RESUME OF HIGH CAPACITY GRAVITY SEPARATION EQUIPMENT FOR PLACER GOLD RECOVERY

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INTRODUCTION

Most gold-dredge operations in the United States were ordered closed by the government in 1942 during World War II after operating very profitability since 1895. Most remained closed after the war due to the ever widening gap between increased mining costs and the fixed price of gold.

Placer gold that once made up about 35% of our domestic gold production has steadily declined and now accounts for about one percent of the total domestic supply.

Due to this decline in gold-placer mining operations gravity separation technology has received very little attention in the U.S. and has remained essentially unchanged since the heyday of the gold dredges. Gravity technology in those days consisted mainly of sluice box and riffles, jigs, various amalgamation plates and drums or various combinations of these devices. Most of the present day gold-placer operations and gold recovery equipment used in sand and gravel plants are still utilizing these same methods.

One of the major problems with the sluice box, riffles and jigs used on the dredges were that they were notoriously inefficient at recovering the exceedingly fine gold that was commonly referred to as flood, flour or colloidal gold. These recovery methods might have been entirely appropriate for deposits where most of the gold is fairly coarse and can be easily separated by even the most rudimentary gravity devices. But, unfortunately, this very fine gold makes up a large percentage of the gold in most of the remaining placer deposits and especially those that are being utilized today for sand and gravel production.

The phenomenal and meteoric rise in gold prices in the past few years has stimulated a renewed interest in domestic gold mining and many deposits once considered valueless or at best marginal at past gold prices are now potentially mineable at a profit and will become even more attractive if new and more appropriate technology can be found and applied.

There have been many new inovations in gravity separation technology since the days of the gold dredge and most of these have been developed outside of the U.S., where placer deposits are being mined and processed for various other minerals such as rutile, illeminite, zircon, cassiterite and even diamonds. Many of these newer methods could be very profitably applied to gold recovery in many present day placer or sand and gravel operations.

As the title suggests, it is the purpose of this brief presentation to acquaint you with some of the more recent and successful high capacity gravity separation equipment that would be appropriate for gold recovery in high volume placers and gravel plants.

As U.S. Bureau of Mines metallurgists John Gomes and George Martinez point out in their excellent paper "Recovery of By-Product Heavy Minerals From Sand and Gravel Operations" there are many sand and gravel deposits that contain other valuable heavy minerals that could also be economically recovered by utilizing the same gravity separation methods and techniques. These minerals should be kept in mind if you decide that a new evaluation of your deposit is warranted, or if you are comtemplating a new or revised gold recovery plant.

Gravity Separation Equipment

Gravity equipment can be roughly divided into three basic groups 1) large volume, high capacity equipment where the processing of large tonnages are required, and 2) medium capacity equipment where processing of moderate tonnages are economically feasible in fairly rich deposits or in isolated areas where transport of equipment or scarcity of water might be a problem 3) low capacity equipment that is used mainly for upgrading primary concentrates or handling smaller, higher-value ores. Usually some combination of the 3 types of equipment are required for an efficient placer operation.

Since each placer deposit is unique, recovery equipment will necessarily have to be custom designed for each situation in order to achieve maximum efficiency, this of course, requires a minimum amount of preliminary data and engineering criteria before intelligent choices can be made.

Tests should be made to determine the following:

1. Grade of Ore to be Recovered.

   Sampling and evaluation of placer deposits is not a simple task and usually requires a geologist or mining engineer familiar with the many types of placer deposits and experienced in placer sampling techniques.

   The high unit value of gold, its erratic distribution both vertically and laterally, it occasional concentration in "pay streaks" and the large rock size usually found in placers make large scale sampling and testing mandatory.

   Extreme caution should be used when using fire assays as a testing technique for determining recoverable gold in placers. Fire assays can be misleading and will usually result in over-evaluation of a placer if taken and evaluated by inexperienced personnel. Free gold assays made with testing equipment that simulates actual recovery equipment combined with Spectographic analysis, fire assays etc. will usually give a more complete and reliable analysis.

   Since we are dealing with a by-product in sand and gravel operations, extensive testing normally required when an entire mining operation has to be assured of complete amortization is not usually necessary, you should however do enough careful testing to assure yourself that any proposed investment will have a reasonable chance of being returned with an acceptable profit margin.

2. Physical and Chemical Characteristics of the Recoverable Mineral.

This includes the particle size distribution, particle shape, coatings if present, their chemical make-up, specific gravity and fineness of gold, identification of alloys and any impurities present, (Gold can be so finely divided and pounded into such extremely flat, thin particles that they will actually float in water and defy most gravity separation techniques.)

3. Other Valuable Heavy Materials To Be Recovered And Their Physical and Chemical Properties.

4. Size Of Feed To Recovery Unit.

5. Fluctuation Ranges Expected In Amount Of Feed And Feed Size If Any.

6. Other Minerals Or Chemicals Present That Might Hinder Gravity Separation Such As Silt, Clay, Oil, Etc.

There is some gravity separation equipment that uses air instead of water, such as the pneumatic jig produced by the Oliver Manufacturing Company in Rocky Ford, Colorado, and various other air blowing devices.

A comparison of specific gravity differences in air and in water however, will show that gravity separation in water is much more efficient and should be used whenever available.

Example:

$$\frac{\text{sp. gravity gold in air} = 19.3}{\text{sp. gravity rock in air} = 2.6} = 7.4$$

$$\frac{\text{sp. gravity gold in } H_2O = 19.3-1}{\text{sp. gravity rock in } H_2O = 2.6-1} = 11.4$$

In other words, gold is 7.4 times heavier than rock in air and 11.4 times heavier than rock in water.

Installation Data Required

1. What is throughput and feeding arrangement to recovery unit?
2. Continuous or intermittent operation? How long?
3. Feeding method to recovery unit.
4. Head room and plant space available.
5. Discharge requirements for recovery unit?
6. Special tailing disposal requirements, closed or open system?
7. Additional power supply availability.
8. Type and amount of operating labor required.
9. Availability of water and condition such as clay or oil contamination, etc.

I. High Capacity Gravity Separation Equipment.

1. Jigs -

The conventional jig is essentially an open tank filled with water with a screen on top. This screen holds a layer of coarse, heavy particles usually referred to as "ragging". The tank is usually divided into several compartments with a hutch and spigot on the bottom for collecting and drawing off the heavy mineral concentrates.

Mechanically operated diaphrams or plungers inside the tank cause the water to pulsate in an up and down motion and as the ore is fed over the ragging in slurry form, the pulsating action of the water causes a separation of the heavy minerals which penetrate through the ragging and screen down to the hutch while the lighter minerals are carried away by the cross-flow to the next jig or to be discarded as tailings.

The conventional jig is still one of the most efficient high capacity gravity separators in the coarse size ranges from 1" down to about 100 mesh but recovery efficiency usually drops significantly in size ranges below 100 mesh. Conventional jigs require a large amount of floor space and head room and the feed sometimes has to be divided into 30 or more equal parts. These jigs require experienced supervision since they can blind over due to fluctuation in feed size or lose considerable efficiency if not constantly adjusted to feed changes.

One fairly recent innovation in jig design that its manufacturer's claim overcome most of the drawbacks of the conventional jig is the circular Cleveland Jig manufactured in Amsterdam and marketed by I.H.C. Holland in Mystic, Connecticut. This new jig has a single point feed distribution and takes up very little floor space as compared to convention jigs. However, the most significant

advantage of this jig, due to a modified plunger movement, is its substantially increased efficiency in recovering very fine heavy minerals that are normally lost by conventional jigs.

If you have restricted floor space, very fine gold and a marginal water supply, then you should certainly thoroughly investigate the possibilities of this new jig.

2. Pinched Sluices.

A large variety of pinched sluices have been in use for gravity separation for centuries.

A pinched sluice, is a small sluice that narrows down at the discharge end and as the ore slurry is crowded into a progressively narrower opening, the heavy materials tend to migrate towards the bottom and the lighter material is forced up over the heavy minerals. The minerals are discharged from the sluice in a substantially segregated flow and this discharge flow can then be split into concentrates, middlings and tails.

A large number of these sluices were required for a high capacity operation and a considerable amount of efficiency was lost due to sidewall interference of the sluices and the large amount of recirculation pumping required.

The Reichert Cone concentrator is a new innovation in gravity separation and is based on the pinched sluice concept. If a number of pinched sluices are arranged side by side, they will form a circular tank with each individual sluice forming a separate compartment. If the sides of all the sluices are removed you then have a circular tank with an inverted cone for the bottom.

If ore slurry is fed to the tanks circumference, the material will migrate towards the center and the ore will

become crowded due to progressively less space and a gravity separation will take place as in the individual pinched sluice. This is basically the Reichert Cone Principle and the advantages of the Reichert Cone is that one inverted cone takes the place of a large number of pinched sluices, the sidewall interference if completely eliminated with substantial increase in efficiency, feed can be centrally and uniformly fed by use of a distribution cone.

A large number of these cones can be stacked one over the other and in various combinations making it a very compact and versatile recovery unit.

The Reichert Cone is an Australian innovation developed by Mineral Deposits, LTD., of Southport, Queensland Australia. The cones are made of fiber-glass covered with rubber. They are mounted in a self-supporting frame and weigh only 2½ tons for a 75 ton feed capacity.

The Reichert Cone can handle a slurry feed of about 60% solids and a maximum feed size range is about 10 mesh. This unit is very efficient at recovering very fine particle sizes and the size ranges effectively concentrated are about 30 to 35 mesh down to 270 to 325 mesh. Fluctuation in feed has to be controlled within fairly close tolerances and the proportion of clay sizes to feed should be below 5 percent.

The Reichert Cone usually has to be used with other gravity separators such as spirals and shaking tables for a complete recovery unit. The Reichert Cone has no moving parts and has a very low unit operating cost. It has a long equipment life with low maintenance. It uses much less water than conventional jigs and sluice and riffle systems. This unit should be considered when extremely fine gold or other fine materials are to be recovered and where plant space or wash water is at a premium.

3. Spiral Concentrators.

Spirals were invented by Mr. Humphreys of the Humphreys Gold Corporation in an effort to find an easy and inexpensive way of recovering gold.

They were introduced in 1943 and have since been used in many mining operations all over the world for a large variety of mineral and gravity concentration applications.

The Humphreys spiral is a helical sluice concentrator. As the feed slurry is introduced into the spiral channel, the minerals in the slurry begin to settle and classify. Particles having the greatest specific gravity move to the inside path of the spiral where the distance traveled in the spiral is the shortest and these heavy minerals then form a slow moving fluid film. The lighter particles are carried to the outside of the spiral due to centrifical and other forces. The heavy minerals concentrated in the inside of the spiral can then be split off into collecting ports.

The maximum feed size is about a No. 4 screen size and will effectively concentrate a particle size range from a No. 10 mesh down to a No. 200 mesh.

As with the Reichert Cone, the feed pulp density must remain fairly constant and operates on a pulp density of 25 to 35% solids by weight.

The main draw back to Humphrey's spirals were that they are made of cast iron and are heavy with each unit having a fairly low throughput requiring a very large number of units for high capacity operations. These units took up a large amount of plant space and required experienced supervision.

The Reichert people recently introduced a new version of the Humphrey spiral made out of rubber-lined, light-weight fiberglass and have combined 2 to 3 spirals into one unit thereby greatly reducing the number of units and plant space requirements.

These units are also usually used in combination with other gravity separating devices for a complete recovery unit. This unit would have application where medium to high tonnages are expected and where the particle size of the valuable minerals are in the medium to fine range.

4. Sluice Box and Riffles.

Sluice box and riffles are one of the oldest forms of gravity separation devices known and have been used in various forms since ancient times.

If properly designed and operated they are usually a very effective gold-saving device for gold with particle sizes in the coarse to medium size range. They require very little supervision and tolerate large fluctuations in feed volume, (although recovering is reduced when the riffles are overloaded) require a moderate amount of maintenance and have a low initial and low unit operating cost. On the negative side, they have never been effective in recovering fine gold, they tend to pack with black sand and lose recovery efficiency, they require frequent clean-ups and therefore more clean-up labor, and require a large amount of plant space and a very large amount of fairly clean wash water. Riffles three main functions are to retard the material moving over them in order to give the heavy minerals a change to settle, to form beds of "quick-sand" that will trap and hold the gold which settles into them, and to create turbulence which will more effectively expose the suspended heavy minerals to the quick-sand trap.

Sluice design must include the proper slope (usually 1 1/8" to 1 3/4" drop per running foot) in order to transport the material. Riffle design must be able to entrap the gold particles in a current swift enough to transport the ganque material yet slow enough to permit a quick-sand bed to form that will trap and hold

the gold in place. The efficiency of the riffle system is adjusted by changing either the slope, amount of feed and velocity of the water.

Most studies have shown that turbulent water is much more effective in trapping fine gold than quiet running water. This is due to the fact that a fine particle of gold suspended in a slurry or in water will statistically have a much greater chance of being trapped if you increase the amount of exposure to the trapping medium. A particle of gold suspended in quiet running water may go over a long series of riffles and never once be exposed to the trapping medium, (in this case the quick-sand bed) but if that same suspended particle of gold is in very turbulent water, it may be exposed to the trapping media many times as it boils over and around each riffle.

If you increase the riffle angle and water velocity to increase turbulence in the standard sluice and riffles, you will also wash out the sand bed which is needed as the trapping and holding medium. The end result is that in the conventional riffle design, you are limited in the amount of turbulence you can create before destroying the trapping medium.

Approximately 700 sq. ft. of riffle area is required for each 100 TPH of sand feed. Some gold dredge designers have doubled this in areas where there was a large proportion of fine gold.

If you have a choice between building a long narrow sluice or a short, wide one for the same riffle area, the long narrow sluice will obviously be considerably more efficient for fine gold recovery since a single gold particle traveling over 200 feet of riffles will have a much greater chance of being trapped than traveling over 50 feet of the same riffle area.

Most gold dredges used 30" wide sluices, however, I prefer 20" wide since the narrower sluice reduces the

chance of sanding-up and meandering when fluctuations in feed are encountered. Wash water requirements will vary with the nature of the feed material and plant configuration but normally for a good turbulent flow about 1,700 GPM will be required for each 100 TPH of sand feed.

At our Teichert Aggregate plant in Sacramento, we had a small 300 sq. ft. riffle recovery plant designed and operated by experienced dredge people. When gold prices began their steep rise, we decided to take a second look at this operation. Our testing program showed that we were losing considerable amounts of very fine gold to our settling ponds and our sand products. A study of the available equipment showed that an expanded riffle system would be most appropriate for our plant if we could solve the turbulence versus sand bed problem and increase the fine gold recovery.

Subsequent experimenting with various new riffle designs in combination with various matting materials to replace the quick-sand as a trapping and holding medium eventually led us to the present riffle design system and long stand astro-turf combination that we feel has solved this problem.

When we replaced the old riffle systsm with 300 sq. ft. of the new riffles and astro-turf, we increased our rate of recovery by about 2½ times. We then expanded our riffle system to its present 1,800 sq. ft. and again increased our recovery rate to about 4 times the original recovery rate.

We don't feel that we have the ultimate design yet and we are still experimenting with other riffle designs in the hope that we can still further increase our present recovery rates.

For those of you who wish to try an expanded riffle system, I feel that this data should give you a good starting point but you should keep in mind that each

placer deposit is unique and each recovery plant will require a considerable amount of "custom tailoring".

5. Wright Impact Tray.

This is another pinched sluice type gravity separator that relies on a hydraulic effect for separating the heavy minerals from the gangue rather than the use of slots or cutter plates. A normal bank of trays consist of 16 starts two trays wide and 8 trays high. One bank occupies about 750 cubic feet of plant space and can be fed at rates up to 150 TPH. Banks can be stacked two high and can then handle up to 300 TPH. The trays are made of fiberglass and coated with polyurethane. Pulp density should be about 50 to 65% solids and maximum feed size should be in the coarse sand range. This is one of the latest innovations in gravity separation equipment and was designed to specifically perform over a wide range of feed rates and to tolerate trash and overside in the feed with the ability to reject it to the tailings. Since this is a relatively new device, not too much is known about its efficiency in the various size ranges. This new gravity separation device should definitely not be overlooked when considering a new recovery unit.

II. Medium Capacity Gravity Separation Equipment.

1. Ainlay and Knudsen Bowl Concentrators.

These bowls, to my knowledge, have never been used with any great success in large capacity operations but I wanted to include them since they have been around for a many years and you will always hear them mentioned when discussing gold recovery equipment.

The Ainlay Bowl, as the name suggests, is a bowl shaped basin 12 to 36 inches in diameter mounted on a vertical shaft in the center of the bowl. The inner surface of the bowl is lined with rubber riffles. A sand slurry is fed around the shaft in the center and as the bowl is spun on the shaft at about 1200 FPS peripheral speed at the bowl rim, centrifugal force forces the material outward and upward, the gold catches in the riffles and the lighter material continues upward and out over the rim to the tailings. Capacities are 5 to 10 yards per hour for the 36" bowl and a series of bowls are required for a high capacity operation. The recovery plant is shut down when the riffles become full and are cleaned out. Since these units have not been widely used in high capacity operations, there is very little information available as to their efficiency as a fine gold recovery unit. A 12" unit can be purchased fairly cheaply however for a trial pilot plant operation for those of you who might be interested in this type of separator.

2. Bartles-Mozley Table.

This table is a recent invention deveopled in England for the recovery of extremely fine heavy minerals in the general size range of 5 to 10 microns although it is claimed that particles down to one micron in size can be recovered. This table is a flowing film type concentrator where pulp is flowed over a 4' x 5' fiberglass deck that is suspended at a 1° to 3° angle to the horizontal. An orbital motion is imparted to the deck.

This orbital motion tends to stop and settle out heavier and smaller particles from the flowing film and permits the larger and lighter particles to flow off the deck to the tailings.

This is essentially an automated batch type operation and when the decks become charged with heavy particles the decks are automatically tilted and the heavy minerals are rinsed off to a collecting tank. One unit consists of 40,10' x 5' tables mounted in a frame about 8' x 6' x 8' tall.

The main area of application of these tables are the treatment of material finer than 150 mesh. These tables are extremely efficient in these size ranges and should be considered as a medium capacity unit for recovering extremely fine, heavy minerals.

3. Johnson Type Cylinder Concentrator

The Johnson concentrator first introduced in 1926 in South Africa consisted of a slowly revoloving cylinder 3 feet in diameter by 12 feet long with a 3.75 slope on its axis. The inside of the cylinder was lined with riffled rubber matting. A launder was placed inside the cylinder which ran the full length of the cylinder and was sloped towards the discharge end. Spray bars were placed inside the cylinder and the spray was directed towards the top.

As material was fed to the upper end of the slowly rotating cylinder, the heavy minerals were trapped in the riffle matting and carried to the top where the spray washed the heavy minerals down into the launder located directly beneath. The concentrates were then carried out of the cylinder to be further concentrated.

Rotation of the cylinder is very slow, about 3 revolutions per minute, and feed size is usually fairly fine - in the minus 10 mesh range. A saw tooth rubber

riffle was used and was about 1/8" deep, 3/16" wide and 1/8" apart.

The rotation of the drum usually had to be opposite the blunt edge of the rubber riffle but if the riffling were suitably spiraled then the drum could be rotated with the sharp edge of the riffle leading.

The Johnson concentrator could handle 40 to 120 tons per hour as a pre-concentrator and could accept moderate fluctuations in feed rate. The percent of moisture in the feed is the controlling factor in the amount of concentrate recovered - the lower the percentage moisture, the higher the recovery of heavy minerals.

This unit uses very little power with a 2½ horse-power motor being completely adequate in most cases. Very little water is required but a fine size (10 mesh) and fairly uniform feed is required for optimum efficiency.

These units would probably be an excellent pre-concentrator where water is scarce and placers are all mostly in the fine size range as in desert areas for example.

4. Plane Table Concentrator.

The plane table is a very simple device for pre-concentrating heavy minerals that will handle fine sized material in the minus ten mesh. Tonnages are generally in the 30 to 50 TPH range.

The plane table was introduced in South Africa in 1949 and consists of a sloping steel table about 14 feet long and 3½' wide with a slope of 8° to 12°.

