs per ton of charged feed (about 0.04 lbs. nickel per ton of charged feed).

**EXAMPLE IV**

Granular screen undersize feed as used in Example I is
fiberized in a hammer mill and then passed through a mechanical air separator to remove fiber and fines. The coarse fraction from the separator is then magnetically separated to produce an enriched nickel and magnetite concentrate.

This concentrate is ball-milled dry in 100 pound quantities in a 2½ foot diameter mill containing 1 inch and one-half inch balls for three hours. The ground material is wet-screened to produce a 325-mesh oversize fraction that contains 20 percent awaruite, 62% Fe₂O₃, and 18 percent remainder, the major constituent of which remainder is serpentine. The nickel produced is in the order of 15 percent of the fraction, or in other words, 75 percent of the awaruite.

**EXAMPLE V**

The procedure of Example IV including the original screening, fiberization, air-separation, and magnetic separation is used to prepare a feed material for the mechanical impact procedure.

In this example, the magnetic concentrate is wet-processed in 100-pound quantities in the ball-mill described in Example IV for 1½ hours, and then wet-screened to obtain 325-mesh oversize fraction that contains an estimated 30 percent Ni.

1. A process for concentrating the nickel alloy awaruite found in asbestos ore tailings comprising:
   a. magnetically separating the asbestos ore tailings to obtain a magnetically attracted, nickel-enriched fraction, and a waste fraction;
   b. mechanically impacting the nickel-enriched fraction to increase the maximum dimension of the awaruite particles and to fracture the remaining materials into smaller particles; and
   c. separating the increased-dimension awaruite particles from the smaller particles of unwanted materials to recover an awaruite-rich product.

2. The process of claim 1 in which the asbestos ore tailings consist of particles that pass a 10-mesh screen.

3. The process of claim 1 in which the nickel-enriched fraction is mechanically impacted by ball-milling to produce substantially flat, platelike particles of awaruite.

4. The process of claim 2 in which the nickel-enriched fraction is mechanically impacted by ball-milling to produce flat, platelike particles of awaruite.

5. The process of claim 3 in which the increased dimension awaruite particles are separated from unwanted materials by a procedure which includes wet screening.

6. A process for concentrating the nickel alloy awaruite found along with asbestos fiber, serpentine rock and magnetite in asbestos ore tailings comprising:
   a. magnetically separating the asbestos ore tailings to obtain a magnetically attracted nickel-enriched fraction, and a waste fraction;
   b. fiberizing asbestos remaining in the nickel-enriched fraction;
   c. removing asbestos fiber from the nickel-enriched fraction;
   d. mechanically impacting the nickel-enriched fraction to increase the maximum dimension of the awaruite particles and to fracture the remaining materials into smaller particles; and
   e. size separating the increased dimension awaruite particles from the small particles of unwanted materials to recover an awaruite-rich product.

7. The process of claim 6 including a step in which asbestos in the asbestos ore tailings is fiberized and separated from the tailings prior to the tailings being magnetically separated to increase the efficiency of the magnetic separation step.

8. The process of claim 6 in which the nickel-enriched fraction is mechanically impacted to produce substantially flat, platelike particles of awaruite.

9. The process of claim 6 in which the size-separating step includes wet-screening the increased dimension awaruite particles from unwanted materials.

10. The process of claim 6 in which a dry nickel-enriched fraction is mechanically impacted by ball-milling.

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