

Oct. 10, 1939.

C. P. REES ET AL

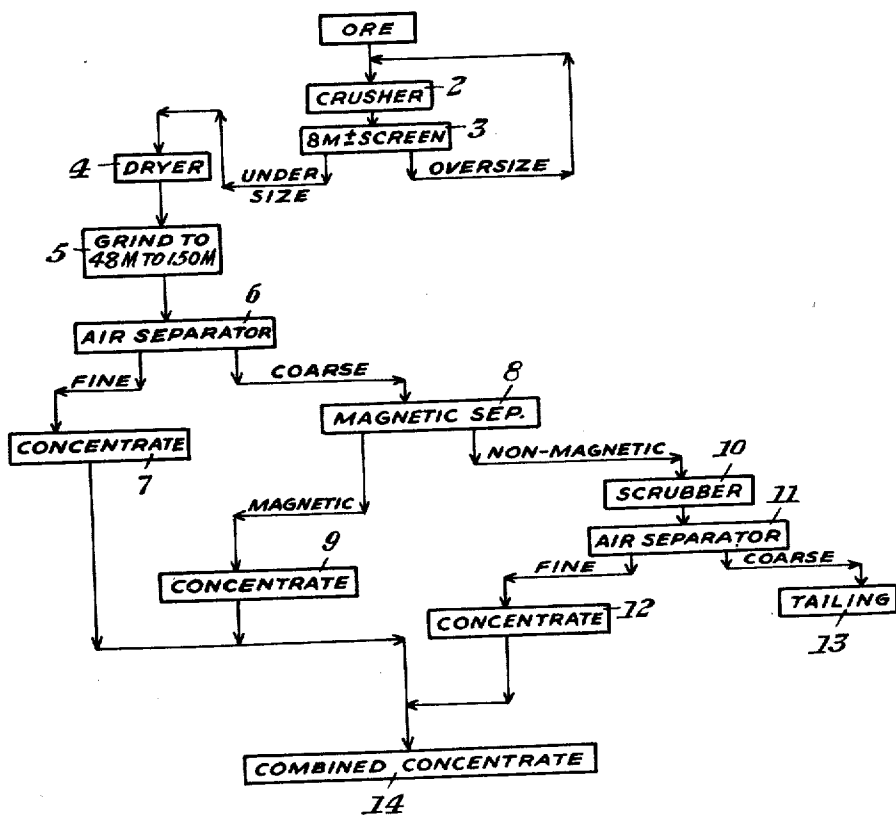
2,175,484

DRY CONCENTRATION OF CARNOTITE ORES

Filed Nov. 19, 1936

4 Sheets-Sheet 1

Fig.1.



INVENTOR

*Charles P. Rees
Holbert E. Dunn and
Archibald A. Sproul*

by
Stebbins, Blake & Parmelee
Their Atty.

Oct. 10, 1939.

C. P REES ET AL

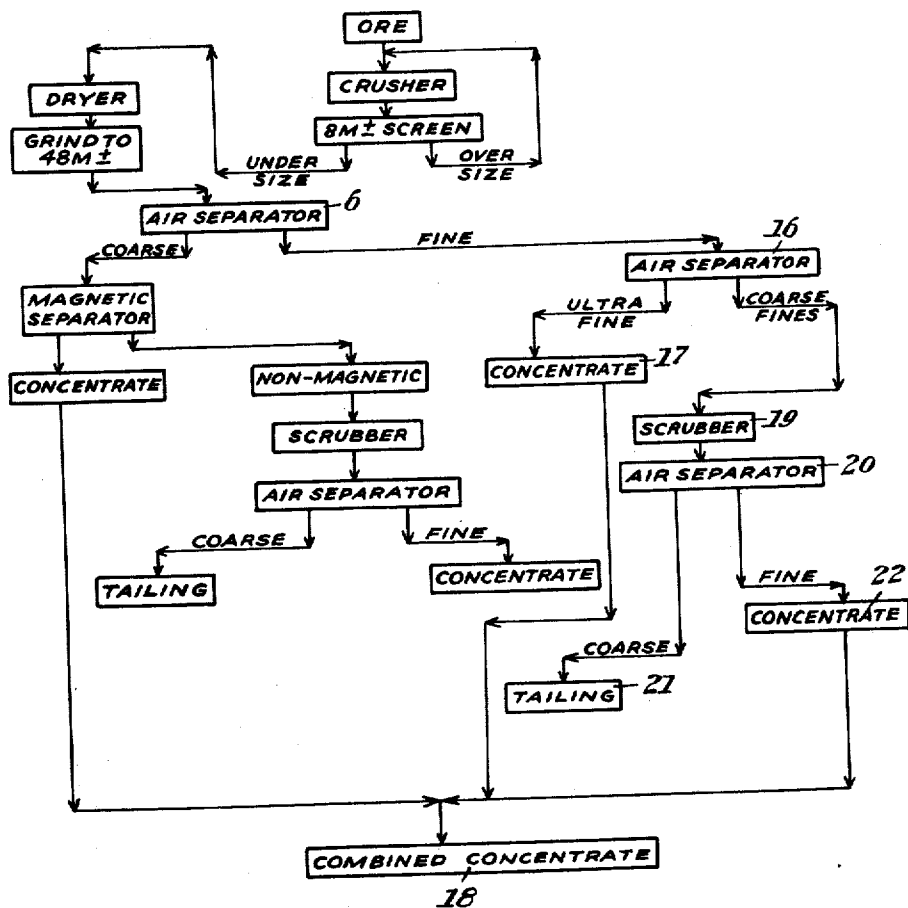
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4 Sheets-Sheet 2