The table is separated and stepped down about one third and two thirds of the way down. A launder is placed under each separator horizontally across the width of the table. A feed box with distribution plates are at the head of the table. The table surface is covered with riffled rubber matting running longitudinally and is similar to the rubber matting used in the Johnson concentrator.

As a thin film of pulp is fed over the table, the heavy minerals tend to migrate down and concentrate in a slower moving film, in the rubber riffles. On reaching the separated stepped down section of the table the slow moving, heavy minerals gravitate or drip into the launders below and the lighter, faster moving gangue material passes over the separated area down to the next table section.

This table has no moving parts and is practically maintenance free. It is a simple device that can be constructed and operated in remote areas where water is at a premium and where the gangue minerals are in the fine size range.

5. Riffled Belt Concentrator.

The Belt concentrator was also another innovation of South Africa and was also introduced around 1949. It is a slow moving rubber riffled belt 5' wide and about 24' long. The belt is sloped from 10° to 12° and moves upward at about one and one quarter foot per minute.

The pulp, as in the Johnson Concentrator and Plane Table, is usually minus 10 mesh size and is introduced to a feed box at the upper end of the belt. The feed box spreads the pulp out over the belt in a thin film and flows down over the riffled belt. The pulp flows in the opposite direction of the moving belt and as the heavy minerals settle out of the pulp they are caught in the rubber riffles and are carried up in the opposite direction.

The heavy minerals are then washed out of the riffles as they are carried under the upper head pulley. This type of concentrator would have similar applications as the Johnson and Plane Table Concentrators.

All three of these concentrators could be used very effectively as final stage clean-up devices in conjunction with the higher capacity gravity equipment.

6. Heavy Media Separation.

This type of gravity separation is also known as "sink-float" separation and is one of the oldest patented mineral processes still in use today. It was developed in Germany in 1848 and has been used to upgrade coal deposits and for concentration of iron deposits in the U.S. for many years.

Improved equipment and the use of magnetite as a heavy media has brought the costs of heavy media separation down to where sand and gravel plants now use the process to upgrade marginal gravel deposits by floating out the soft, lighter rock - costs are usually in the 30¢ to 50¢ per ton range.

This process is analogous to a controlled quick-sand trap where particles lighter than the specific gravity of the quick-sand medium will float over the quick-sand surface and the heavier particle will sink and effect a sharp separation of the heavy and light particles.

Instead of sand, most heavy media processes use either a fine ground magnetite or ferrosilicon - as a suspended medium. Magnetite is limited to a maximum media specific gravity of about 2.8 and ferrosilicon to a maximum of 3.5.

Heavy-media separation is not applicable to all minerals and size of the particles being separated is a most important factor.

Separation of sizes down to 28 mesh are normally good and separation of sizes down to 65 mesh are possible but would probably be marginal.

Heavy media separation can be used to eliminate other minerals from a deposit that might otherwise interfere with a more appropriate process and is usually considered as an adjunct to other processes.

7. Hydrocyclone Preconcentrator.

Hydrocyclones are normally used for classification of material into separate sizes but they have also been used as a preconcentrator to enrich heavy minerals such as metal sulphides, metal oxides and precious metals.

This is a gravity or centrifugal concentrating process using water pressure to produce the centrifugal force. Centrifugal separaters such as the Ainlay and Knudsen Bowl produce a centrifugal force by rotating the bowl casing, the hydrocyclone produces a centrifugal force of the suspension by feeding the pulp into a stationary cone shaped bowl tangentially under pressure.

The hydrocyclone is an effective preconcentrator where ores are in fine size ranges - usually ten mesh or smaller.

III. Low Capacity Gravity Separation.

The following is a list of low capacity gravity separation units that are normally used in conjunction with the high and medium capacity units for upgrading preconcentrated heavy minerals and for clean-up work.

I have not gone into the details of their operation since most of these have been used for many years in the mineral industry and details of their operation and function can be found in such books as Taggart's "Handbook of Mineral Dressing" and Peel's "Mining Engineering Handbook".

1. Wilfley and Deister Type Shaking Tables.
2. Elutriators by rising water current.
3. Spiraled revolving wheel concentrator.
4. Shaken bed type separators.
5. Vanners - similar in action to the moving belt concentrator described earlier but with a shaken bed motion added to increase speed and separation.
6. Stirred Bed Separators, or Chance Cone Separators similar to rising current elutriators but with stirring motion added to increase speed of separation.
7. Diamond Pan - a quick-sand separator using rotary agitation to create the sand-supporting force and upward impulse.

The above list of equipment and their discussion is certainly not meant to be a complete treatise on gold recovery and all of its attendant problems, but it will hopefully provide a starting point for your own investigation if you so decide.

For the sake of brevity and at the risk of over simplification, I have kept the discussion on equipment operation to its most rudimentary level and I would like to apologize in advance where my explanations might not do justice to the equipment.

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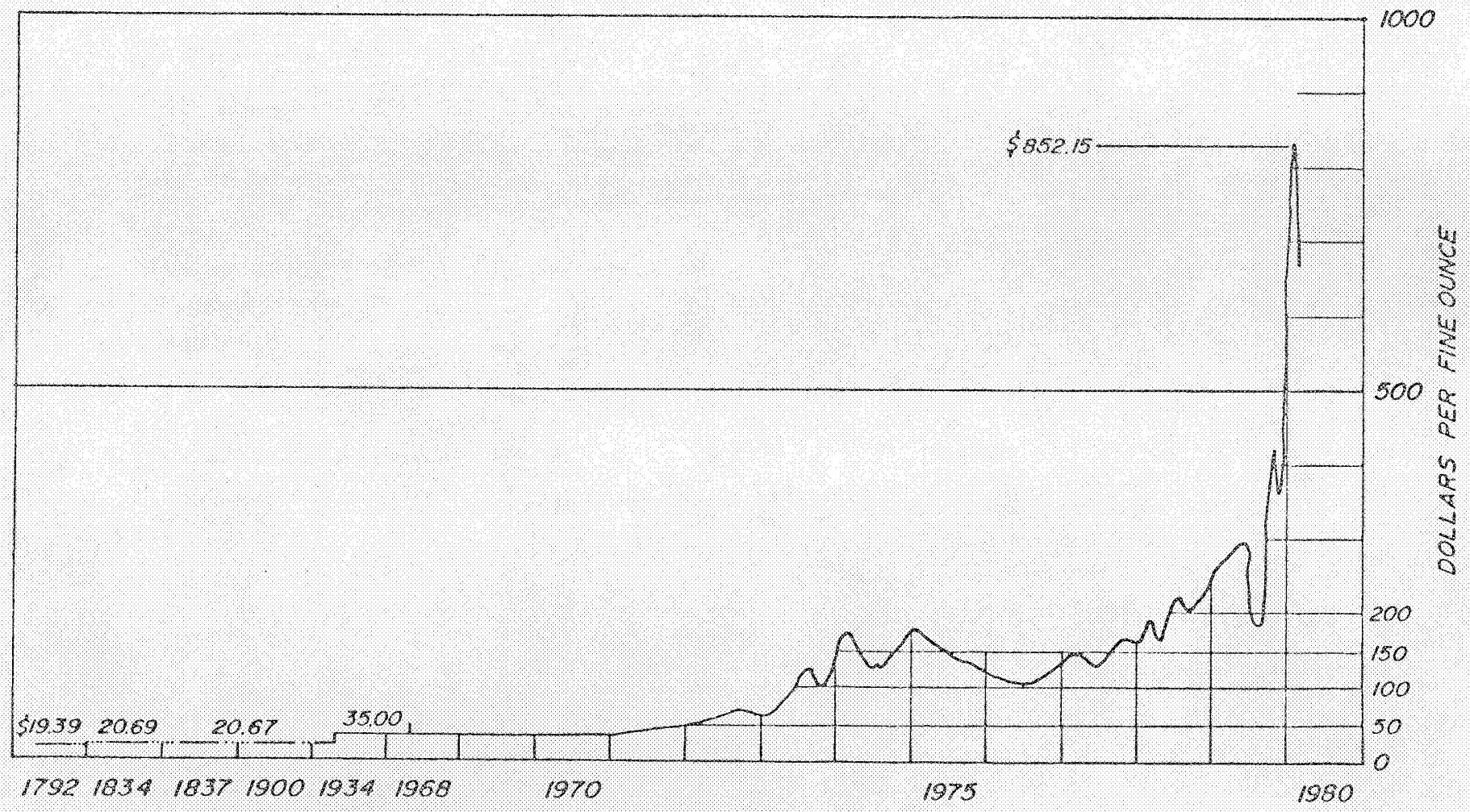
APPROXIMATE GOLD VALUES



ADAPTED FROM COLLINS & READ, 1971

WET TREATMENT

SIZING
- SCREENING (WITH SIEVE BEND)
- CLASSIFICATION
- HYDROCYCLONE

GRAVITY CONCENTRATION
- D.M.S. (CONES, DRUMS)
- D.M.S. (CYCLONES)
- JIGS
- SHAKING TABLES
- SPIRAL CONCENTRATORS
- SLUICES
- TILTING FRAMES

MAGNETIC SEPARATION
- LOW INTENSITY SEPARATIONS
- HIGH INTENSITY SEPARATIONS

FLOTATION
- AGGLOMERATION
- FROTH FLOTATION

LEACHING
- CONTINUOUS

DRY TREATMENT

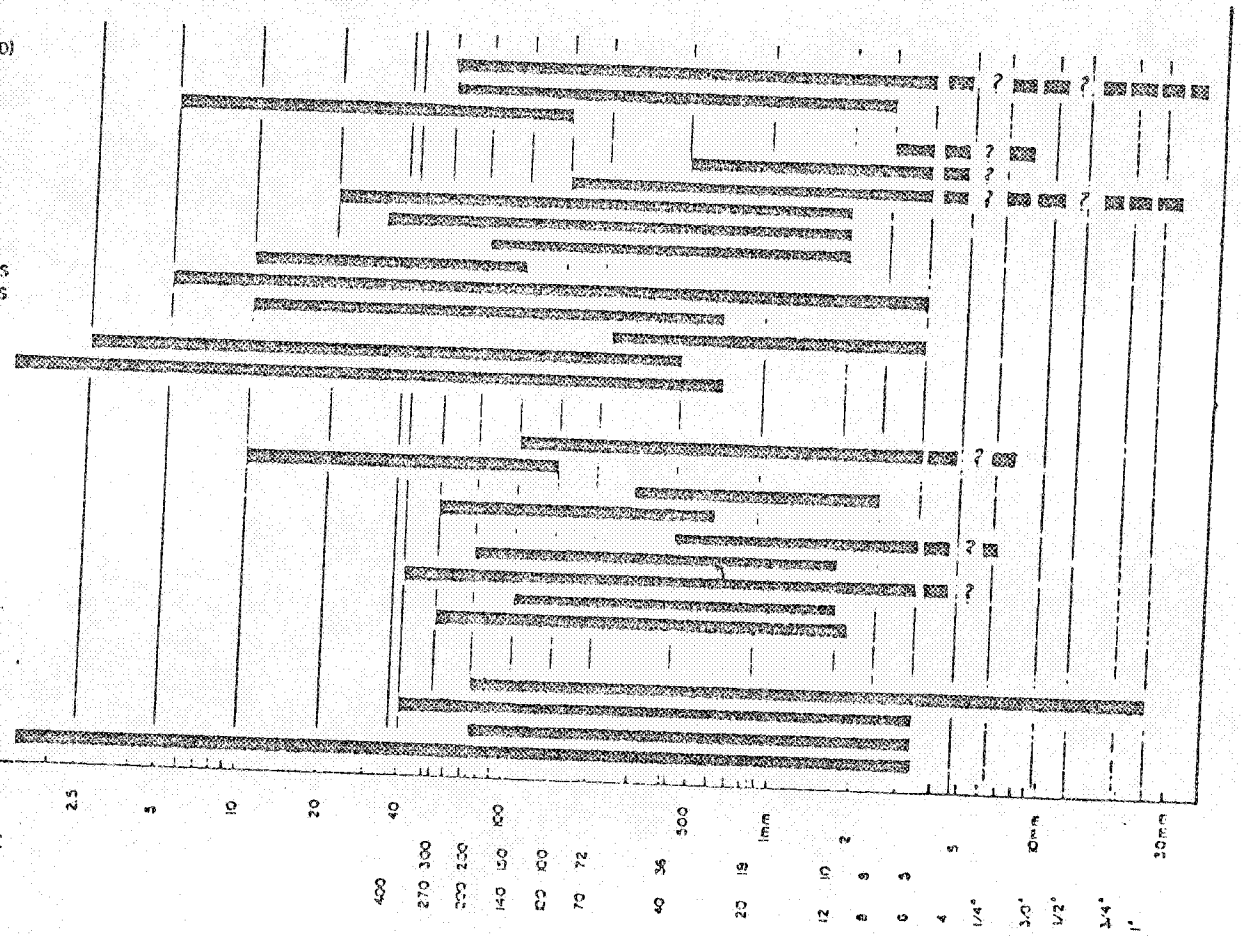
SIZING
- SCREENING
- CYCLONES

GRAVITY CONCENTRATION
- JIGS
- TABLES
- FLUID BED
- PINCHED SLUICE

MAGNETIC & ELECTRICAL SEPARATION
- MAGNETIC SEPARATION
- ELECTROSTATIC
- HIGH TENSION

CIM BULLETIN, MAY 1975

WET TREATMENT
- JIGS
- PINCHED SLUICES & CONES
- SPIRALS
- SHAKING TABLES



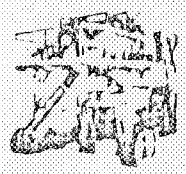
PARTICLE SIZE
- MICRONS & MILIMETERS
- BRITISH STANDARD SIEVE SIZE
- U.S. STANDARD SIEVE SIZE

DENVER

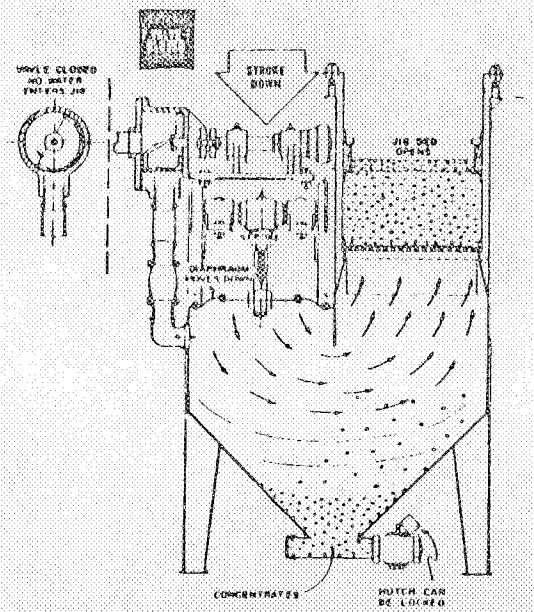
PRINCIPLE OF OPERATION

SYNCHRONIZED PULSATIONS FOR HINDERED SETTLING

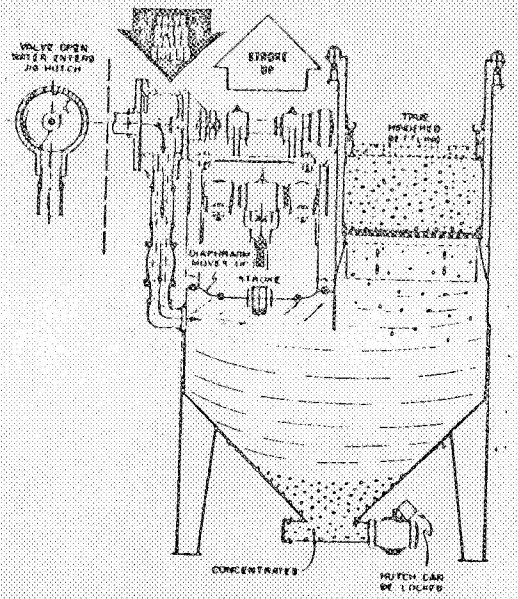
The DENVER "Selective" Mineral Jig operates on the basic principle of hindered settling. In order to effect a concentration it is necessary that there be a differential in the settling rate of the solids treated. Synchronization between the rotating water valve and the plunger is achieved by a rubber timing belt. The rotating water valve permits injection of water into the hutch only during the plunger recovery (suction) stroke. This results in upward pulsations only to the jig bed leaving true hindered settling conditions and concentrating action, which is automatic and completely controlled. The rotating water valve eliminates any "suction" action which would tend to draw contaminants into the hutch product.



Typical application for gold or tin recovery in the DENVER Portable Placer Machine. Write for Bulletin #5 522



In the upper sectional view the rotating water valve (synchronized with the plunger shaft) has closed and the plunger is moving the diaphragm on its downward stroke which creates an upward pulsation to open up the jig bed. During this period lighter gangue particles are carried upwards further than the heavier mineral particles. At the completion of the upward pulsation the rotating water valve has completed a 180° arc or half of a circle and is opening to admit water.



In this sectional view the plunger diaphragm is starting on the upward stroke. The water valve automatically opens at the start of this directional change of the diaphragm plunger, thus eliminating any "suction" action in the jig bed on the upward stroke of the diaphragm. External forces are eliminated and true hindered settling takes place as gravity closes the jig bed. Heavy particles settle fastest, ready for the next concentration cycle.

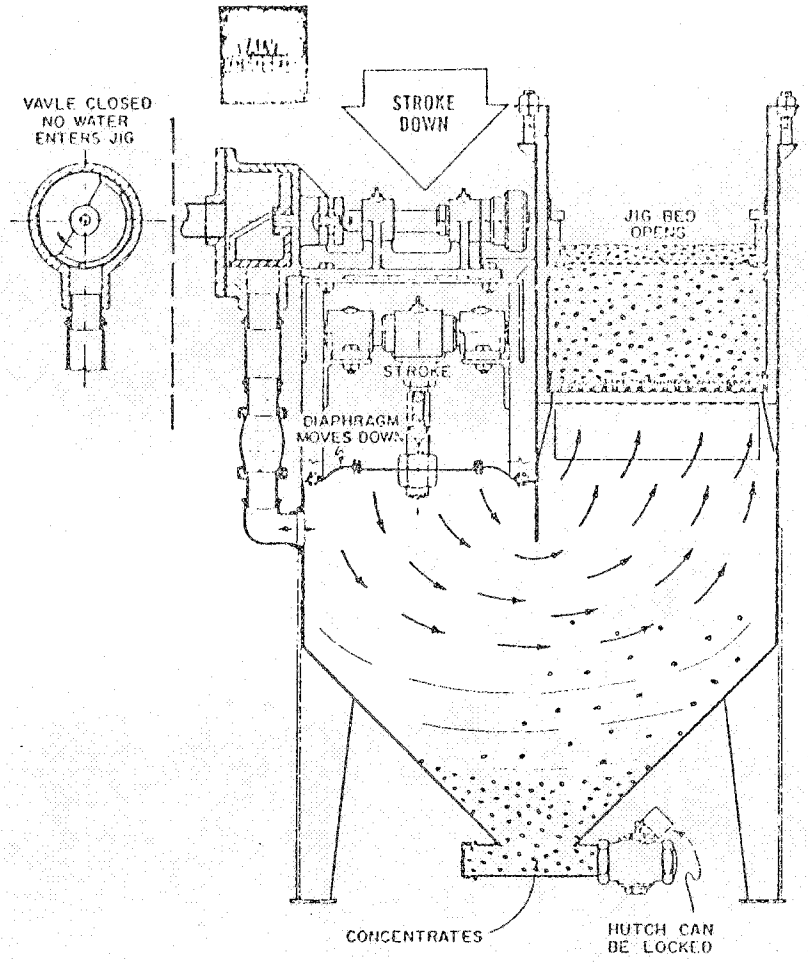
DENVER

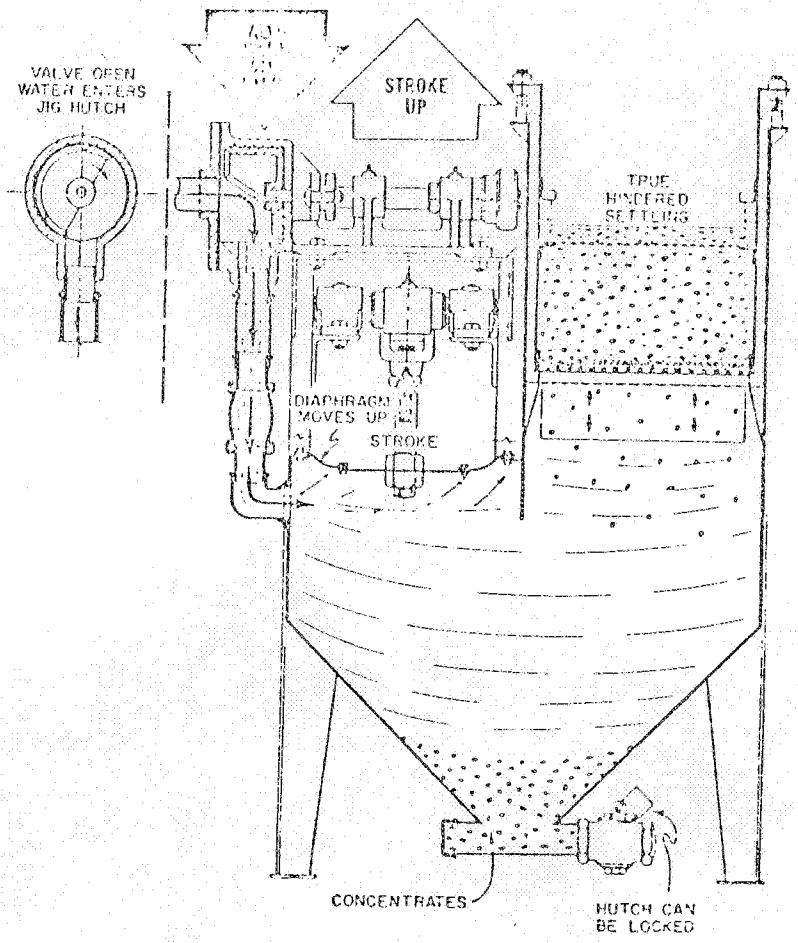
AUTOMATIC Distinctive FEATURES

The DENVER MINERAL JIG is practically automatic in operation, requiring minimum attention. There are five points of adjustment to secure the specific operating conditions required such as ratio of concentration and grade of hutch product.

