A continuous, laboratory-size density separator for granular materials

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Summary. Details are given for the construction of a continuous, density separator from standard laboratory glassware and equipment. The separator can treat up to 5 g/min of granular material from 150 to 2000 μ in grain size, and the liquid used is continually recirculated by a simple airlift.

DURING an investigation of the mineralogical composition of alluvial tin ores it became necessary to carry out quantitative density separations of small proportions of heavy minerals from large quantities of low density siliceous grains. The usual methods of heavy-liquid separation would have entailed the repeated treatment of small batches of material but the simple separator described below enabled the separation to be carried out continuously and without supervision.

The *apparatus* is shown in figs. 1, 2, and 3. It is constructed from standard laboratory equipment except for the separating vessel, which can be made very easily from pieces of glass tubing.

The feed hopper is a standard glass funnel of 3 in. diameter with the bottom of the stem cut at right angles to its main axis. The feeder is a vibratory spatula that can be supplied by most laboratory supply houses. The mixing funnel is a 2 in. glass funnel, which should have a stem at least 2 in. long. The separating vessel is made from a 4 in. length of 1·5 in. diameter glass tubing, which is drawn to approximately 0·25 in. diameter at the lower end. An overflow arm consisting of 0·2 in. glass tubing is attached near the upper end of this vessel, the lower end of which is closed with polyvinylchloride tubing fitted with a pinchcock (c, 7 in fig. 1).

Collecting funnels A and B are standard laboratory funnels. Ordinarily, funnel A should be slightly larger than the feed hopper funnel. Conical baskets made from wire- or nylon-mesh are placed in the collecting funnels to collect the granular material and to allow the liquid to drain off.

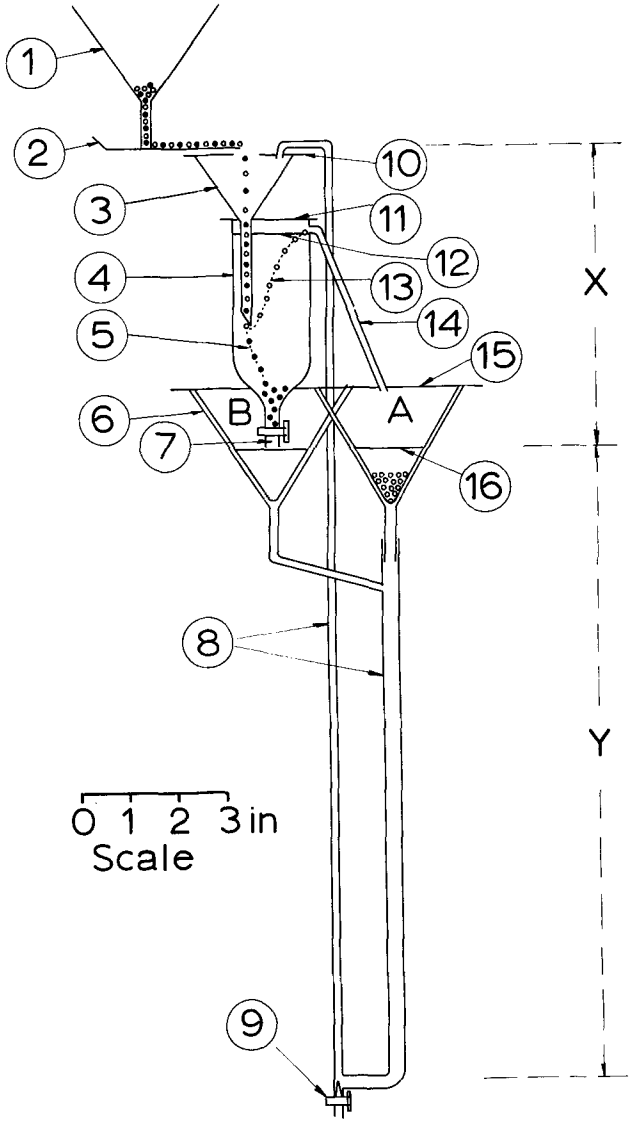
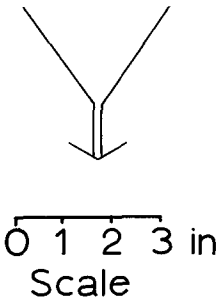
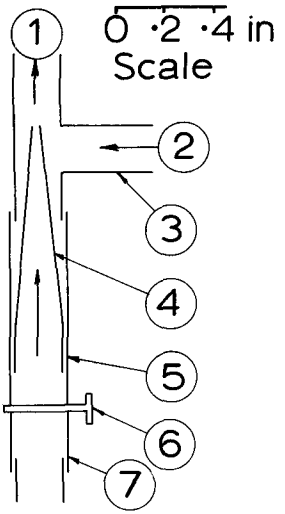