Fig. 2.



INVENTOR
Charles P. Rees
Holbert E. Dunn and
Archibald A. Sproul

By *S. Levens, Blunk & Parnell*
Attorneys

Oct. 10, 1939.

C. P. REES ET AL

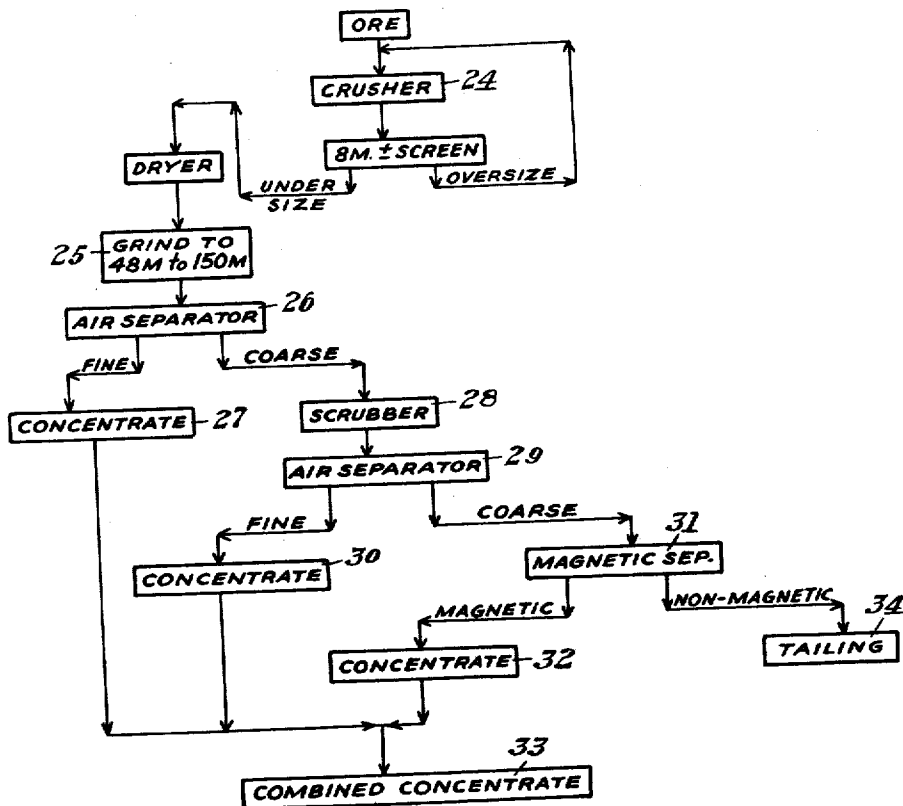
2,175,484

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Filed Nov. 19, 1936

4 Sheets-Sheet 3

Fig. 3.



INVENTOR

Charles P. Rees
Holbert E. Dunn and
Archibald A. Sproul

S. Robbins, Blue & Penman, Inc.
New York

Oct. 10, 1939.