1. **Dilution Control:** Variation in the amount of dilution through the rotating water valve is the main control point for volume or grade of hutch product.
2. **Stroke:** Change of stroke is accomplished by an easy adjustment on the eccentric for controlling the depth and intensity of the pulsating stroke.
3. **Screens:** Upper screen is a trash screen. Lower wedge bar screen supports jig bedding material. Screen opening limits size of material passing to the hutch compartment.
4. **Bedding Material:** Size and quantity of artificial bedding material determines size and number of particles that are passed through and recovered as concentrate. Depth of bedding controls volume passing through.
5. **Speed:** By varying the jig speed the rate of pulsation may be changed.

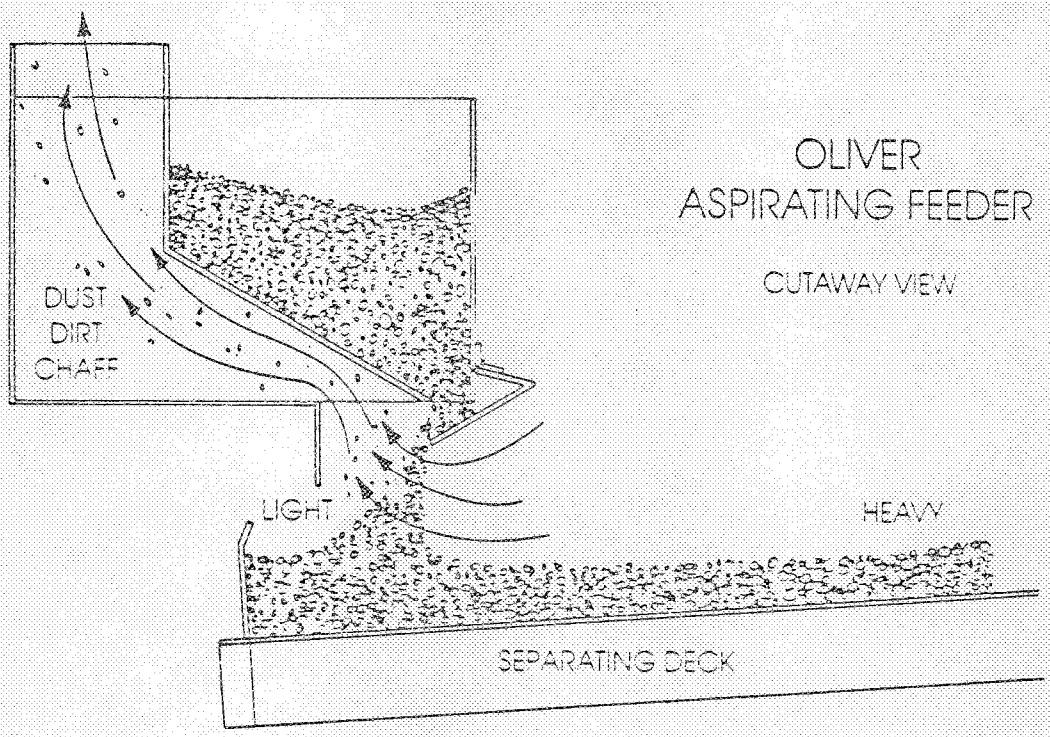
STANDARD JIG



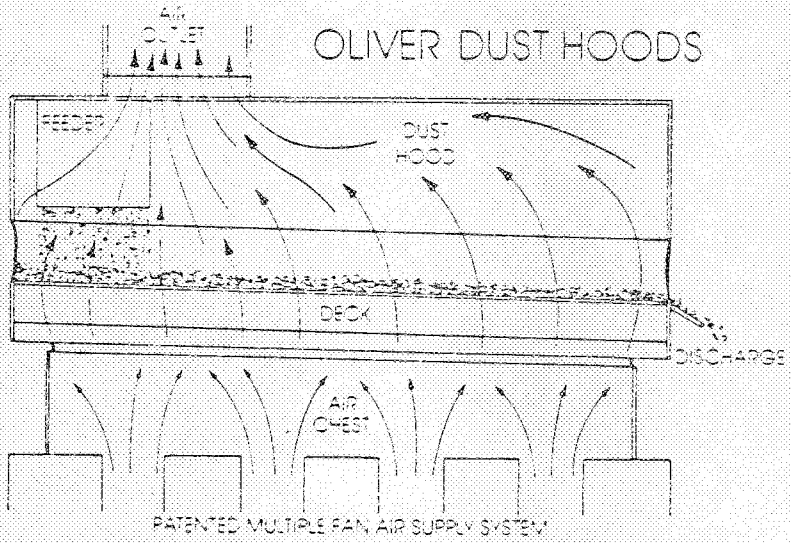


STANDARD JIG

The Oliver Aspirating Feeder. The Aspirating Feeder is the most economical form of dust control where dust and chaff are only a minor problem. The Oliver Aspirating Feeder (see drawing) has air suction built into the ribbon type feeder supplied with the machine. As materials are fed onto the deck, a column of air is pulled through them to remove the dust. In most cases the Aspirating Feeder is capable of handling 90 percent of a moderate dust problem. The Aspirating Feed Hopper is available alone or in combination with a 1 HP fan for those plants lacking a built-in air system. Aspirating Feeders are available for all Oliver machines regardless of their age.



PNEUMATIC JIG



The Oliver Dust Hood. The Dust Hood operates on the pressure vacuum principle (discussed below) and should be used in instances where the percentage of dust in the material is too high to be handled by the Aspirating Feeder. Oliver manufactures a complete line of Dust Hoods which feature built-in feeders, large windows for better visual access, easy exhaust air adjustment and flexible skirting. They are available for all gravity separators and stoners including machines already in the field.

Air Supply Systems and their Relationship to Dust Control. Three systems of air supply are used with gravity separators. The most common is the *pressure system* in which a fan or fans, mounted *below* the deck, forces air through the material to be separated. This method gives the most even air distribution for optimum product separation and is the least expensive. The major drawback to the pressure system is that all dust and other light material is discharged directly into the air supply of the plant.

A number of manufacturers build gravity separators based on the *vacuum or suction principle*. In these machines, air is drawn through both the deck and the material to be separated by fans

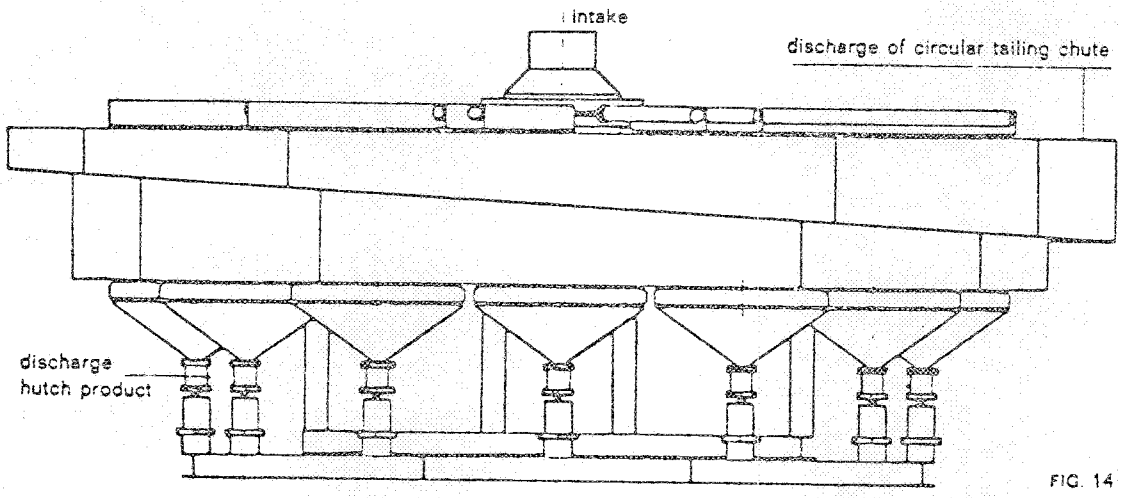
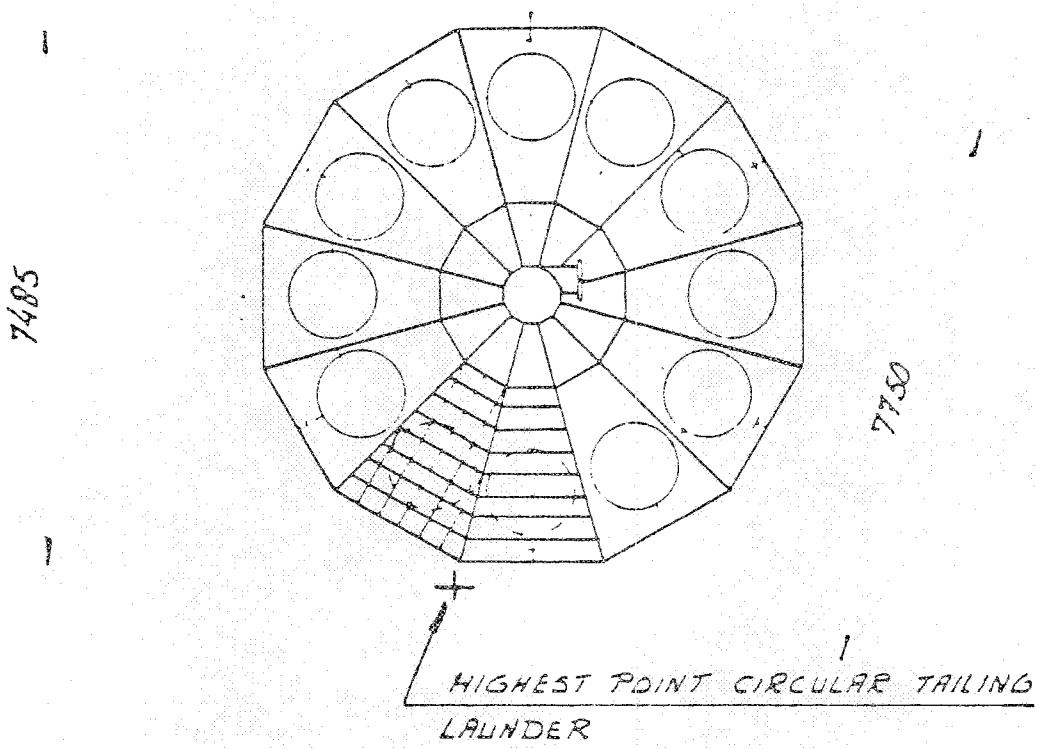
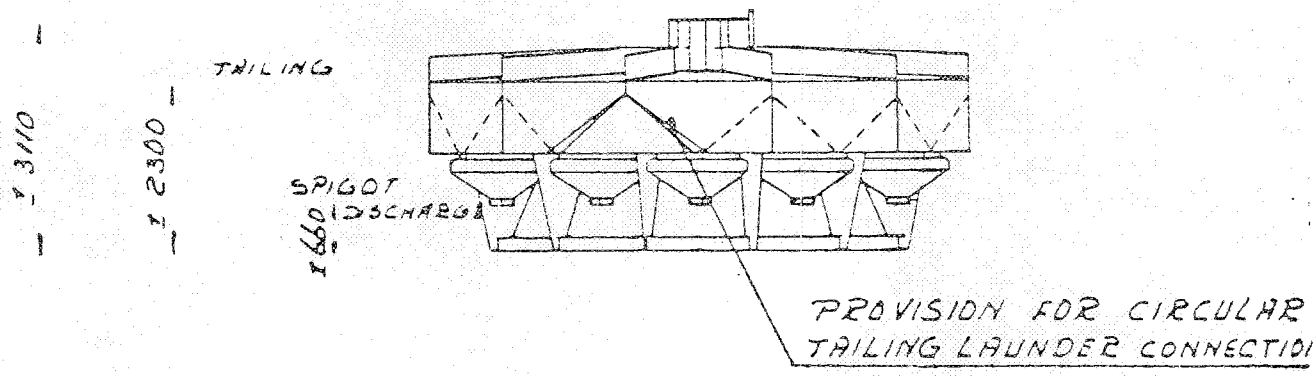
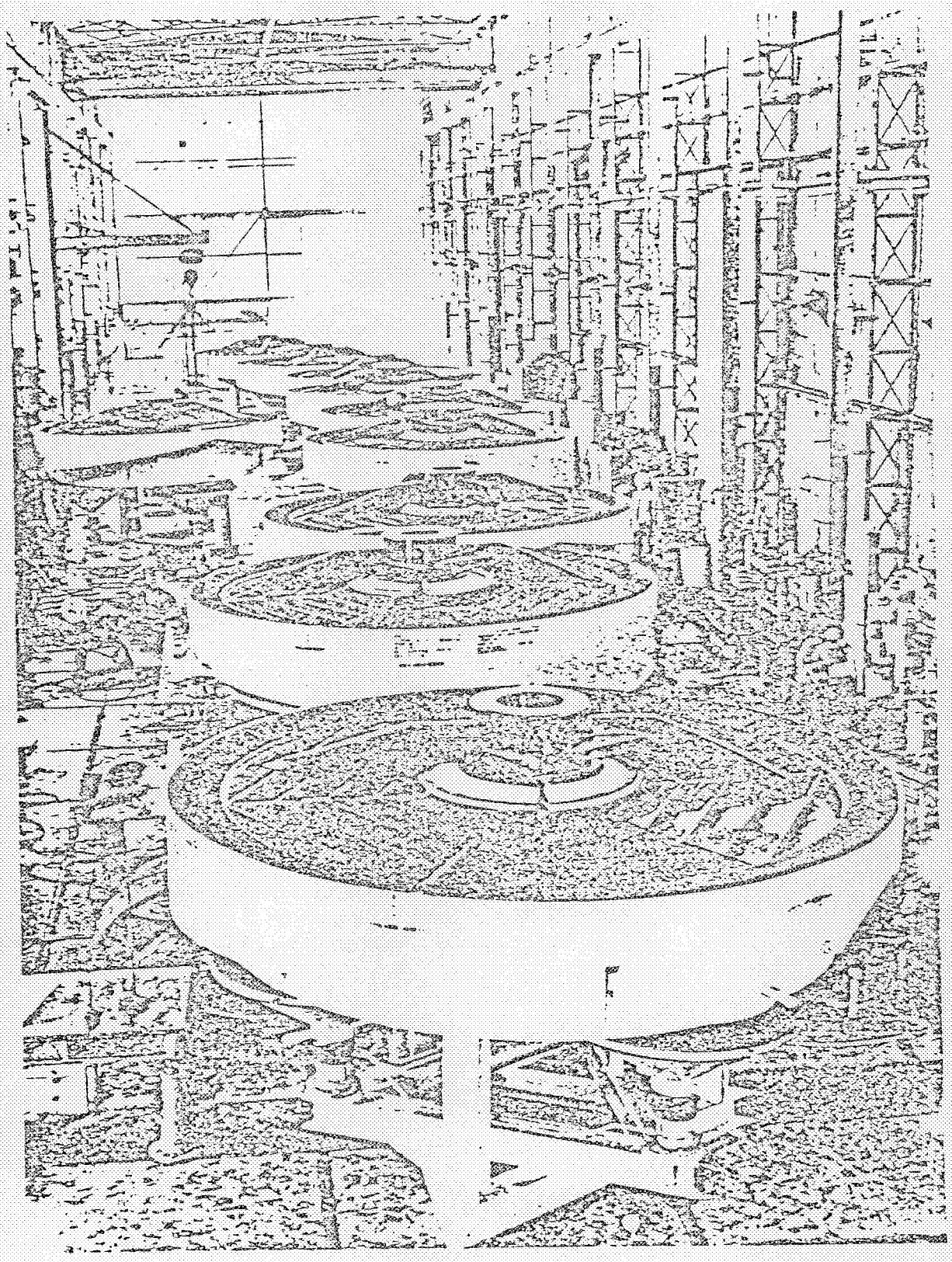