FIG. 1. Details of the construction of the main apparatus. 1, feed container; 2, feeder; 3, mixing funnel; 4, separating funnel; 5, heavy grains; 6, collecting funnels A and B; 7, pinchcock C; 8, air-lift tubes; 9, pinchcock D; 10, loose-fitting cover; 11, close-fitting cover; 12, liquid level in separating vessel; 13, light grains; 14, overflow carrying light grains; 15, loose-fitting cover on collecting funnels; 16, liquid level in collecting funnels.

The liquid drains into a vertical, glass or polyvinylchloride tube about 12 in. long and 0·2 in. in diameter that forms one arm of an air-lift by which the liquid is returned to the mixing funnel for re-use. Fig. 3 shows details of the construction of the air inlet at the base of the air-lift tubes. This is made from a glass T-joint into one arm of which a small





FIGS. 2 and 3. FIG. 2 (left): Cross-section showing how the feed container rests on the vibratory feeder. FIG. 3 (right): Details of the air inlet on the air-lift. 1, air plus heavy liquid; 2, heavy liquid; 3, glass T-joint; 4, tapered glass tube; 5, flexible tube; 6, pinchcock D; 7, main tube to air supply.

glass jet has been fitted. The vertical distance between the free surface of the liquid in the collecting funnels and the base of the air-lift tubes (Y, fig. 1) must be at least twice as great as the distance from the collecting funnels to the extreme top of the air-lift tubes (X, fig. 1). This will ensure a steady, uniform return flow of the liquid.

The complete apparatus is clamped together using standard laboratory clamps. Rubber is attacked by most of the commonly used heavy liquids and it is desirable to use glass or p.v.c. tubes throughout the apparatus. The air-lift can be connected to a bench supply of compressed air or to a gas cylinder. Many bench supplies tend to fluctuate and it has been found that cylinders give a steadier, more reliable gas flow. Some liquids may oxidize if air is continually blown through

them and it may be necessary to use compressed nitrogen as the 'air'-lift supply. Pinchcock D (9 in. fig. 1), on the air supply, has been found to be useful as it allows a more delicate control of the air flow than the valves that are usually fitted to compressed air supplies. The pinchcock should be closed whenever the apparatus is not in use to prevent heavy liquid draining into the lower parts of the air-lift tubing and possibly into the laboratory air supply.

Operating procedure. The dried sample is placed in the feed hopper, which is clamped so that it rests gently on the vibratory feeder (see fig. 2). Sufficient heavy liquid, of a density intermediate between the densities of the materials to be separated, is used to fill the separating vessel and to half-fill the collecting funnels A and B. The air-lift is then carefully adjusted to give a return flow to the mixing funnel in the form of a slow stream of small bubbles. When the air-lift is correctly set the vibratory feeder is switched on to give a feed rate of up to 5 g/min. The separation will then proceed without further attention until the feed hopper is emptied.

The heavy liquid and the feed are thoroughly mixed in the mixing funnel and then pass into the separating vessel. It is important that the resulting pulp is introduced into the separating vessel below the surface of the liquid in that vessel. This helps to ensure that the grains are properly wetted and that no heavy particles are carried away on rafts of the light, floating fraction. Care should also be taken to ensure that the feed is introduced into the separating vessel as far from the overflow arm as practicable. This allows as long a period as possible for the particles to attain their correct position in the liquid. Furthermore, the velocity of the liquid between the point of entry and the overflow must be kept as low as possible by minimizing the amount of liquid being recirculated. Under these circumstances there will be little opportunity for heavy particles to be carried over with the light fraction and a high quality separation will be obtained.