C. P. REES ET AL

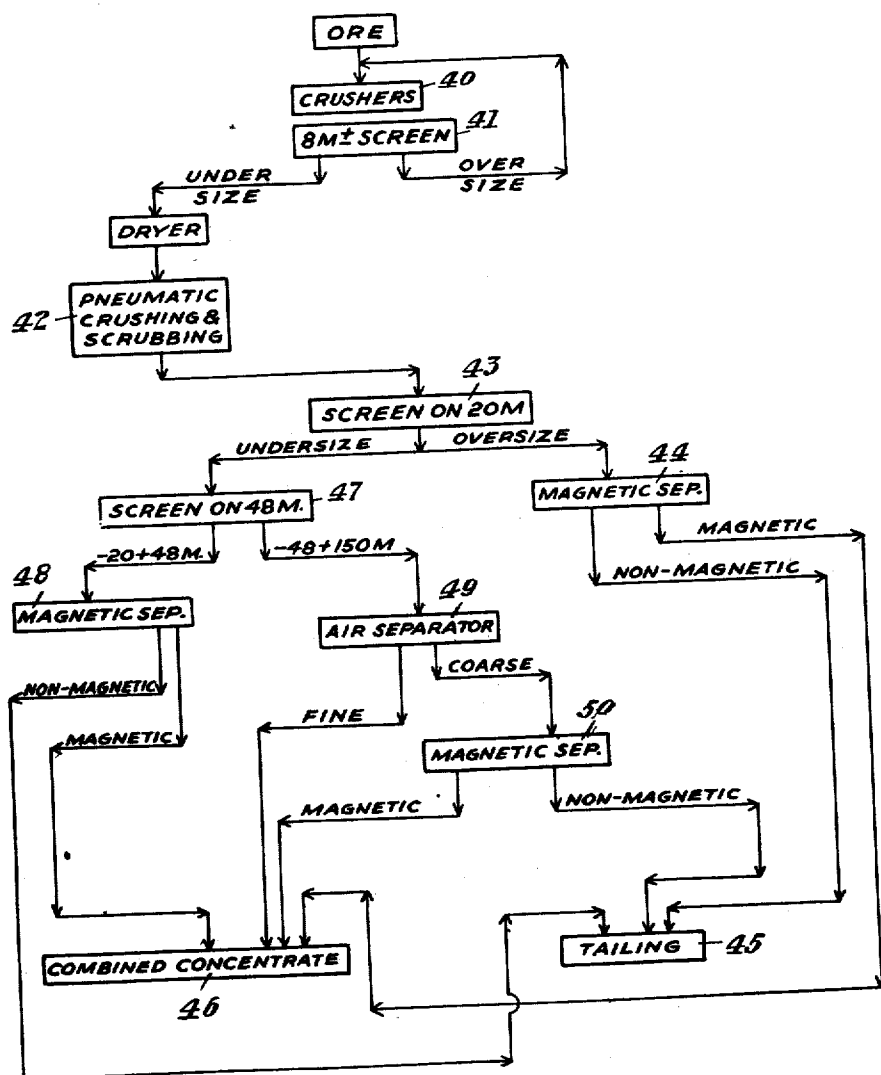
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DRY CONCENTRATION OF CARNOTITE ORES

Filed Nov. 19, 1936

4 Sheets-Sheet 4

Fig. 4.



INVENTOR
Charles P. Rees
Holbert E. Dunn and
Archibald A. Sprout

by
S. Levine, O. Levine & Parnell
T. A. 1939.

UNITED STATES PATENT OFFICE

2,175,484

DRY CONCENTRATION OF CARNOTITE ORES

Charles P. Rees, Yonkers, N. Y., and Holbert E. Dunn, Crafton, and Archibald A. Sproul, Bridgeville, Pa., assignors to Vanadium Corporation of America, Bridgeville, Pa., a corporation of Delaware

Application November 19, 1936, Serial No. 111,626

6 Claims. (Cl. 209-2)

The present invention relates to the treatment of carnotite ores for the recovery of vanadium and uranium, and more particularly to the recovery of vanadium concentrates therefrom.