FIG. 14

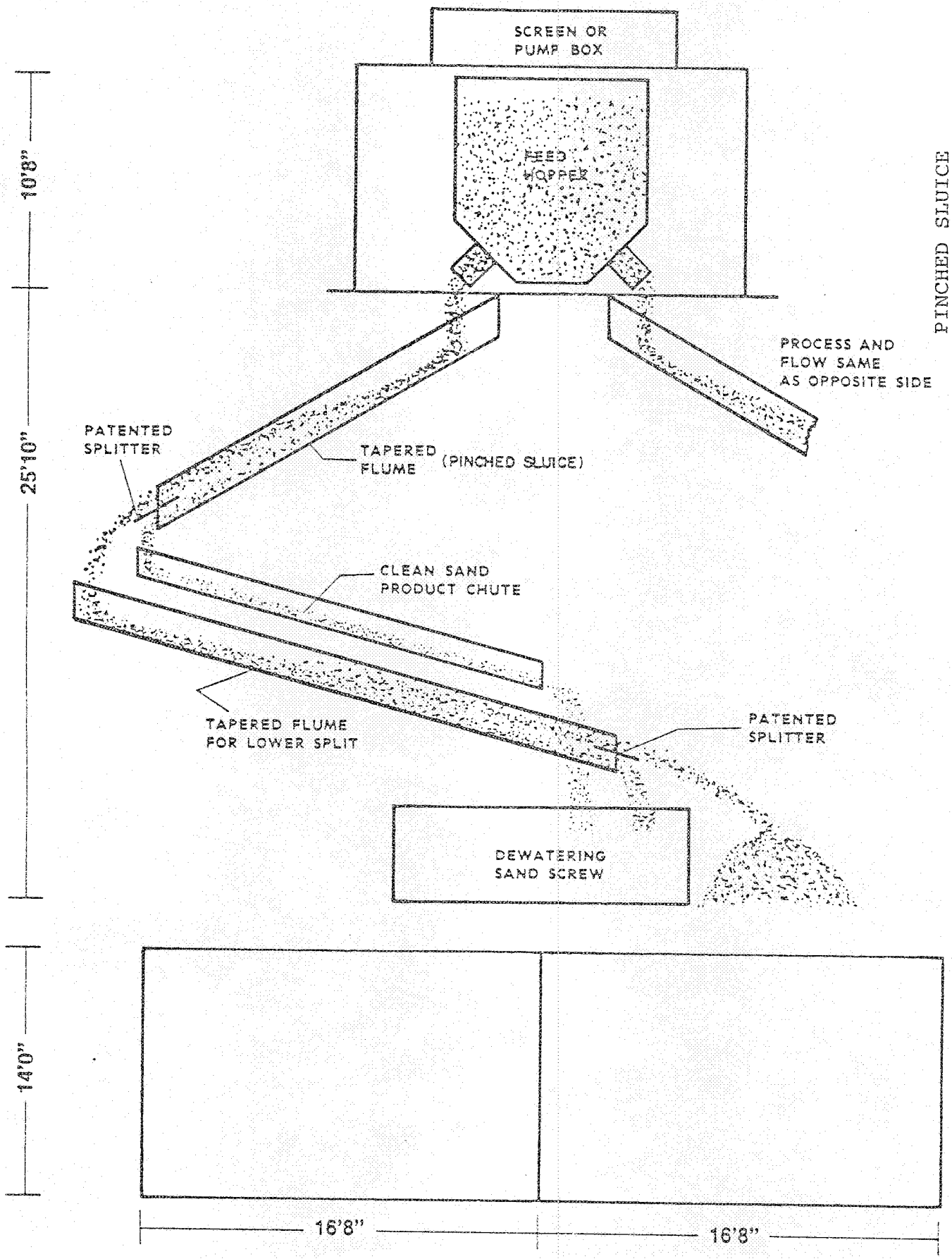
CIRCULAR JIG





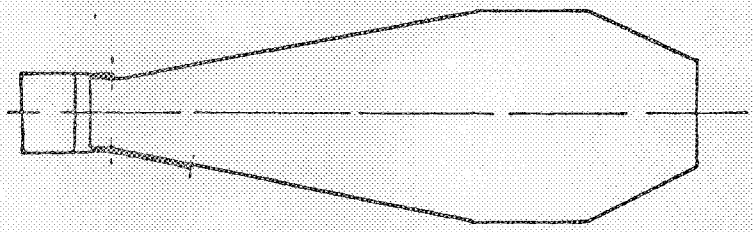


5.1 Type 12 IHC-Cleaveland jigs as fabricated in Holland ready for transport (June 1975)

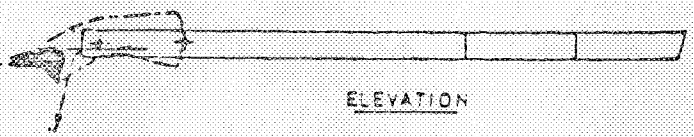


FOOTING LAYOUT

DIAGRAM 2·4
MK 6 TRAY



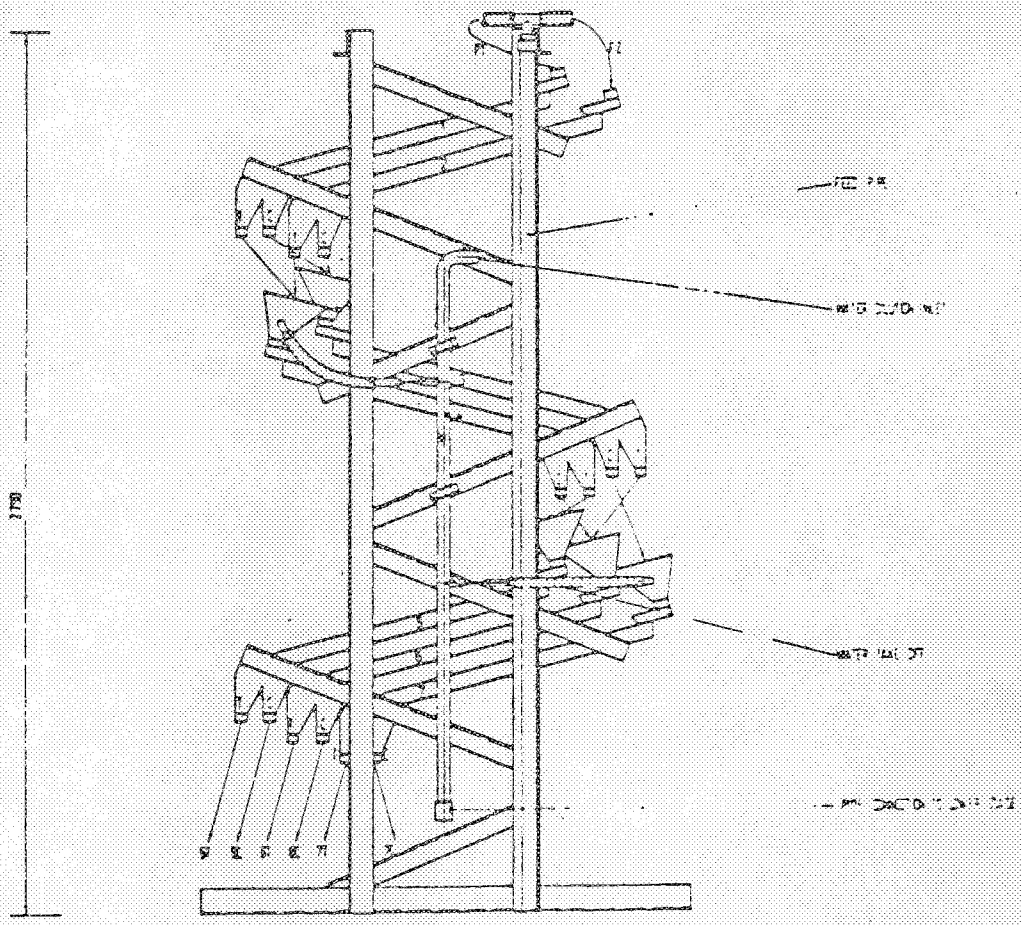
PLAN



ELEVATION

TAIL CONCENTRATE

PINCHED SLUICE



MARK 6 TRAY TEST RIG
7 TRAY INSTALLATION

The Reichert Cone Concentrator

An Australian Innovation

by Robert A. Graves
Group Metallurgist
Mineral Deposits Ltd.

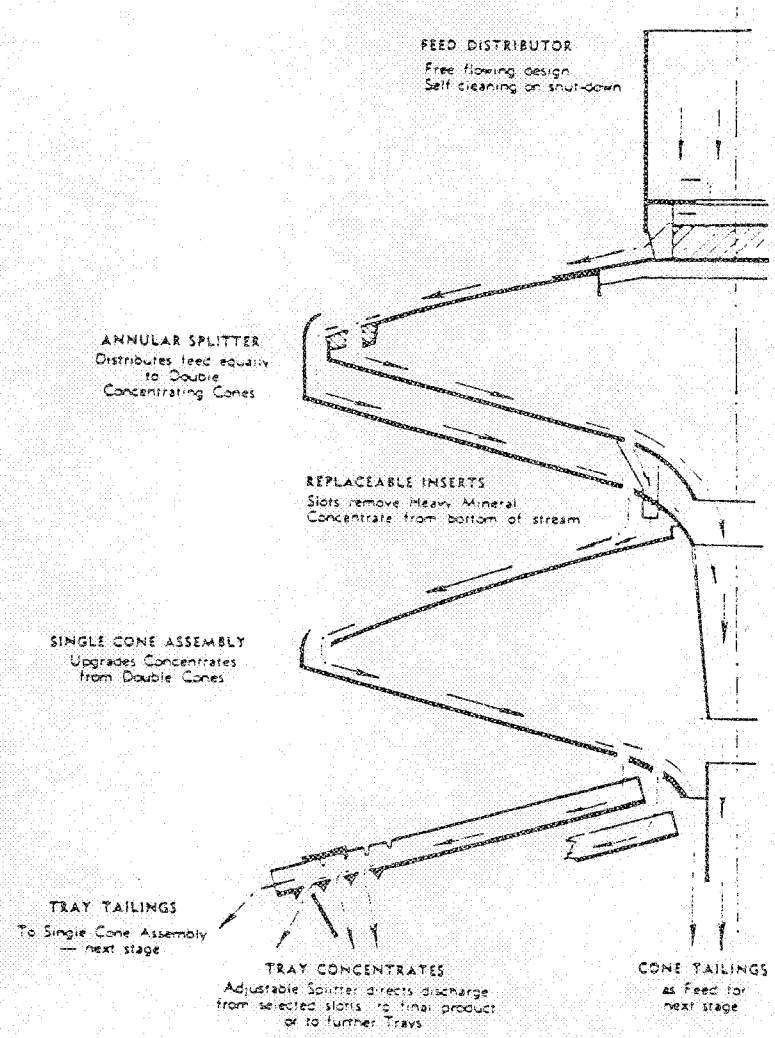


Fig. 1. General configuration of Reichert cone concentrator. Feed to device is a 60 percent solids pulp that is delivered evenly around top of distribution cone

DIAGRAM 2.1
SINGLE CONE ASSEMBLY

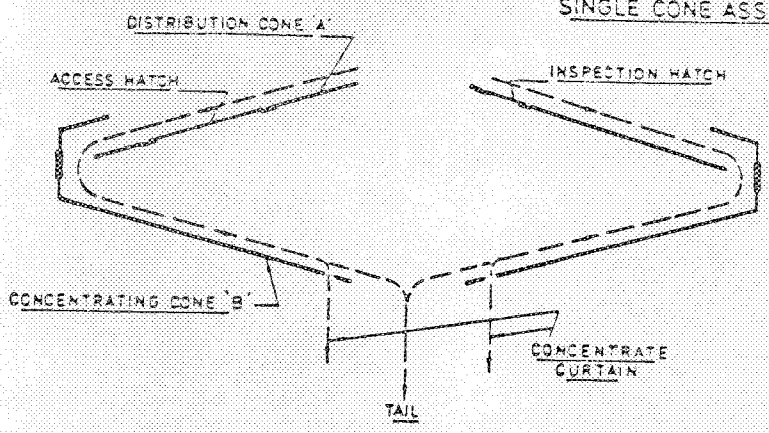


DIAGRAM 2.2

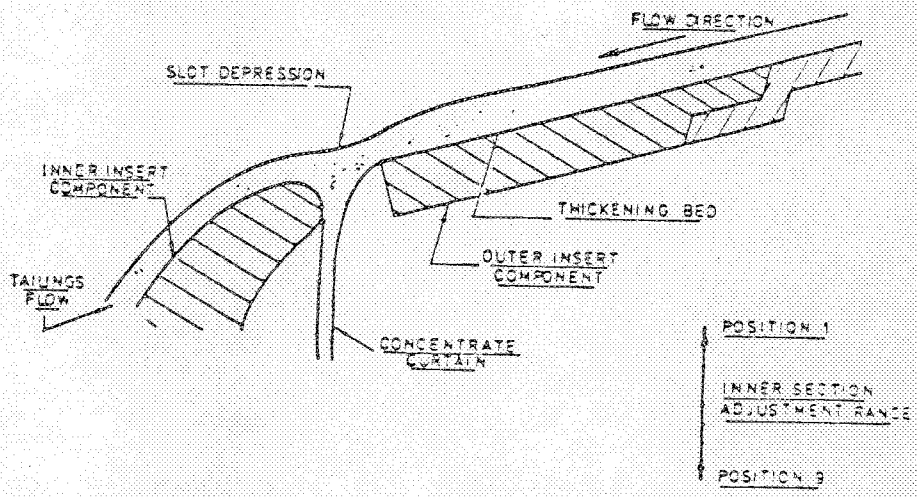
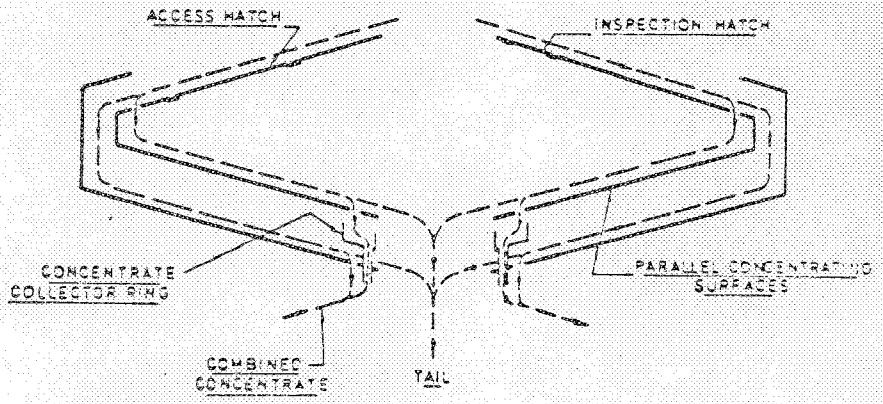
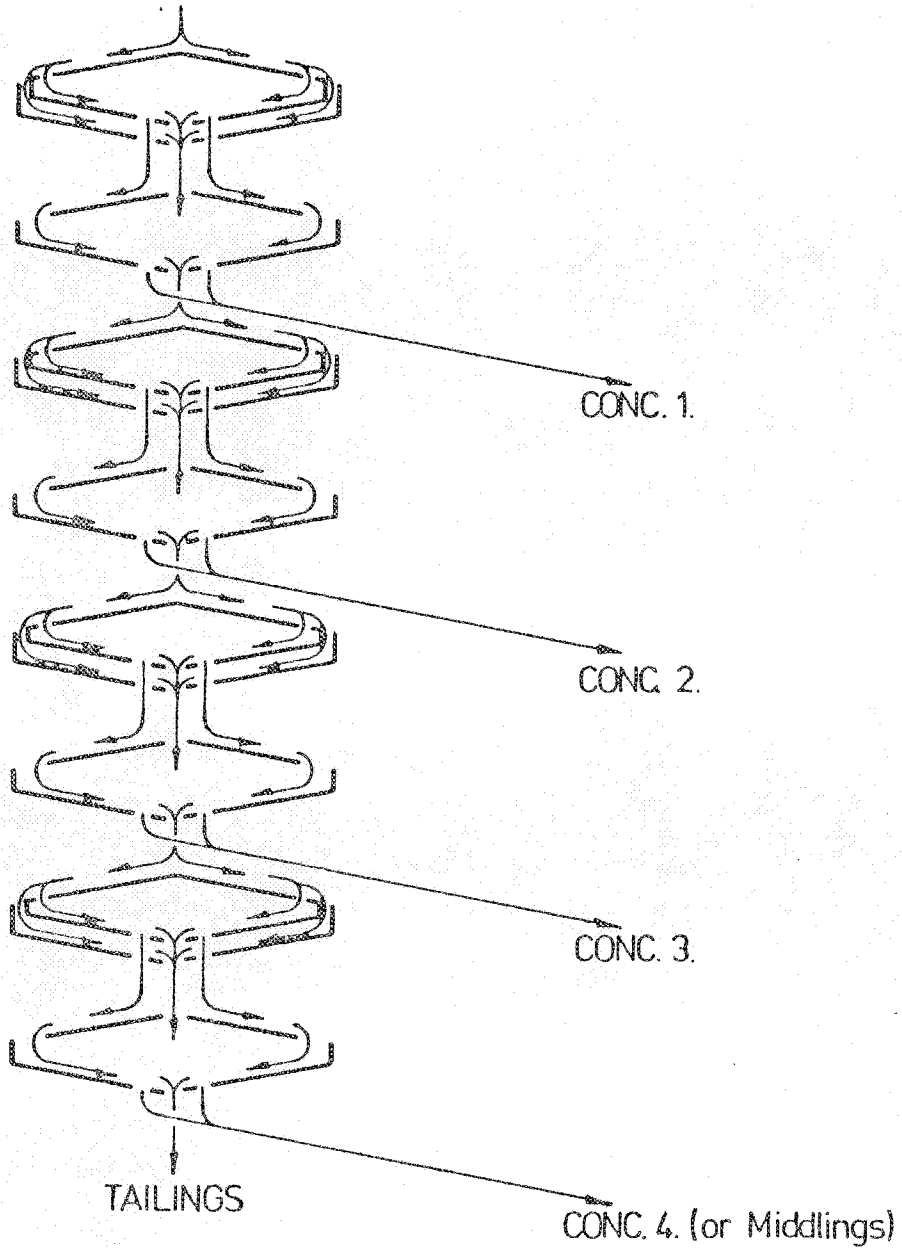
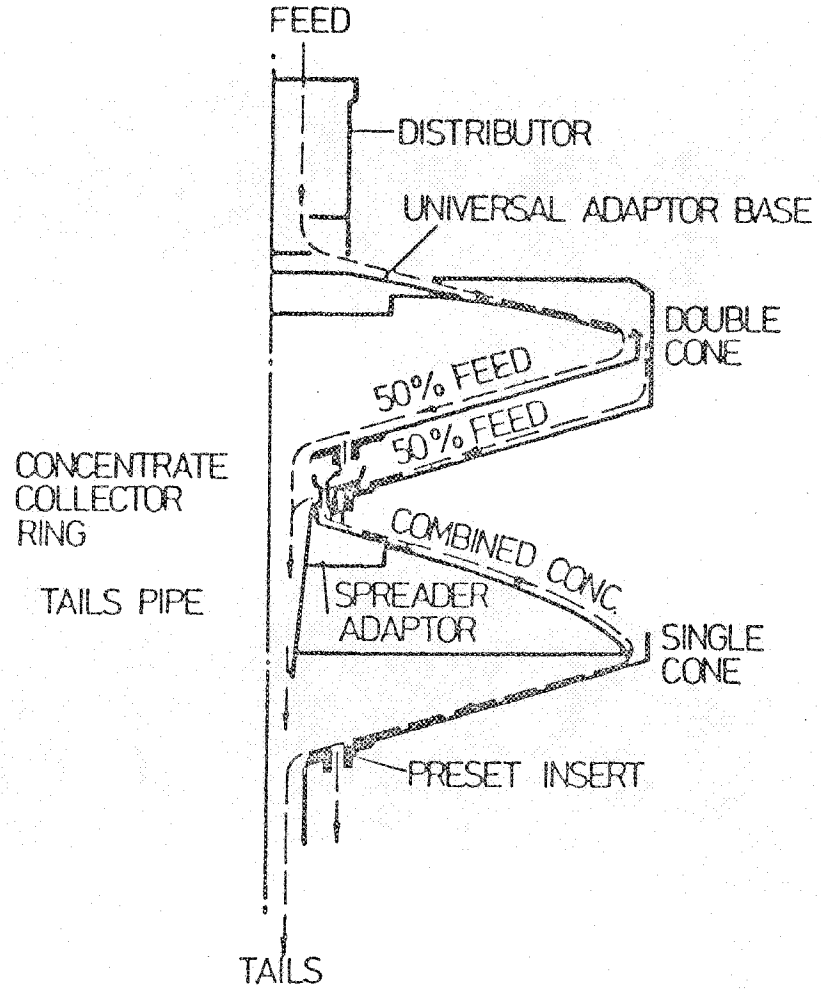


DIAGRAM 2.3
DOUBLE CONE ASSEMBLY



REICHERT CONE CONFIGURATION USED FOR THE ROUGHER AND SCAVENGER CIRCUIT IN BOTH PILOT AND FULL SCALE PLANTS.