The lower density particles float to the surface of the liquid and are carried with the overflowing liquid into the mesh basket in funnel A. If the light grains form the bulk of the sample the capacity of the feed hopper should always be slightly smaller than that of the collecting funnel. In this way there will be no danger of the grains overfilling funnel A during an unattended operation. The liquid drains off the particles and is returned by the air-lift to the mixing funnel.

The particles of higher density sink to the bottom of the separating vessel where they are usually allowed to remain until the end of the

separating period and are drained into funnel B. If, however, the heavy particles form an appreciable proportion of the sample, then provision can be made for pinchcock C to be opened to allow a slow discharge of heavy particles into collecting funnel B during the separation. Regular attention will be necessary to prevent this outlet from choking. Alternatively, the body of the separating vessel may be made sufficiently large to accommodate all the heavy grains from an individual separation.

When a draining tray is fully loaded it is lifted out of the collecting funnel and can be replaced, if necessary, with a fresh tray. The particles can be removed from the loaded tray by inverting it in a beaker containing a solvent appropriate to the heavy liquid being used. The grains that are deposited in the beaker are washed by stirring with a glass rod and the solvent is then decanted away. This washing procedure is repeated with clean solvent until all the heavy liquid has been removed from the particles. The heavy liquid dissolved in the solvent can be reclaimed by the usual reclamation methods. Only 300 ml of liquid is used to operate the circuit described in fig. 1 and the amount actually lost during a separation is negligible. A much smaller separator can be made for use with expensive or dangerous liquids.

Many of the liquids that are suitable for use in an apparatus of this type are toxic and the separator should, whenever possible, be used in a fume-cupboard as a small amount of the liquid vapour will always be blown about by the air-lift. This effect can be minimized by covering the mixing funnel with a loose fitting cover through which the air-lift tube enters. Loss of vapour from the separating vessel and from the collecting funnels can also be reduced by fitting covers on them.

The liquid can be finally recovered from the apparatus by disconnecting the air-lift tube at point 7 (fig. 3) and allowing the liquid to drain into a suitable container.

Limitations. The maximum size of particle that can be treated is only limited by the sizes of the apertures in the apparatus. The equipment shown in fig. 1 can separate grains up to about 2 mm in size. The minimum size that can be treated depends on the density of the particles but any grains smaller than about 100μ become difficult to handle because of agglomeration by electrostatic forces; the usual lower limit for mineral separations in this apparatus is about 150μ (100 mesh B.S.S.). If the feed rate is kept low it is possible to treat the complete size-range, 2000–150μ, in a single operation. The apparatus is not suitable for use with very volatile liquids as loss by evaporation may become excessive. If a mixture of two liquids is used as the separating medium the loss of a

highly volatile fraction will completely alter the separating density of the apparatus.

The maximum feed rate will depend on the size, size-range, and densities of the grains. Feed rates up to 5 g/min. were readily achieved when using alluvial minerals in an apparatus similar to that shown in fig. 1. When an excessively high feed rate is used the lighter particles tend to form a raft over the surface of the liquid in the separating vessel. Once such a raft has formed the lighter grains will collect at its base and the raft will thicken downwards and may fail to pass through the overflow aperture. This effect can be overcome either by reducing the feed rate or by periodically stopping the feed and giving the raft time to break up. The maximum weight of sample that can be treated in a single separating cycle is controlled by the size of the feed hopper and of the collecting funnels. The apparatus used for test work on siliceous mineral grains has a capacity of approximately 200 g.

Water is immiscible with many of the commonly used heavy liquids and particles that are filmed with water will not be 'wetted' by the heavy liquid. Thus, it is usually essential to ensure that the feed material is completely dry.

During a number of tests it was found that both the 'float' and the 'sink' products of a separation could be produced at over 99 % purity in a single operation.

Applications. The apparatus can be used for a large variety of mineralogical separations and it should also be useful for treating many other types of granular materials. It is ideally suited to the treatment of alluvial minerals or beach sands as the size distribution of these materials usually falls between the size limits of application of the separator. Furthermore, the proportion of the heavy fraction is usually so small that there is no need for a continuous discharge of the 'sink' product.

Attempts are being made to increase the usefulness of the apparatus by using suspensions of fine-grained solids instead of heavy liquids. This may make it possible to carry out separations at a separating density of up to about 5.

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