5 The mineral carnotite, a potassium uranium vanadate, corresponding more or less to the formula $2\text{UO}_3 \cdot \text{V}_2\text{O}_5 \cdot \text{K}_2\text{O} \cdot \text{XH}_2\text{O}$, occurs most frequently in sand stone as a yellow earthy or finely crystalline encrustation on the individual grains of sand and in the joints and fractures between the grains, often adhering tenaciously to them. The size of the sand grains varies greatly, but is usually from 0.1 to 0.2 mm. in diameter, or from 150 to 65 mesh.

15 Carnotite ores occur extensively in Colorado and Utah in numerous deposits scattered over an extensive area. Most of the deposits are located considerable distances from rail transportation so that hauls are long and expensive. Concentration is, therefore, of vital importance, and, furthermore, as little or no water is available in most localities, dry concentration methods employed at the source are particularly desirable.

25 The accompanying drawings are flow sheets which diagrammatically illustrate various ways in which our process may be carried out, it being understood that these flow sheets are given by way of example only and that the processes may be modified in accordance with the particular type of carnotite ore which is being treated.

30 It has been customary in treating carnotite ores either by the dry or wet process to prepare the ore for concentration by breaking it to from 40 to 80 mesh in crushers and rolls in order to free the sand grains. Further attrition is then applied to the 40 to 80 mesh grains to rub or abrade the adhering carnotite which often sticks fast to even the smooth surface of a grain.

40 In the dry process, the scrubbing is accomplished by means of various mechanical devices, such as impact pulverizers, hammer mills, beater mills, or even wire brushes acting between a pair of revolving steel plates. The fine powdered carnotite so freed is separated from the coarse, barren sand by means of cyclone air separators.

45 In the wet process, the scrubbing is accomplished by washing the 80 to 100 mesh sands in a revolving tank or trommel provided with a mechanical rubbing device. The fine, free particles of carnotite in suspension are decanted after the silica has settled in the tank. This elutriation is repeated as often as economical.

50 We have found that such attrition methods are quite efficacious for the recovery of vanadium and uranium when present in the ore predom-

inantly as carnotite conforming approximately to the above formula and as indicated by a ratio of uranium to vanadium of the order of 4.7 to 1 established for the mineral, but when used in concentrating low grade ores in which the values exist in ratios differing appreciably from this, as for example of the order of .5 part uranium to 1 part vanadium as is the case in many of the ores classed as carnotite type ores, the recoveries drop to about 50% for both the values, and the grade of concentrate is so low as to become unmarketable.

For example, when a 48 mesh carnotite ore, analyzing 0.34% uranium and 1.36% vanadium or a ratio of 0.256 to 1, is scrubbed in a cylindrical mill with rubber balls to aid in gentle attrition, a concentrate analyzing 3.55% vanadium is produced at a recovery of 51.5% of the vanadium content. Substituting other gentle grinding media such as $\frac{3}{8}$ inch porcelain balls, $\frac{1}{2}$ inch flint pebbles, lowers the grade of the concentrate to 2.2 to 2.6% vanadium with recoveries of 86 to 74%, respectively. Micro-examination of the air-separated or wet-screened concentrate shows the drop in grade to be caused by increased percentage of gangue fines, even with such a gentle gradation in grinding.

Further, when an ore analyzing 0.32% uranium and 1.00% vanadium, or a ratio of 0.32 to 1, is scrubbed in a rubber-lined beater mill of a type in common usage in the art, we obtain a concentrate analyzing 1.5% vanadium and 0.59% uranium with recoveries of 67.5% of the vanadium and 8.9% of the uranium and with a ratio of concentration of 2.26 to 1, or 2.26 tons of ore required to make one ton of concentrate. Increased recoveries are obtained at the expense of the grade of concentrate, which grade is so low as to be not economically workable.

40 It becomes apparent from the above that some other method of freeing the values is imperative if low-grade ores, that is, run of mine ores are to be utilized, and the economic losses ensuing from the present practice of "high-grading" the rich ore pockets prevalent in these ore bodies are to be avoided.

50 We have found that when carnotite ores are broken down to approximately single grain size, an appreciable portion of the values are present as free grains of the same size order as the gangue grains of sand, and further, that these grains constituting the values of the ore possess a hardness at least approaching that of the silica grains themselves. For this reason, they are not pulverized and recovered as slimes or

finest in the usual wet or dry processes of concentration, but escape with the coarse sand as tailings.