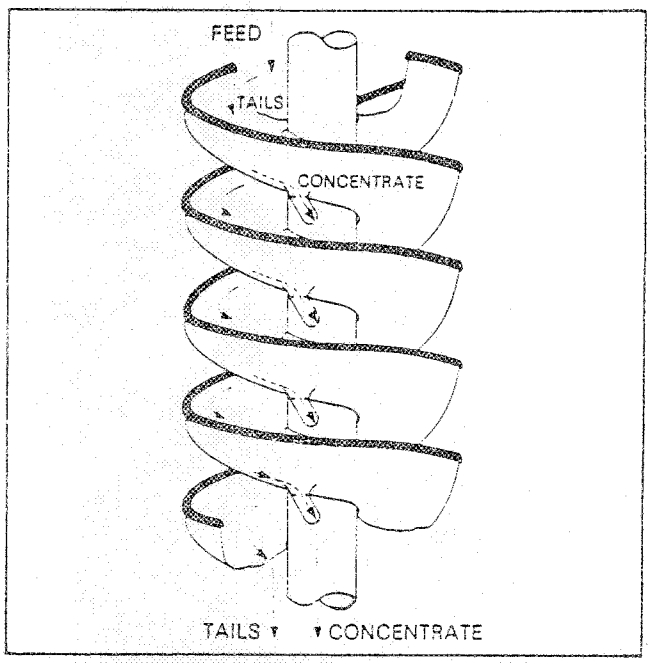
REICHERT CONE CONCENTRATOR

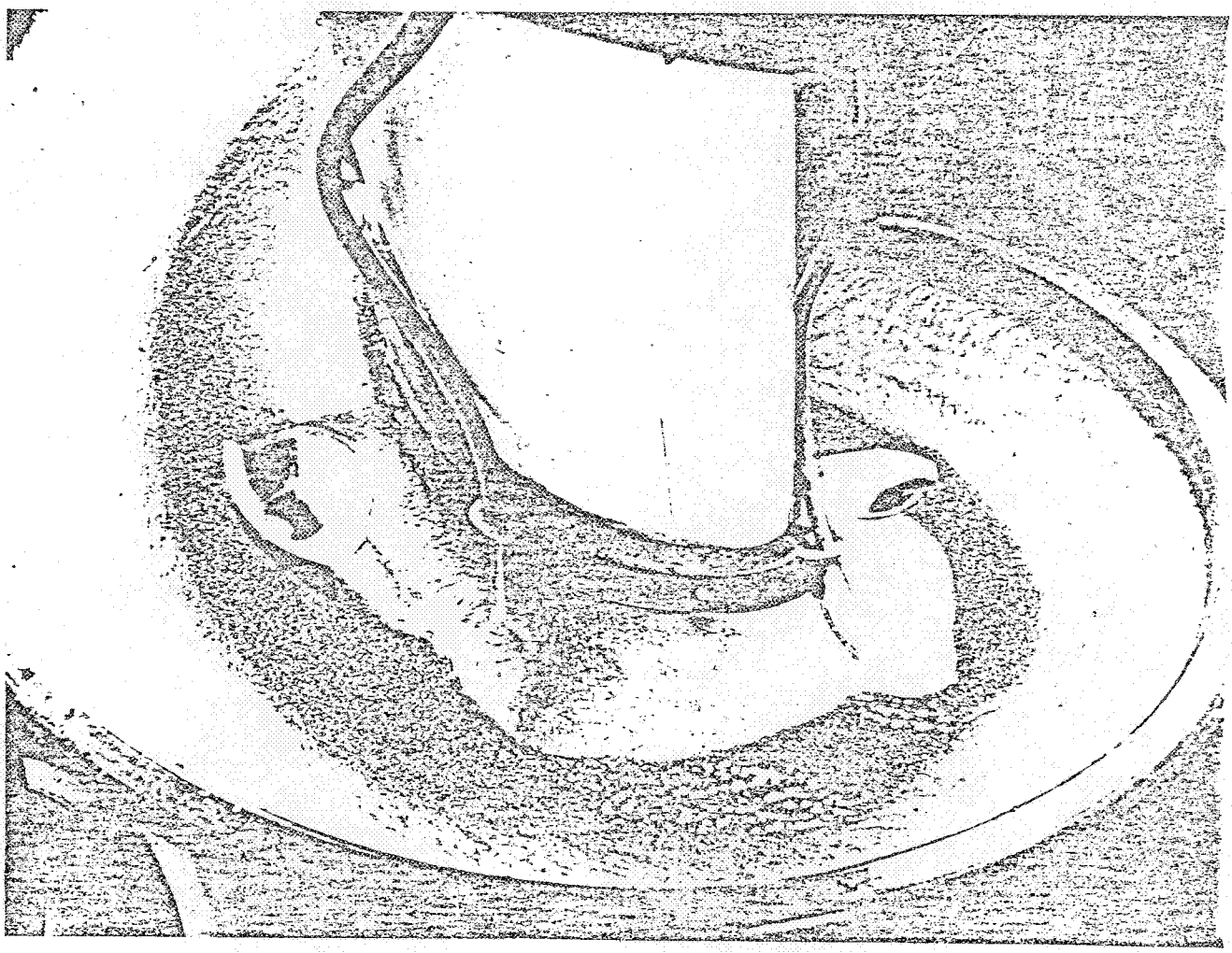
REICHERT CONE CONCENTRATOR

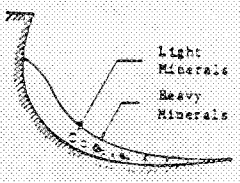
Reichert Cone Concentrators installed in Mineral Deposits Limited's Research and Engineering Department's test stand. Other equipment in the test stand includes full size spiral separators, shaking tables and separation units.

The diagram at right indicates the movement of pulp within the Reichert twin spiral.

The illustration below shows the function of the splitting device and washwater system incorporated in the new Reichert spiral concentrators.

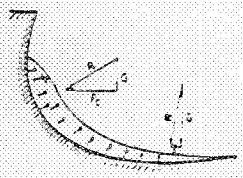






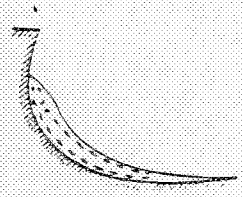
SIZING AND BANDING OF MINERALS IN THE SPIRAL

FIGURE 3



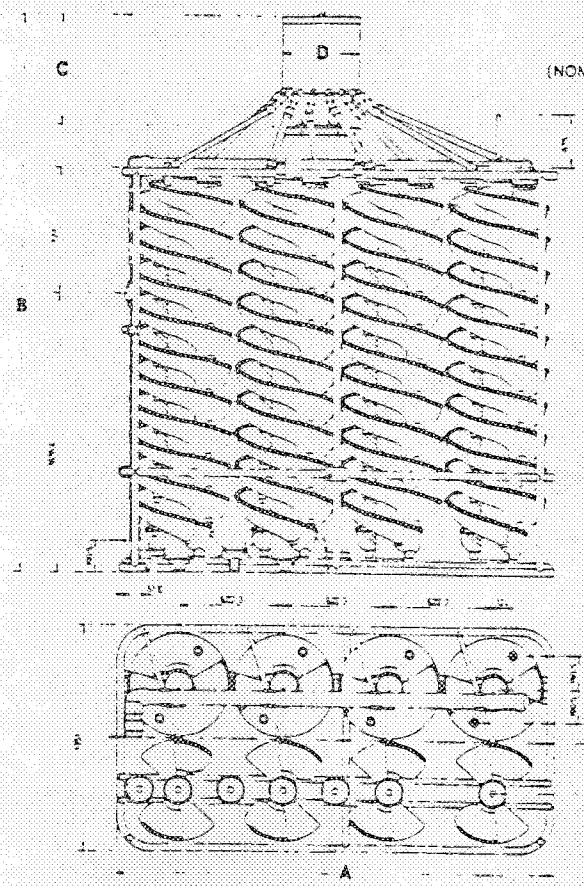
FREE SETTLING PHASE OF THE SEPARATION

FIGURE 2

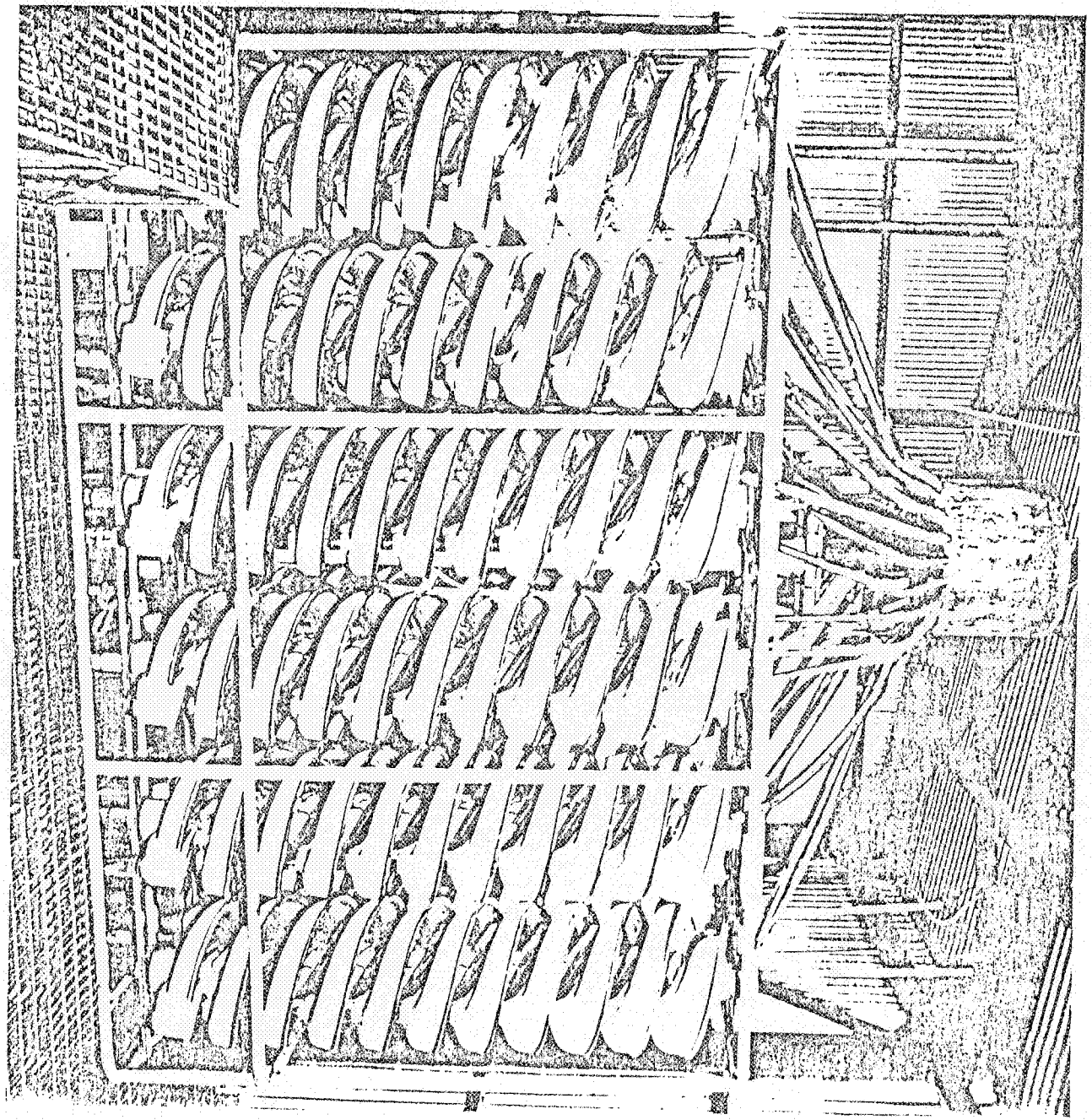


CROSS-SECTIONAL FLOW

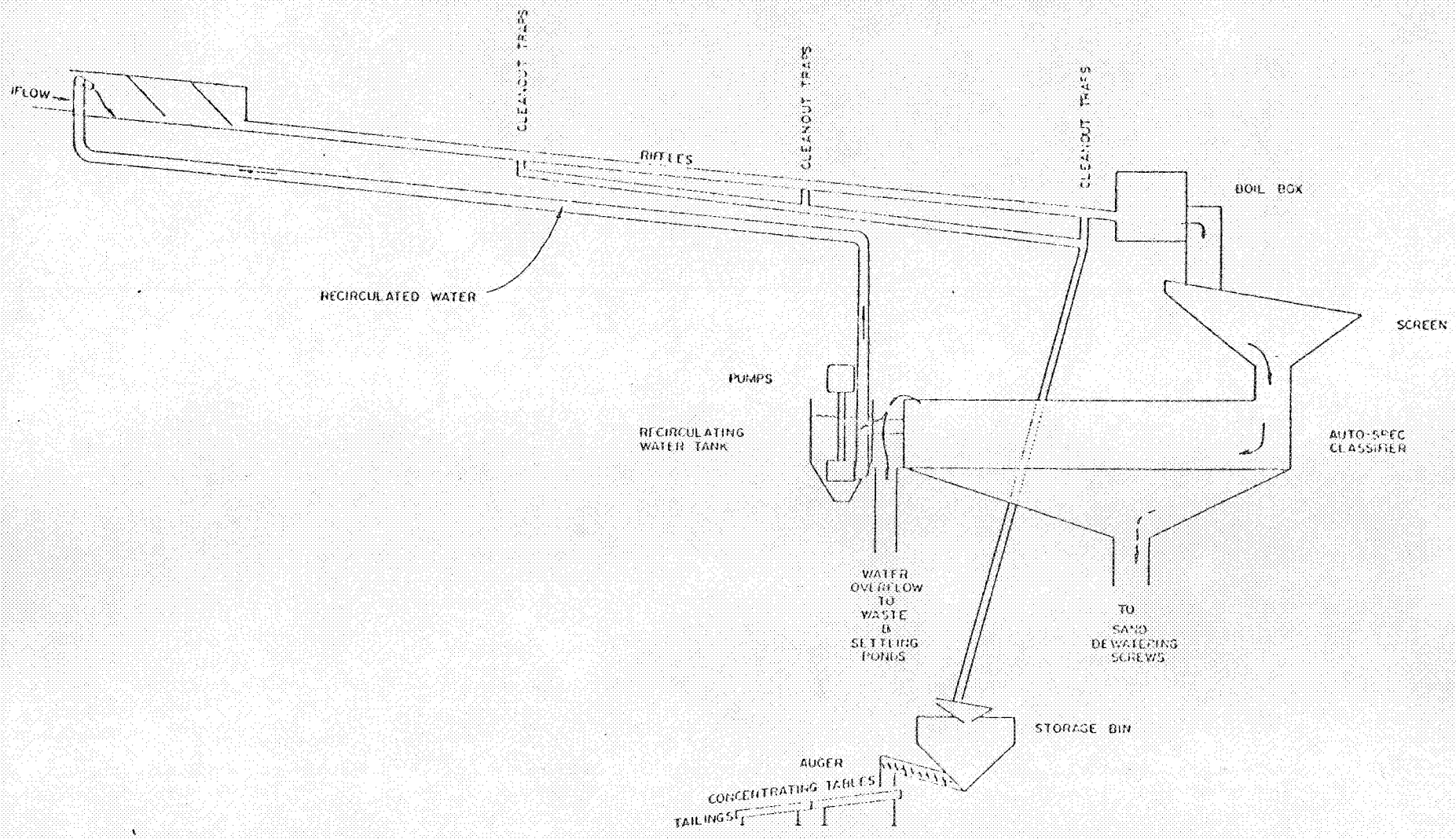
FIGURE 4

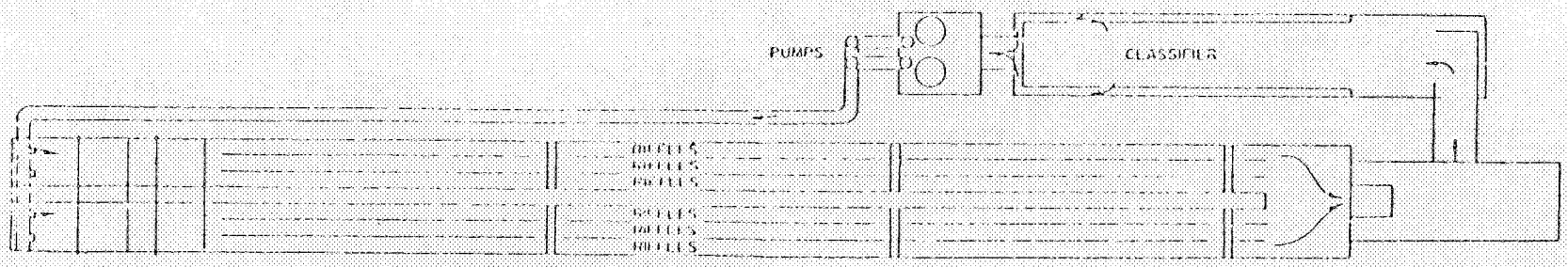


Spirals, with the exception of the two spiral unit, are packed for shipment mounted on a wooden base and covered with a corrugated metal tank. Ancillary equipment for these spirals is packed in two separate containers and despatched with the main unit.
The two spiral unit is packed for shipment in a wooden crate with all ancillary equipment.

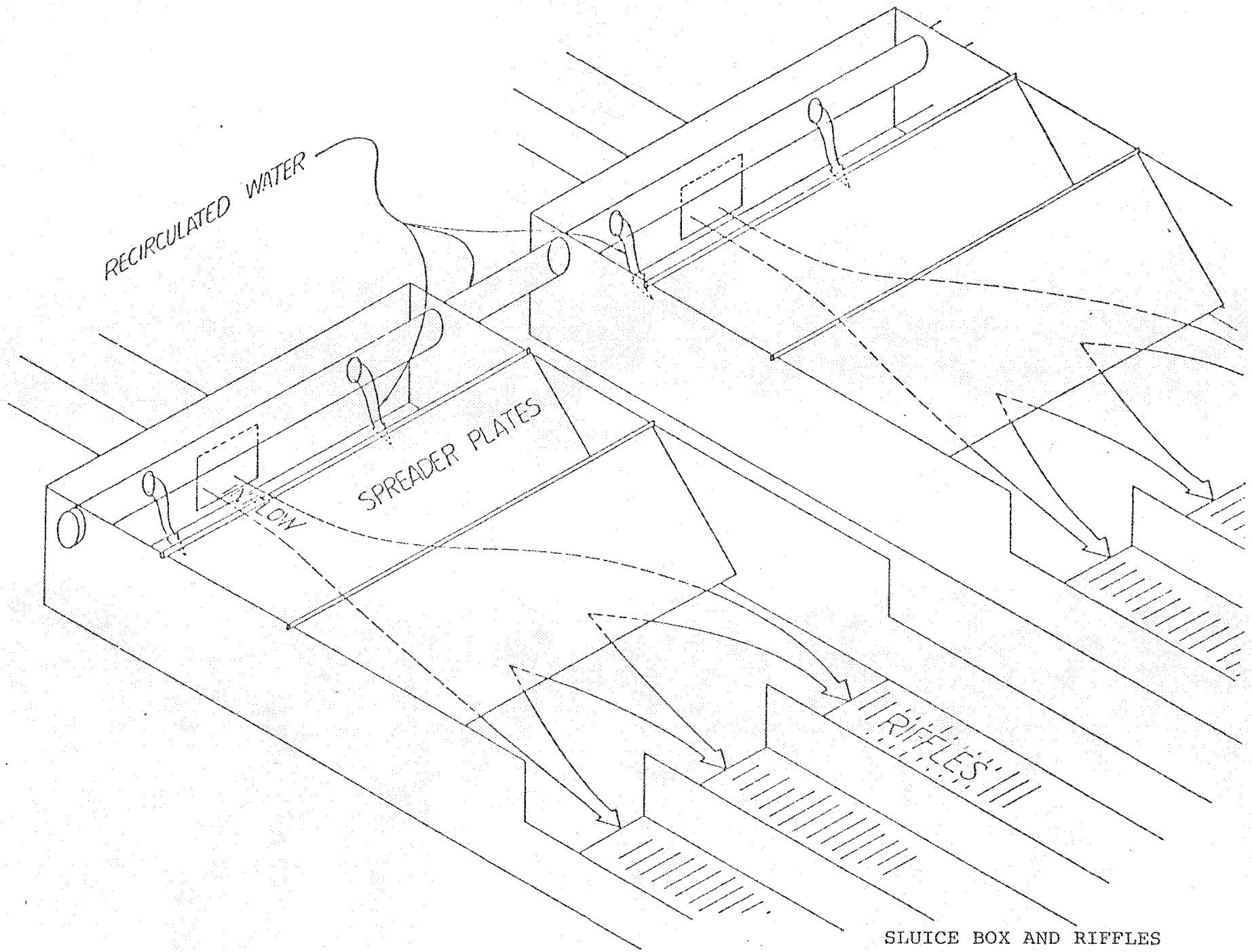


SPIRALS

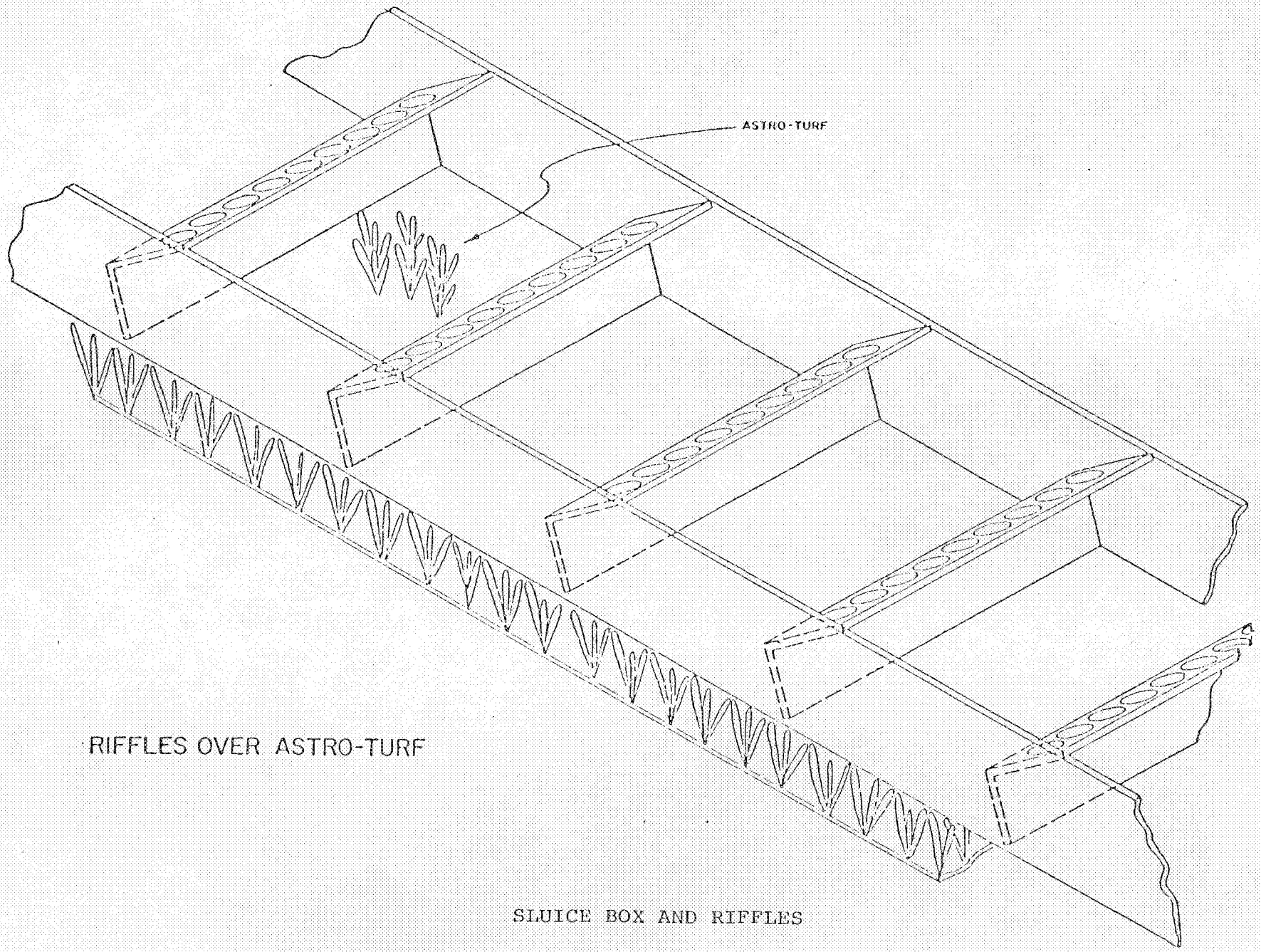




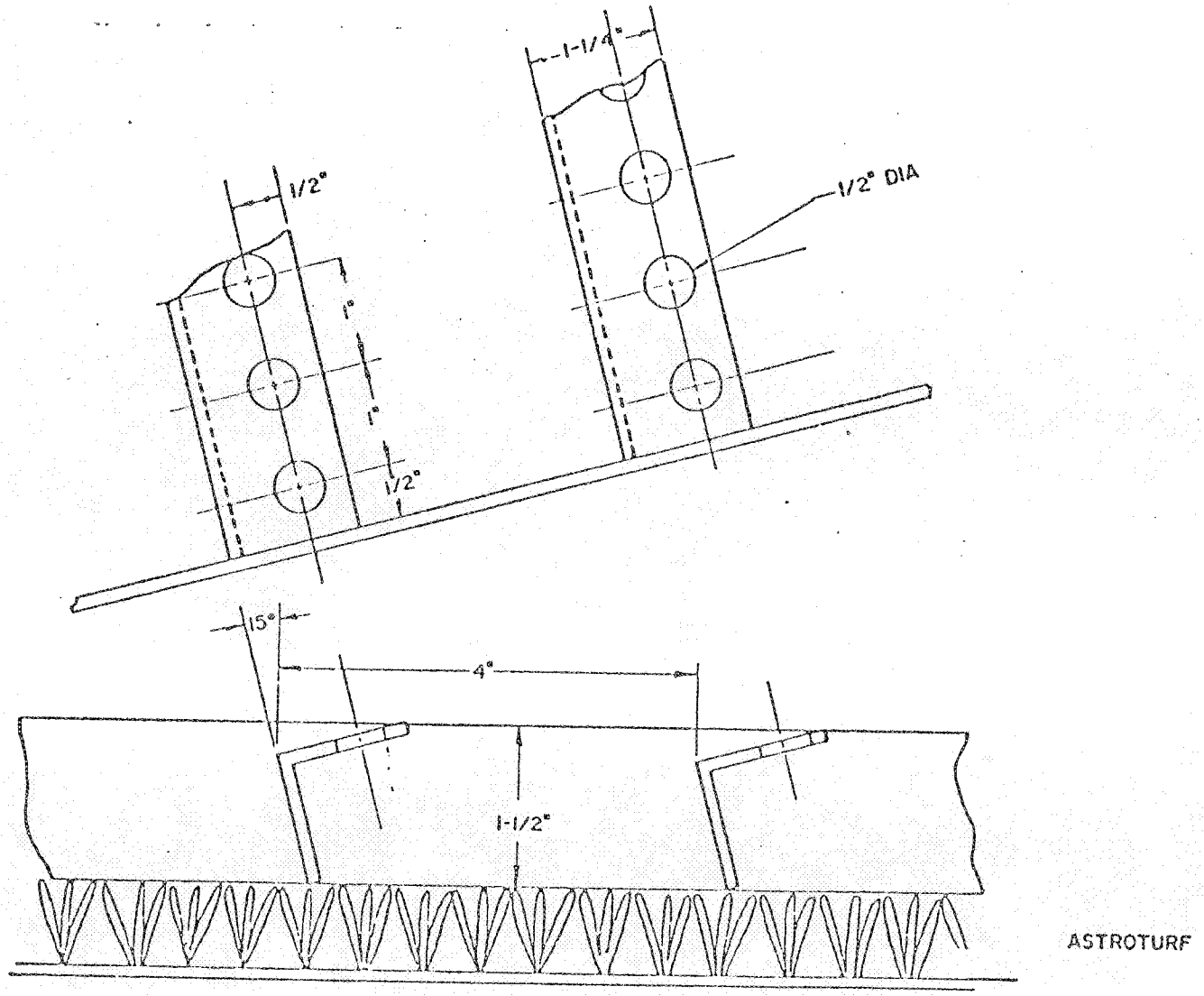
SLUICE BOX AND RIFFLES



SLUICE BOX AND RIFFLES



SLUICE BOX AND RIFFLES

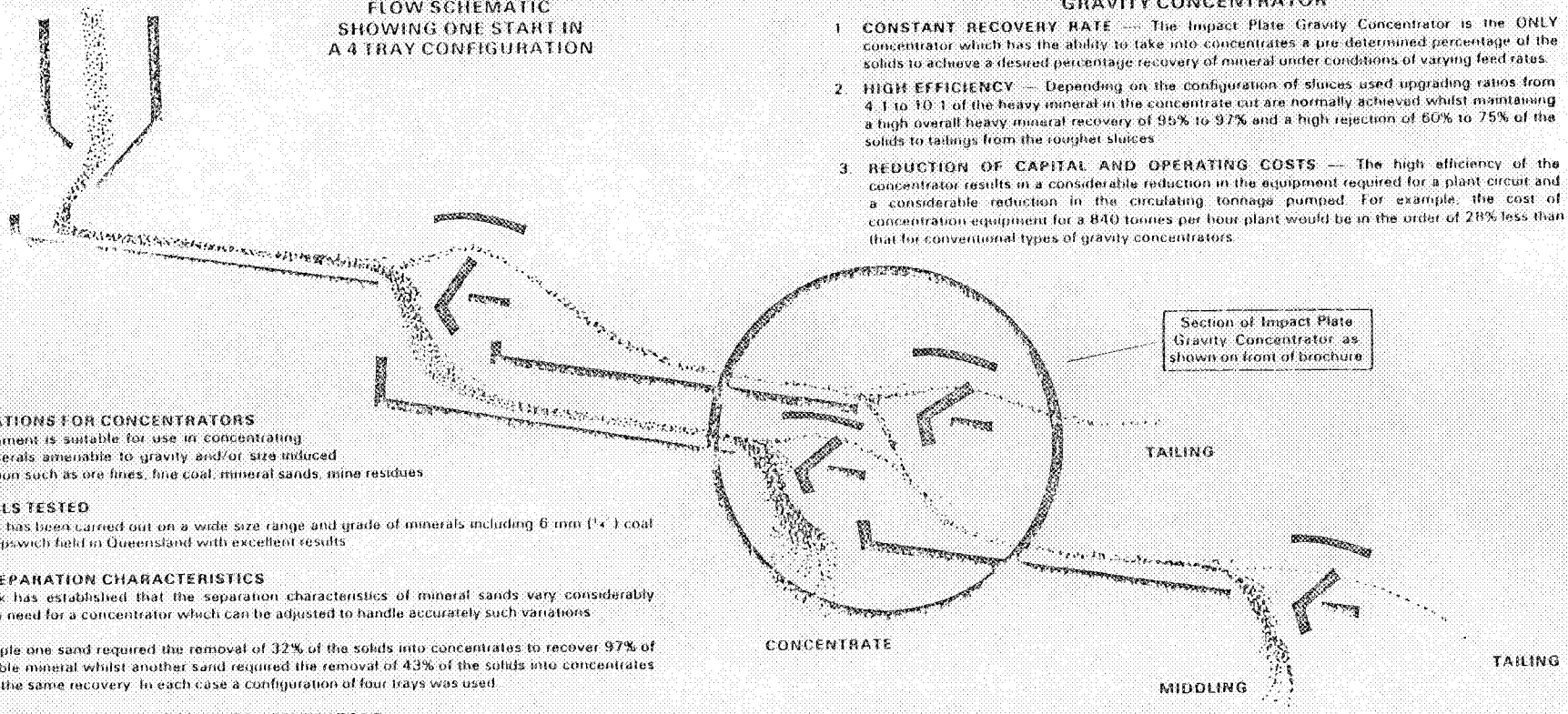


RIFFLE DETAIL

SLUICE BOX AND RIFFLES

THE WRIGHT IMPACT PLATE GRAVITY CONCENTRATOR

PRODUCT DISTRIBUTION FLOW SCHEMATIC SHOWING ONE START IN A 4 TRAY CONFIGURATION



PRINCIPAL ADVANTAGES OF THE IMPACT PLATE GRAVITY CONCENTRATOR

1. **CONSTANT RECOVERY RATE** — The Impact Plate Gravity Concentrator is the ONLY concentrator which has the ability to take into concentrates a pre determined percentage of the solids to achieve a desired percentage recovery of mineral under conditions of varying feed rates.
2. **HIGH EFFICIENCY** — Depending on the configuration of sluices used upgrading ratios from 4:1 to 10:1 of the heavy mineral in the concentrate cut are normally achieved whilst maintaining a high overall heavy mineral recovery of 95% to 97% and a high rejection of 60% to 75% of the solids to tailings from the roughet sluices.
3. **REDUCTION OF CAPITAL AND OPERATING COSTS** — The high efficiency of the concentrator results in a considerable reduction in the equipment required for a plant circuit and a considerable reduction in the circulating tonnage pumped. For example, the cost of concentration equipment for a 840 tonnes per hour plant would be in the order of 28% less than that for conventional types of gravity concentrators.

APPLICATIONS FOR CONCENTRATORS

The equipment is suitable for use in concentrating many minerals amenable to gravity and/or size induced stratification such as ore fines, fine coal, mineral sands, mine residues.

MINERALS TESTED

Test work has been carried out on a wide size range and grade of minerals including 6 mm (¼") coal from the Ipswich field in Queensland with excellent results.

SAND SEPARATION CHARACTERISTICS

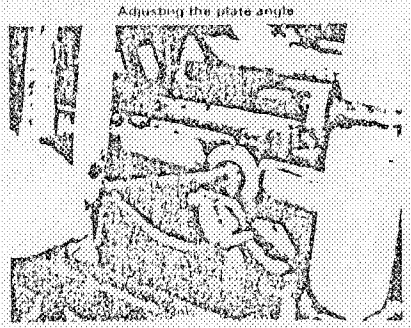
Test work has established that the separation characteristics of mineral sands vary considerably hence the need for a concentrator which can be adjusted to handle accurately such variations.

For example one sand required the removal of 32% of the solids into concentrates to recover 97% of the valuable mineral whilst another sand required the removal of 43% of the solids into concentrates to obtain the same recovery. In each case a configuration of four trays was used.

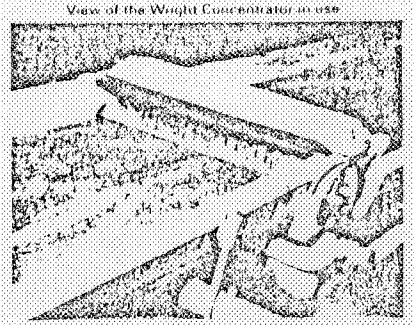
USERS OF IMPACT PLATE GRAVITY CONCENTRATORS

Companies already using the concentrator to treat mineral sands include Consolidated Rutile Ltd and Cudgen R.Z. Ltd. An order from Kibuka Mines operating on King Island is currently being filled.

Adjusting the plate angle



View of the Wright Concentrator in use

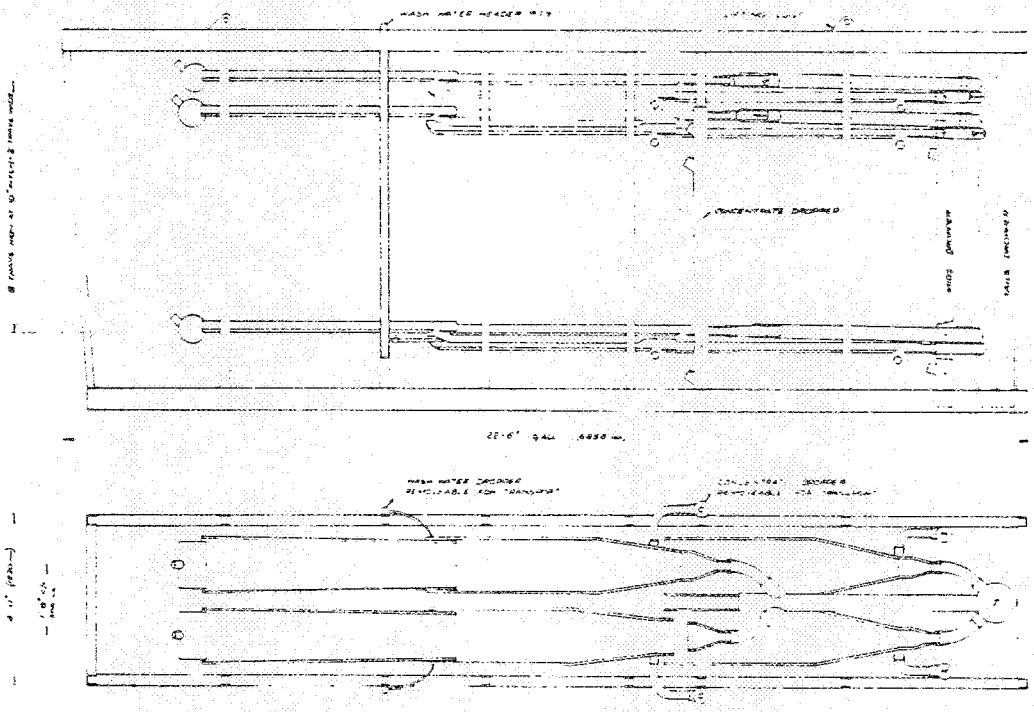


4. **TRASH REJECTION** — Vegetable matter such as roots, leaves, fine gravel, etc. are rejected to tailings and do not lodge in the slot openings as with some concentrators. This is an essential aspect of machine utilisation.
5. **ADJUSTABILITY** — The impact plate setting can be readily and accurately adjusted to achieve and maintain a high recovery of minerals depending on the characteristics of the material being treated.
6. **ON STREAM SAMPLING** — The products from each individual sluice can be readily sampled under operating conditions.
7. **VERSATILITY** — The concentrator sluices can be assembled in various configurations for treating low or high grade deposits to meet the various characteristics of specific minerals.
8. **WASH WATER REDUCTION** — The necessity to apply wash water in the majority of trays to correct the pulp density, as is normal in the conventional machine, is eliminated and it is only necessary to take this corrective action on tray 3 when utilising the Impact Plate Gravity Concentrator.
9. **ELIMINATION OF PICCOLO TUBES** — Wash water is applied by means which are not subject to blockage by fibrous particles or scale.

WRIGHT IMPACT PLATE
GRAVITY SEPARATOR

AUSTRALIAN PATENT APPLICATION 52818/73 — OVERSEAS PATENTS PENDING

WRIGHT IMPACT PLATE
GRAVITY SEPARATOR



WRIGHT CONCENTRATOR MODEL 4A
16 START BANK

GENERAL DETAILS:

Dimensions of bank of trays 16 starts x 4 trays per start 6858 mm x 2820 mm x 1220 mm
22ft 6ins x 9ft 3ins x 4ft 0ins

Weight of steel work (16 starts x 4 trays per start) 1545 kg (3,400 lbs.)

Weight of 4 trays 29 kg (64 lbs.)

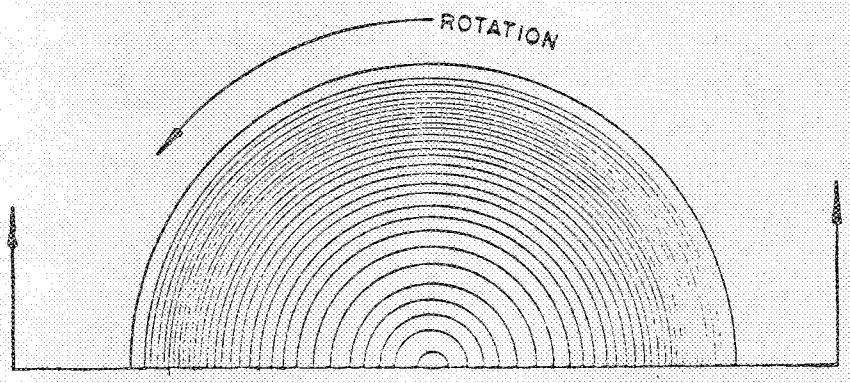
Wash water requirements per start. 12 litres (2 64 gallons) per minute (approx.)