In our process, we prefer to remove these hard vanadium and uranium minerals as early in the size reduction or grinding process as they become free grains, not only to avoid the disadvantages of overgrinding them, but to facilitate their magnetic removal.

In the usual methods of concentrating carnotite ores, they are reduced to 8 mesh or finer by crushers and rolls and the crushed ore is treated in various scrubbing devices, as previously referred to. In our invention, instead of treating the crushed carnotite ore in ball mills, pebble mills or beater mills, we prefer to employ the pneumatic grinding and scrubbing procedure described in the copending application of Holbert E. Dunn, Serial 111,627, filed November 19, 1936. In the Dunn application there is described a method of grinding or scrubbing ores in which the ore particles to be treated are introduced into a compressed air stream and the stream of particles is projected into an impact chamber of wear-resisting material maintained substantially under atmospheric pressure which causes superficial pulverization of the grains, thereby scrubbing the encrusted particles and rounding the sand grains. In this way, the amount of silica fines removed from the sand grains with the puerulent encrusting vanadian and uranium minerals and which ordinarily dilute the grade of the usual air-separated concentrate or the wet elutriation concentrate, as the case may be, is reduced to a minimum.

Referring now to the accompanying drawings, and for the present to Figure 1, this flow sheet represents the simplest application involving the principle of recovering values as coarse as possible and as soon as they become free. The ore as mined is broken in a crusher 2 to a size of 1/2 inch to 1/4 inch lumps. An 8 mesh screen 3 is in closed circuit with the crushers so as to return the oversize particles to it. The undersize particles are dried, if necessary, in a drier 4 and further reduced in size to 48 to 150 mesh in rolls 5 or other standard coarse grinding equipment. It is then treated in an air separator 6 of any of the commercial types, such as the simple cyclone air-gallery, or a mechanically operated dry centrifugal separator, to remove sufficient ultra-fines usually amounting to a 200 to 400 mesh separation as determined necessary in practice in order to render the coarse fraction sufficiently free-running to permit its treatment in magnetic or electrostatic separators. The air-separated ultra-fines, if sufficiently high in grade, are delivered directly to a concentrate storage 7, otherwise they must be treated by a more complex method, as is described hereinafter in connection with Figure 2.

The coarse, free-flowing fraction from the air separator 6 is then magnetically or electrostatically separated in a magnetic or electrostatic separator 8. In order to avoid repetition, we will refer to either magnetic or electrostatic separation as "electromagnetic" separation and this term is used in the claims to be inclusive of either magnetic or electrostatic separation. The magnetic concentrate from the electromagnetic separator 8 is delivered to a concentrate storage 9 and combined with the concentrate from storage 1. The non-responsive product from the electromagnetic separator 8 is treated in a pneumatic scrubber 10, preferably of the type de-

scribed in the above referred to Dunn application. The scrubbed product is then fractionated in an air separator 11 into a fine concentrate 12 and coarse, barren sand tailings 13, the fine concentrate being combined with the previous air-separation and electromagnetic concentrates to form the finished final concentrate 14.

If the air-separated ultra-fines delivered to concentrate storage 7 in Figure 1 are not sufficiently high in grade, they are re-treated by a more complex process, as illustrated in Figure 2. Referring to Figure 2, the ore is crushed, screened, dried, ground and air-separated as described in connection with Figure 1. The fines from the air separator 6 are again air-separated in a separator 16 into ultra-fines and coarse fines. The ultra-fines are sent to concentrate storage 17 and ultimately combined with the other concentrates to form the combined concentrate 18. The coarse fines from air separator 16 are pneumatically scrubbed in a pneumatic scrubber 19, preferably of the type referred to in the Dunn application, and treated in an air separator 20. The coarse tailings 21 from the air separator 20 are discarded and the fine concentrate 22 is combined with the other concentrates.

The coarse particles from the air separator 6 are treated in the same manner as described in connection with Figure 1.

In the processes shown in Figures 1 and 2, 30 the coarse ore particles from the air separator 6 are first treated electromagnetically to remove the responsive particles and the non-magnetic or non-responsive particles are then pneumatically scrubbed to scrub off the encrusting mineral values of vanadium and uranium remaining on the particles. The coarse particles from the air separator may, however, be first scrubbed pneumatically to scrub off the encrusting mineral values, then air-separated, and the coarse particles from the air-separation electromagnetically treated to remove further quantities of the values. This latter method is illustrated in Figure 3.

When a carnotite ore carrying, say, 1.16% vanadium is treated in accordance with the method shown in Figure 3, we obtain, after crushing to 8 mesh in rolls 24 and grinding to 48 mesh in a pebble mill 25 in closed circuit with a 48 mesh screen, and air-separating the ground particles in an air separator 26, an air-separation concentrate of fines 27 analyzing 3.30% vanadium, amounting to 10.45% by weight of the ore and containing 29.74% of the total vanadium. The balance or coarse fraction analyzing 0.91% vanadium is given ten passes through a pneumatic scrubber 28 at 100 pounds per square inch air pressure and then air-separated in an air separator 29 into a fine fraction 30 analyzing 3.46% vanadium, amounting to 6.53% by weight of the ore and carrying 20.07% of the total vanadium, which is thereafter combined with the concentrate 27. The coarse fraction from the air separator 29 analyzing 0.68% vanadium and carrying 50.19% of the total vanadium is passed through a Stearns high intensity magnetic separator 31 and a magnetic concentrate 32 analyzing 5.24% vanadium, amounting to 4.03% by weight of the ore and carrying 19.84% of the total vanadium, is obtained and then combined with the two previous air-separation concentrates 27 and 30 to give a combined concentrate 33 analyzing 3.72% vanadium, amounting to 21.01% by weight with a recovery of 69.65% of the vanadium and a ratio of concentration of 4.76 tons of ore to make one ton of concentrate. The non-magnetic prod-

uct from the electromagnetic separator 31 constitutes the tailings 34 and analyzes 0.41% vanadium, which amounts to 78.99% by weight of the ore and contains 30.35% of the total vanadium.

Figure 4 illustrates a process in which a pneumatic crusher and scrubber of the type disclosed in the above referred to Dunn application is employed in place of the ball mill 5 of Figure 1 for further grinding the crushed ore and in which the processes previously described are otherwise modified. In the process illustrated in Figure 4, the ore is crushed in crushers 40 and rolls 41 to produce an 8 mesh roll product. The product is then dried, if necessary, and then treated in a pneumatic crusher and scrubber 42, preferably of the type disclosed in the above referred to Dunn application, and is then screened on a 20 mesh screen 43. The oversize particles are subjected to electromagnetic separation in a separator 44, the non-magnetic portion being passed to tailings 45 and the magnetic portion being passed to a concentrate storage 46.

The undersize particles from screen 43 are screened on a 48 mesh screen 47. The particles retained on the screen and which are between 20 and 48 mesh are subjected to electromagnetic separation in a separator 48, the non-magnetic portion being passed to tailings 45 and the magnetic portion being passed to the concentrate storage 46.

The portion passing through the screen 47 and being of a particle size between 48 and 150 mesh is subjected to air classification in an air classifier 49. The fine particles from the air classifier are passed to the concentrate storage 46 and the coarse particles are subjected to electromagnetic separation in a separator 50. The magnetic portion is passed to the concentrate storage 46 and the non-magnetic portion to the tailings 45.

If, in carrying out the process illustrated in Figure 4, the 8 mesh roll product is subjected to pneumatic crushing and scrubbing in the crusher and scrubber 42 by employing an air pressure of 140 pounds per square inch and passing the product through the scrubber four times, we obtain a combined concentrate 46 analyzing 4.07% vanadium, amounting to 14.10% by weight of the ore at 55.71% recovery of the vanadium and requiring 7.09 tons of ore to make one ton of concentrate. The discard tailings 45 analyze 0.52% vanadium, amounting to 85.90% by weight of the ore.

When the results of the above treatment are compared to the results obtained in the commonly used beater mill previously referred to, wherein a concentrate containing only 1.5% vanadium was obtained at 67.5% recovery of vanadium with a ratio of concentration of only 2.26 to 1, it is to be seen that the grade of the concentrate has been almost trebled, thus involving the transportation and treatment of only one-third of the quantity of material formerly furnished the smelter or chemical refining operations, and only one-seventh the quantity of material in case the ore itself is transported directly to the smelter or refinery.