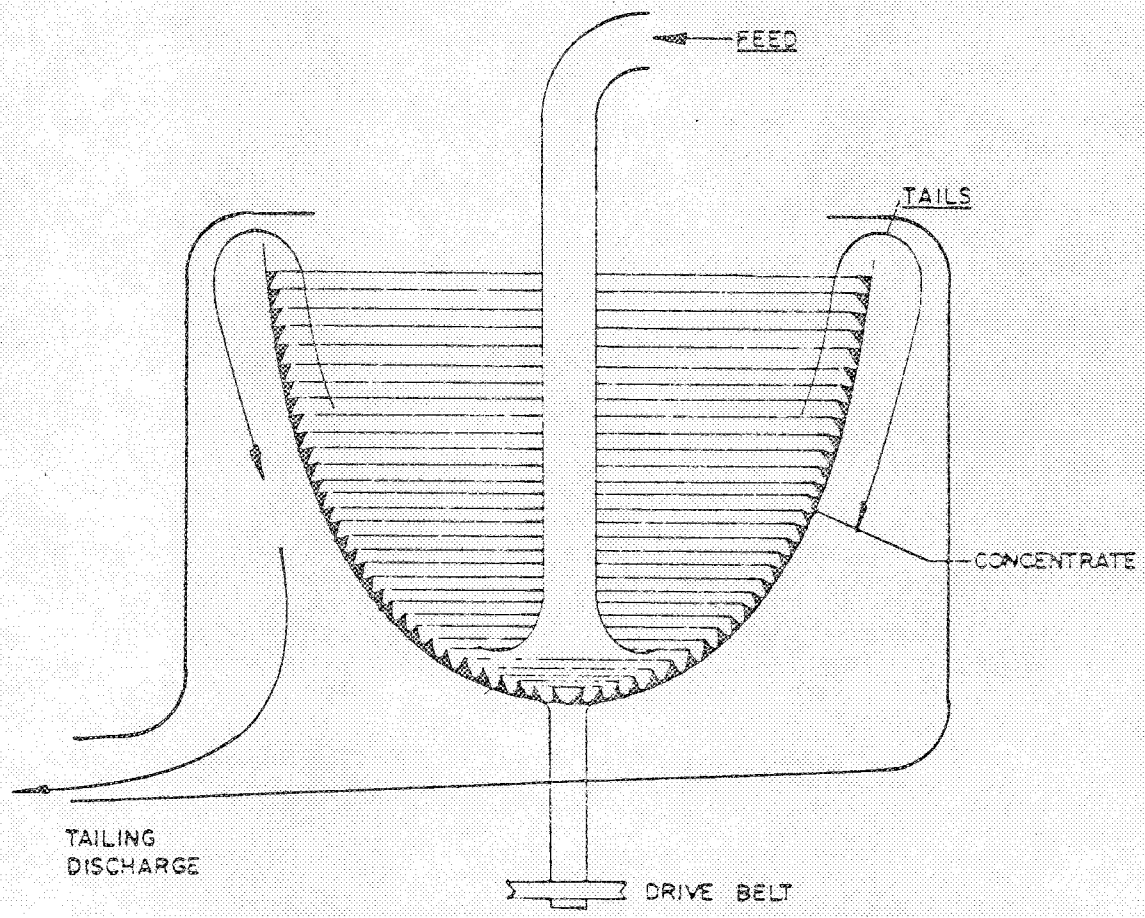
Our Laboratory is fully equipped to carry out tests on representative samples. Approximately 3 tonnes (10 x 44 gallon drums) is required for full scale flowsheet design. The sample should be indicative of the main ore body.

READINGS OF LISMORE PTY. LTD.

P.O. BOX 161, LISMORE, NEW SOUTH WALES 2480, AUSTRALIA

TELEPHONES: LISMORE 21 2478 (3 lines) and 21 6159





AINLAY KND KNUDSEN TYPE BOWLS

COMPACT • HIGH YIELD • HIGH THROUGHPUT

BARTLES-MOZLEY ORBITAL GRAVITY CONCENTRATOR

Economically Recovers Particles Down to 5 Microns . . . From Dilute Pulps, Slimes and Tailings, Industrial Wastes and Effluents

CASSITERITE • COLUMBITE • GOLD • MICAS • PLATINUM • RARE EARTHS • RUTILE • SCHEELITE
TANTALITE • WOLFRAMITE • ZIRCON • FINE METAL PARTICLES • HEAVY CHEMICALS

UNIQUE DESIGN

The Bartles-Mozley concentrator table is unique being capable of economical recovery of fine mineral particles from dilute pulps. The table is a compact, tilting frame gravity concentrator consisting of two assemblies, each of 20 fibreglass decks, which are freely suspended in a rigid frame. A layer of particles in water (pulp) is flowed down each of the inclined decks (1°–3°) to which a controlled orbital motion is imparted. This orbital motion is adjusted by moving an adjustable eccentric weight mounted on a shaft located between the two deck assemblies. It is driven by a small variable speed motor (Fig. 1).

Shear forces are generated in a plane parallel to the plane of the flowing pulp film which can be adjusted to promote selective settlement of the heavier finer particles onto the decks in the 5-80/100 microns size range, as required.

The lighter and larger particles are not collected. The decks are pneumatically-tilted automatically at selected intervals and the collected concentrate washed off.

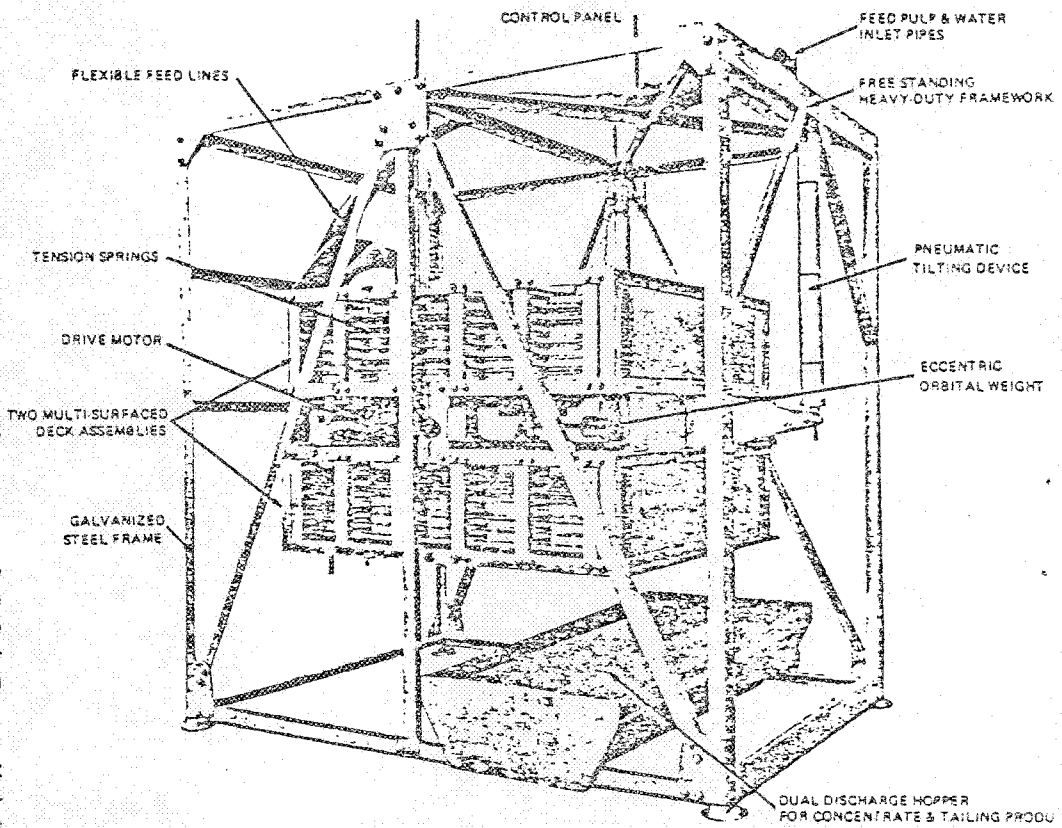


Fig. 1 – STANDARD BARTLES-MOZLEY ORBITAL GRAVITY CONCENTRATOR

The important parameters which must be investigated and optimized for each particular material are orbital speed, eccentric weight and amplitude; deck slope, pulp feed rate and process cycle times for feed, drain and wash. Once established, only an adjustment in the speed is usually required for a given pulp flow rate.

The Bartles-Mozley table is a preconcentrator and the concentrate obtained is usually amenable to further treatment to yield a marketable product by employing flotation, magnetic separation, shaking tables, leaching or high tension separation, etc. The process or processes are selected according to the composition and associated minerals present in the Bartles-Mozley concentrate and the end product requirements. Without the Bartles-Mozley treatment, the economical recovery of the fine heavy values is not possible or feasible. Overall ratios of concentration of treatment systems employing the Bartles-Mozley table may be 500:1 or more.

METALLURGICAL FEATURES

- High recovery of fine heavy particles down to 5 microns.
- High throughout of about 3 tons/hour or more of solids.
- Efficient handling of dilute pulps and low grade feeds.
- Ratio of concentrations up to 10 or more.
- In addition to preconcentration, Bartles-Mozley table will deslime; remove soluble salts and dissolved chemicals; dewater and assist in control of circuit water; separate coarse from fine particles.
- Numerous applications for recovery of heavy mineral values from lode ores; secondary values from flotation tailing; retreatment of tailing dumps; oxides and tarnished sulphides; middling products, pyrite from fine coal.
- Many potential applications in the chemical and allied industries, and in general industry for the recovery of metals, alloys and chemicals from residues, effluents and waste products.
- Process engineering services available to develop integral treatment systems.

DESIGN AND OPERATIONAL FEATURES

- 800 square feet of fibreglass separation surfaces.
- Automatic operation – minimal attention from operators.
- Free standing assembled units, no vibrations – no foundation required.
- Easy adjustment of operating variables.
- Synchronous process timers and pneumatic tilt system.
- Robust construction – rigid galvanized frame.
- Power, water and compressed air consumptions are very small – negligible operating/maintenance costs.
- Multiple units available with sequential timing systems designed to meet customer's requirements.
- Auxiliary equipment can be supplied for use in the overall treatment system, including screens, shaking tables, magnetic separators, etc.
- Engineering services available for preliminary engineering and plant layout studies.

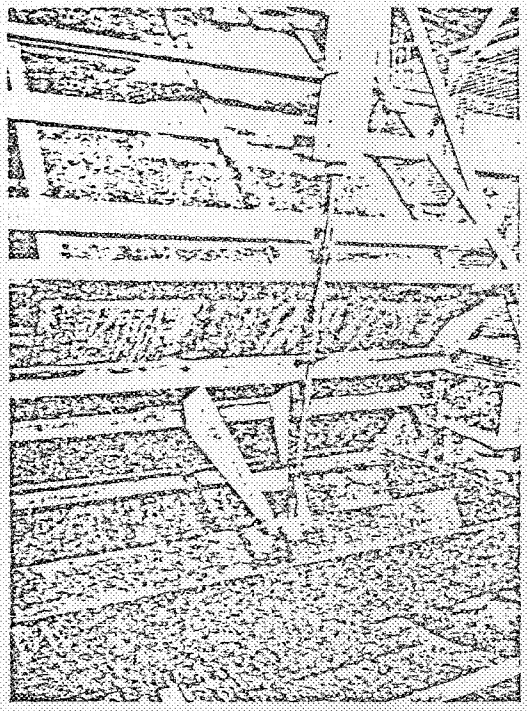


Fig. 7 – MACHINE IS IN TILT POSITION DURING DRAIN AND WASH CYCLES

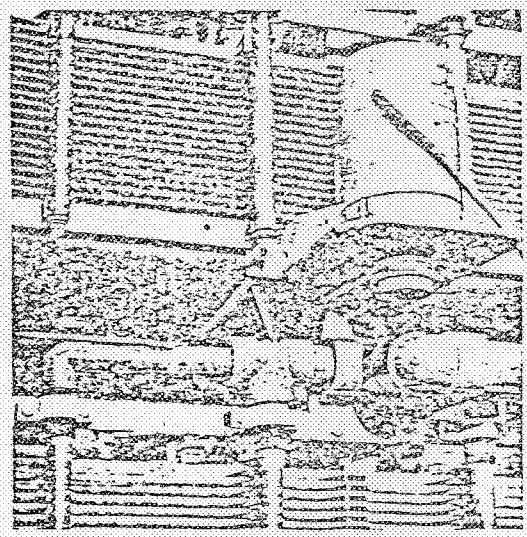


Fig. 8 – VIEW OF FEED LINES, DRIVE AND CLOSELY SPACED COLLECTING SURFACES

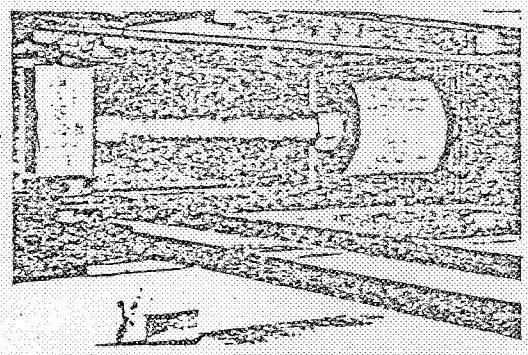


Fig. 9 – ADJUSTABLE, ECCENTRIC WEIGHT CONTROLS ORBITAL MOTION OF COLLECTING SURFACES

The Bartles-Mozley Concentrator patent has been assigned to the National Research Development Corporation (U.K.) with patent applications filed throughout the world. Exclusive world manufacturing rights have been granted to Bartles (Carn Brea) Ltd., a member of the BICC Group. Tennant is the exclusive agent for Bartles in North, Central and South America, and for Australia.

TYPICAL BARTLES–MOZLEY APPLICATIONS

1. Recovery of fine mineral values from lode ores of tin (cassiterite), tungsten (wolframite and scheelite), columbium and tantalum (columbite and tantalite); precious metals (gold, silver and platinum).
2. Retreatment of old mill tailing dumps and mine dumps for tin, tungsten, base metal oxides, precious metals and sulphide minerals recovery.
3. Recovery of secondary values from flotation tailings (tin, tungsten, base metal oxides or tarnished sulphides, etc.)
4. Recovery of fine hematite and magnetite from spiral tailings or for preconcentration ahead of flotation, etc., in iron ore benefication.
5. Sand-slime separation ahead of flotation retreatment of copper, lead-zinc or iron ore tailings.
6. Treatment of sulphide flotation middlings for desliming, dewatering and circuit water control, prior to recirculation.
7. Recovery of fine heavy particles from industrial and metallurgical waste products – slags, drosses, residues, flue dusts, scrap metal dusts, etc.
8. Preconcentration of oxide ores of copper, lead, zinc and to deslime ahead of leaching and/or flotation.
9. Recovery of copper cement from leach liquors.
10. Removal of pyrite and gangue from fine coals.

SPECIFICATIONS

The Bartles Mozley table is a free-standing, compact machine which is shipped normally as a complete unit, ready for installation. No foundation or special bases are required since there are no vibrations. Each unit is supplied complete with variable speed motor, electrical controls, synchronous timers and pneumatic controls for the process timing and tilting systems. The overall size of the standard machine is approximately 6' x 8' x 9' high. Its net weight is only 2,900 pounds, with an approximate crated shipping weight of 3,900 pounds.

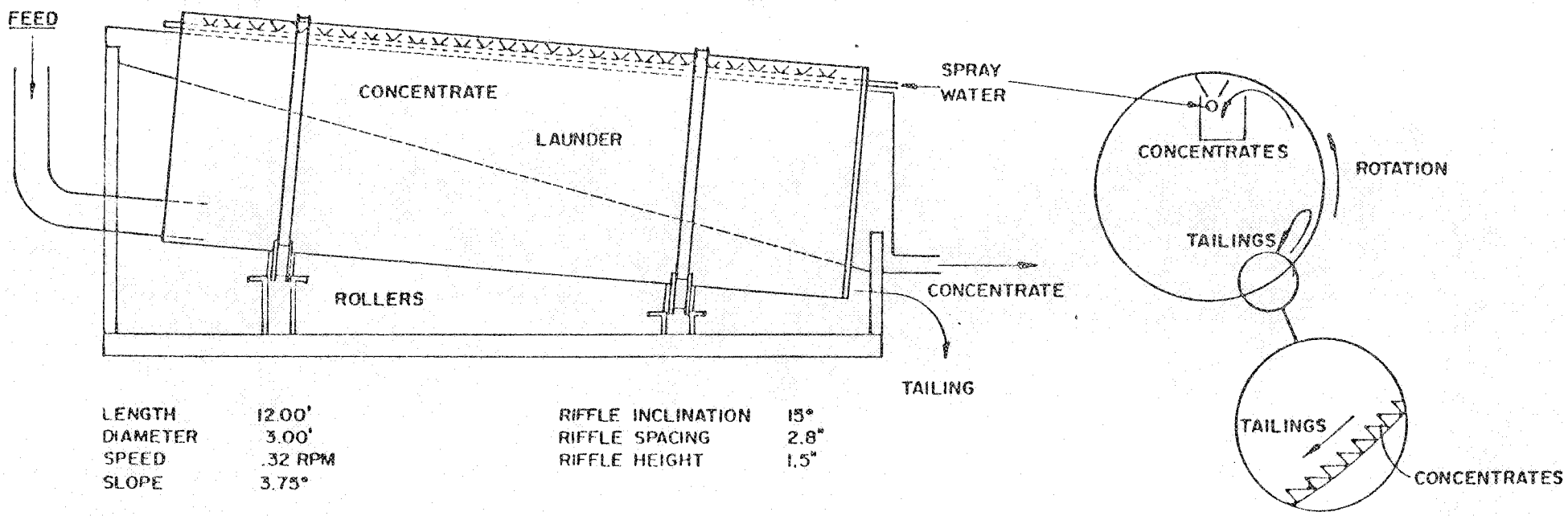
For installations requiring a large number of Bartles-Mozley tables, independent control systems can be provided to permit sequential timing and tilting from a central point for a number of tables to meet process and customer's requirements. *A pilot size table with four 2' x 5' decks is available with manual or automatic timing and tilting systems.*

The standard Bartles-Mozley table has been designed as a dual sandwich unit with 20 fibreglass decks of 4' x 5' size in each sandwich spaced ¼" apart, giving a total surface area of 800 square feet. Power requirements for the ½ HP variable speed motor are negligible. Water requirements for deck washing are small – 160 gallons per hour at a 80 GPM rate. 45/100 PSI compressed air is required to operate the pneumatic tilting systems. Full installation and operating instructions and recommended spare parts list are supplied with each unit.

LABORATORY AND PILOT PLANT FACILITIES ARE AVAILABLE IN NORTH AMERICA, AUSTRALIA AND IN ENGLAND.

We will be glad to analyze your concentation projects and offer our recommendation. Please complete the enclosed Bartles-Mozley Concentrator application data sheet and return a copy by air mail.