The two examples given, which show the results which may be obtained by carrying out our process, indicate the range of possibilities in grade and recovery of concentrate to be obtained by applying our preferred procedures of pneumatic scrubbing, pneumatic separation, and electromagnetic separation. While we have specifically described four preferred variations in the order of applying the various steps in our preferred pro-

cedures, it is to be understood that the invention is not limited to the specific order of steps employed, but that the enumerated steps may be applied in any order best suited to the particular ore under treatment. For example, the air-separated particles may be first electromagnetically treated and the product thereafter subjected to pneumatic scrubbing, as illustrated in Figure 1, or the air-separated product may be first subjected to pneumatic scrubbing and thereafter to electromagnetic separation, as in Figure 3. In any of the processes, the step of drying the crushed ore may be omitted wherever the amount of moisture is insufficient to prevent carrying out the subsequent steps of the process. Furthermore, pneumatic crushing and scrubbing may be employed, as illustrated in Figure 4, for treating the ore at a size coarser than the maximum single grain size in order to break down the ore into approximately single grains. The invention is not limited to the processes specifically described, but may be otherwise embodied or practiced within the scope of the following claims.

We claim:

1. A process of concentrating the vanadium and uranium content of carnotite ores, which comprises crushing the ore to a size only slightly coarser than its single grain size, subjecting the crushed ore to air classification to an extent sufficient to provide a free-flowing feed adapted to electromagnetic separation, subjecting the ore to electromagnetic separation, subjecting the non-responsive discard from the electromagnetic separation to pneumatic scrubbing to remove encrusting vanadium and uranium minerals, and separating the valuable fines from the coarse tailings by air classification.

2. A process of concentrating the vanadium and uranium content of carnotite ores, which comprises crushing the ore to a size only slightly coarser than its single grain size, subjecting the crushed ore to air classification to an extent sufficient to provide a free-flowing feed adapted to electromagnetic separation, subjecting the ore to electromagnetic separation, subjecting the non-responsive discard from the electromagnetic separation to pneumatic scrubbing to remove encrusting vanadium and uranium minerals, separating the valuable fines from the coarse tailings by air classification, and combining the several air-classified concentrates with the magnetic concentrates.

3. A process of concentrating the vanadium and uranium content of carnotite ores, which comprises crushing the ore to a size only slightly coarser than its single grain size and between 48 and 150 mesh, subjecting the crushed ore to air classification to an extent sufficient to provide a free-flowing feed adapted to electromagnetic separation, subjecting the ore to electromagnetic separation, subjecting the non-responsive discard from the electromagnetic separation to pneumatic scrubbing to remove encrusting vanadium and uranium minerals, and separating the valuable fines from the coarse tailings by air classification.

4. A process according to claim 1, in which the fines resulting from the first mentioned air classification are subjected to further air classification and the coarse-fines resulting from said further air classification are subjected to pneumatic scrubbing.

5. In a process of concentrating the vanadium and uranium content of carnotite ores, the steps comprising subjecting the previously crushed ore

at a size coarser than the maximum single grain size to pneumatic crushing and scrubbing at a pressure sufficient to break down the ore particles to approximately single grains while so regulating the pneumatic crushing and scrubbing as to produce the minimum of fines, separating the product resulting from pneumatic crushing and scrubbing into coarse and fine particles, separating the coarse, responsive valuable minerals electromagnetically from the coarse, non-responsive grains, and air-classifying the fine particles to recover the values pneumatically scrubbed from the ore particles.

6. In a process of concentrating the vanadium and uranium content of carnotite ores, the steps comprising subjecting the previously crushed ore at a size coarser than the maximum single grain

size and between 4 and 48 mesh to pneumatic crushing and scrubbing at a pressure sufficient to break down the ore particles to approximately single grains between 48 and 150 mesh while so regulating the pneumatic crushing and scrubbing as to produce the minimum of fines below 200 mesh, separating the product resulting from pneumatic crushing and scrubbing into coarse and fine particles, separating the coarse, responsive, valuable minerals electromagnetically from the coarse, non-responsive grains, and air-classifying the fine particles to recover the values pneumatically scrubbed from the ore particles.

CHARLES P. REES.
HOLBERT E. DUNN.
ARCHIBALD A. SPROUL.

15

CERTIFICATE OF CORRECTION.

Patent No. 2,175,484.

October 10, 1939.

CHARLES P. REES, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 34, for "8.9%" read 80.9%; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of November, A. D. 1939.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

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