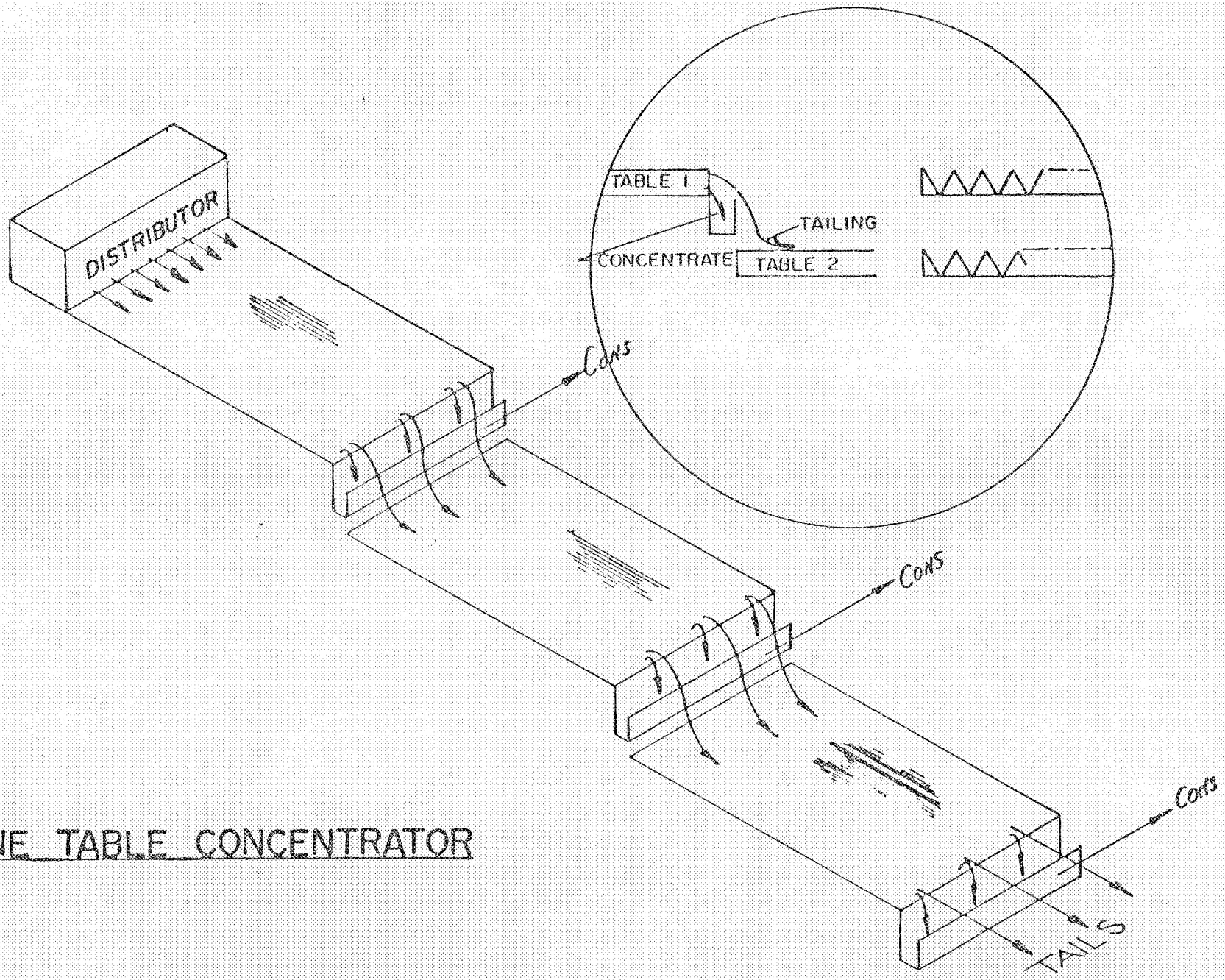
JOHNSON CYLINDER CONCENTRATOR



LENGTH	12.00'
DIAMETER	3.00'
SPEED	.32 RPM
SLOPE	3.75°

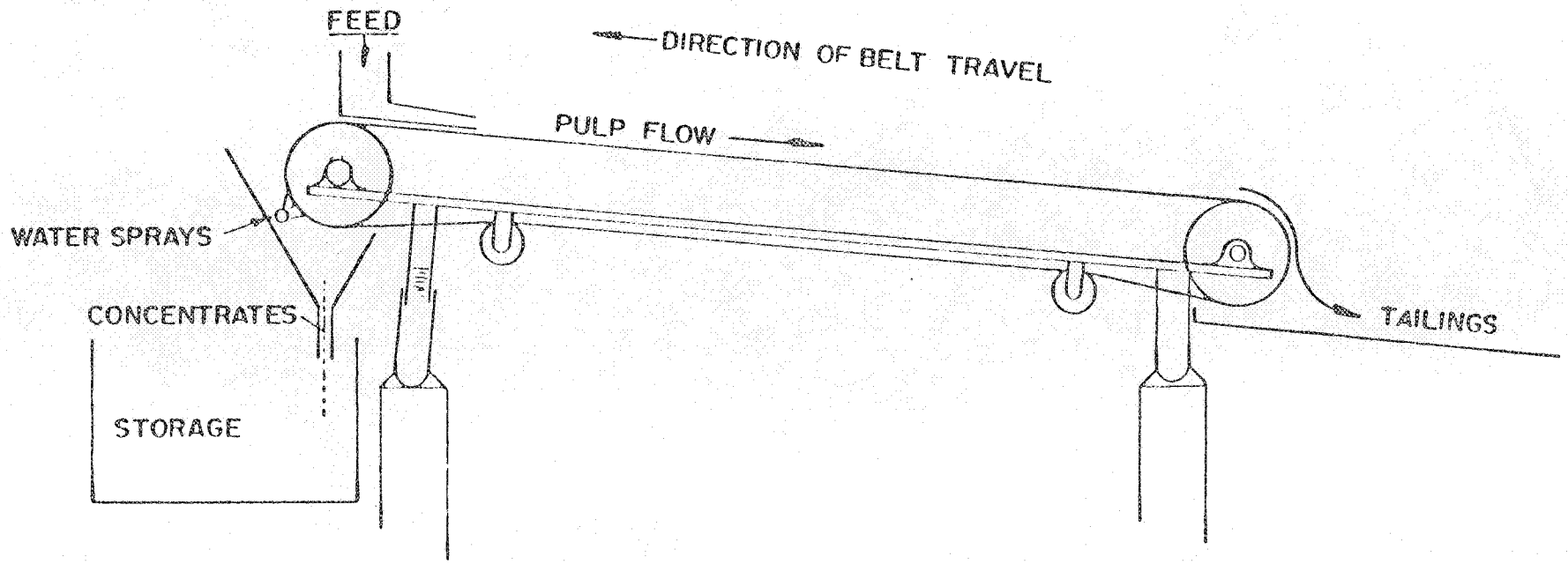
RIFFLE INCLINATION	15°
RIFFLE SPACING	2.8"
RIFFLE HEIGHT	1.5"

JOHNSON CYLINDER CONCENTRATOR



PLANE TABLE CONCENTRATOR

PLANE TABLE CONCENTRATOR



MOVING BELT CONCENTRATOR

MOVING BELT CONCENTRATOR

○ Float ⊗ Middling ● Sink High-gravity medium □ Low-gravity medium

GENERAL SPECIFICATION DATA

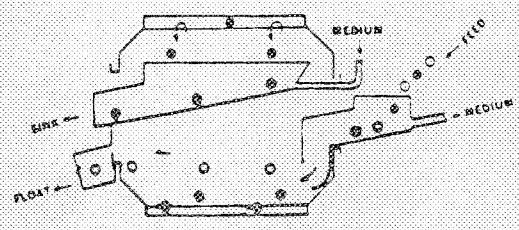
Single-gravity systems

Single drum

Sizes: 6' to 12' diameter

Capacities: to 400 tph

Power requirements: 5 to 20 hp



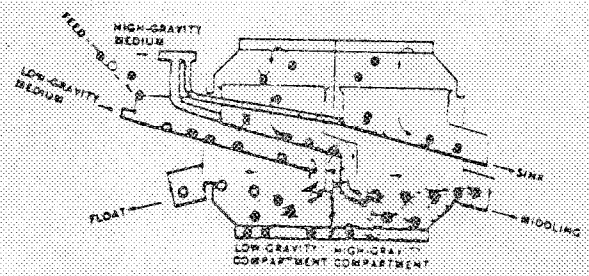
Single-gravity, two-product system with circular weir. Accommodates large particle sizes.

Single drum, dual overflow

Sizes: 6' x 11' to 15' x 23'

Capacities: to 900 tph

Power requirements: 10 to 30 hp



Dual-gravity, three-product system with optional weir sections.

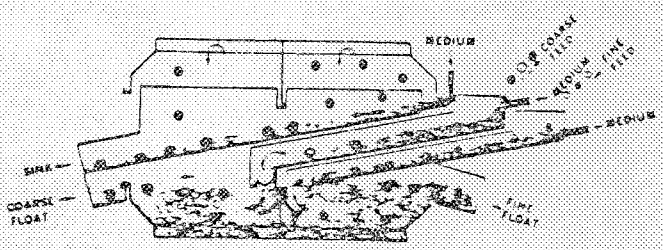
Dual-gravity systems

Dual-gravity, three-product drum

Sizes: 6' x 10' to 12' x 20'

Capacities: to 325 tph

Power requirements: 10 to 20 hp



Single-gravity, two-product system with rectangular weir. Provides large float capacity, classified feed.

Figure 3. Diagram of Drum Product Systems
(WEMCO DIVISION, ENVIROTECH CORPORATION)

○ Float ✕ Middling ● Sink ▨ High-gravity medium □ Low-gravity medium

General specification data

Single-gravity systems

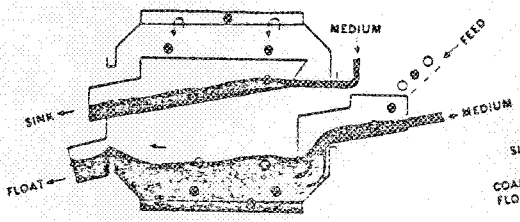
Single drum
Sizes: 6' to 12' diameter
Capacities: to 400 tph
Power requirements: 5 to 20 hp

Single drum, dual overflow
Sizes: 6' x 11' to 15' x 23'
Capacities: to 900 tph
Power requirements: 10 to 30 hp

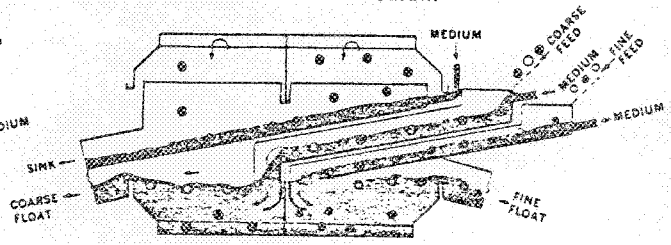
Dual-gravity systems

Dual-gravity, three-product drum
Sizes: 5' x 10' to 12' x 20'
Capacities: to 325 tph
Power requirements: 10 to 20 hp

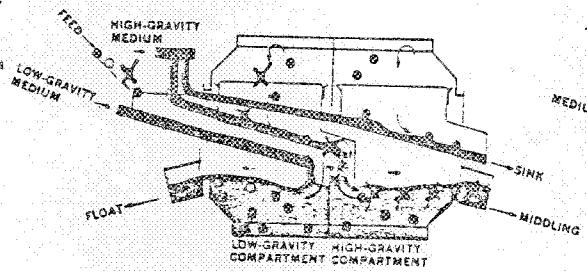
Dual-gravity, four-product drum
Sizes: 5' x 10' to 12' x 20'
Capacities: to 650 tph
Power requirements: 10 to 20 hp



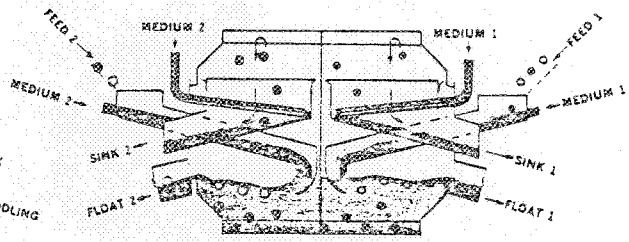
Single-gravity, two-product system with circular weir. Accommodates large particle sizes.



Single-gravity, two-product system with rectangular weir. Provides large float capacity, classified feed.



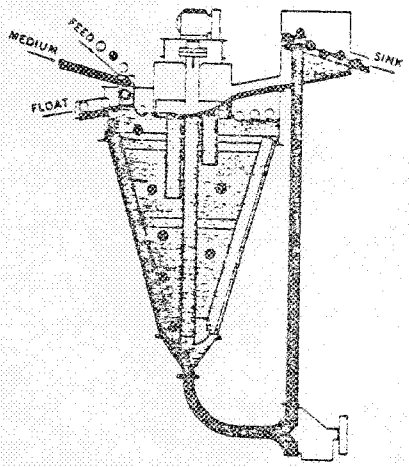
Dual-gravity, three-product system with optional weir sections.



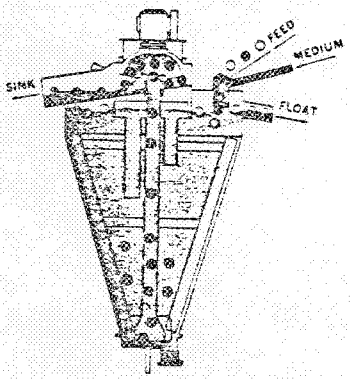
Dual-gravity, four-product system with independent media circuits and optional weir sections.

General specification data

Sizes: 3' to 20' diameter, measured at top of cone
Capacities: to 500 tph
Power requirements: ½ to 10 hp



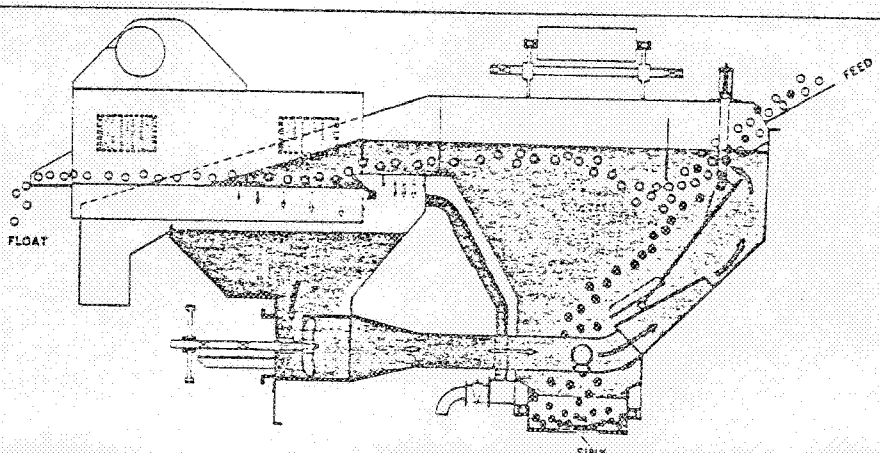
Single-gravity, two-product system with Torque-Flow-pump sink removal.



Single-gravity, two-product system with compressed-air sink removal.

General specification data

Sizes: 16' to 34' wide x 14' long
Capacities: 40 to 600 tph, depending on width and application
Power requirements: 15 to 100 hp



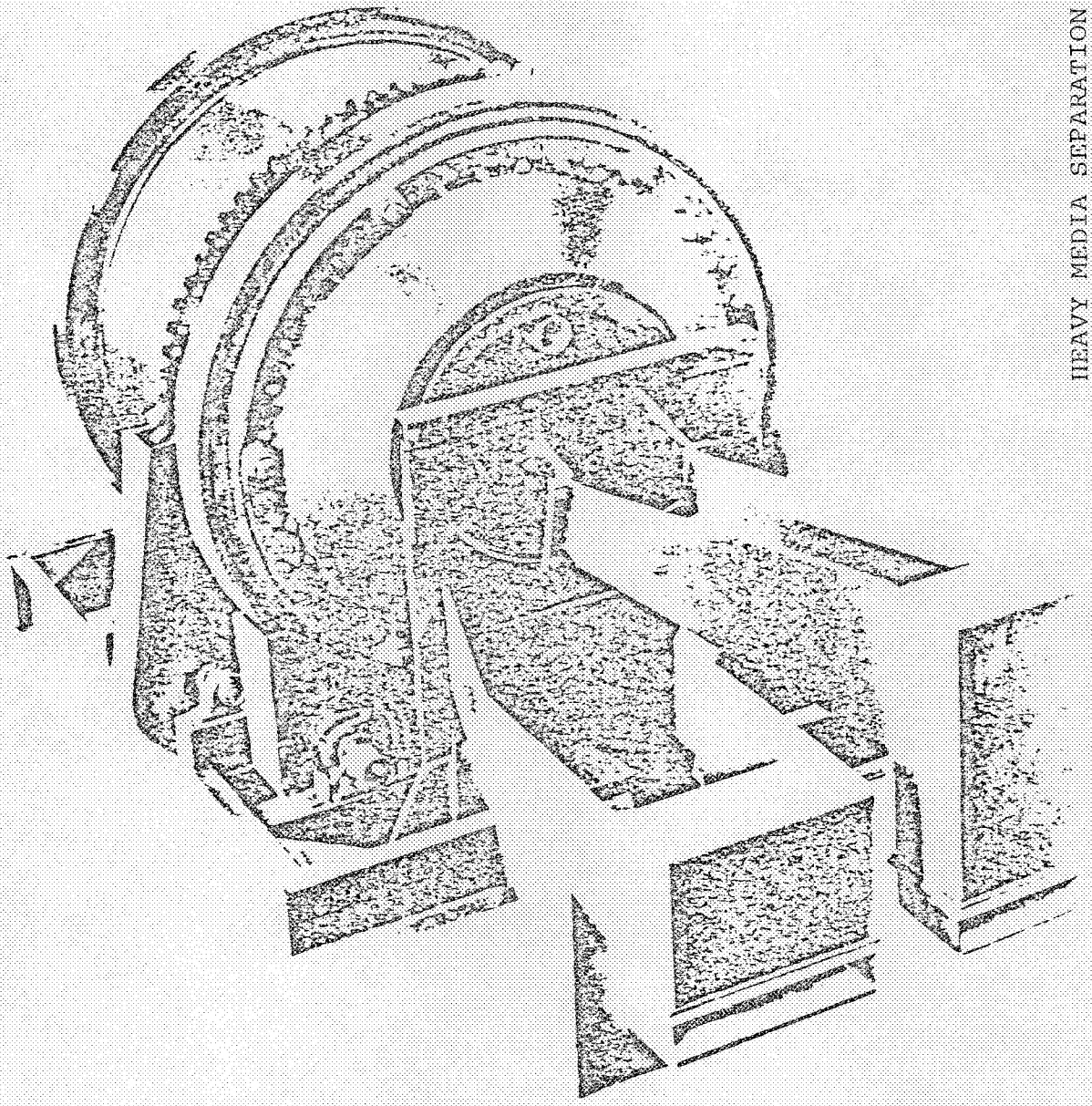


Figure 2. WEMCO H.M.S. Drum
(WEMCO DIVISION, ENVIROTECH CORPORATION)

Fig. 1—Hydrocyclone flow diagram

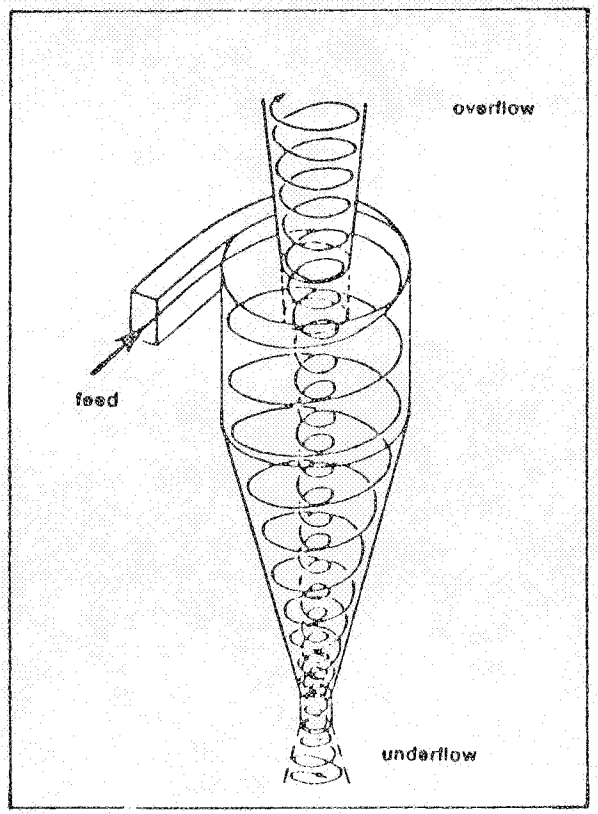
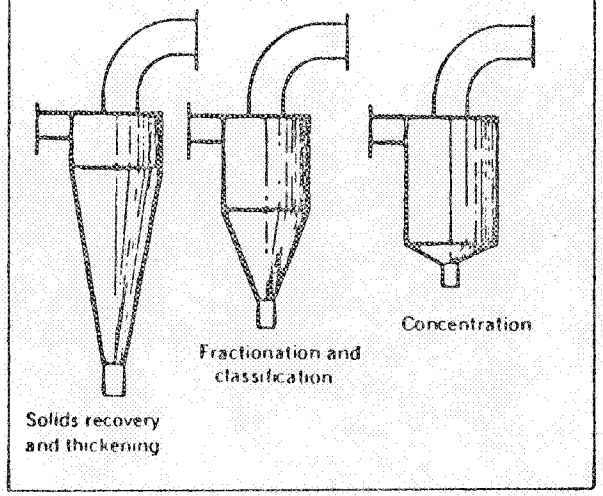



Fig. 9—Cyclone shapes and applications