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STUDY OF A STATIC SCREEN, JIG, SPIRAL, AND A COMPOUND WATER CYCLONE IN A PLACER GOLD RECOVERY PLANT

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ABSTRACT

During the 1986 mining season both laboratory and field test work were conducted to study the performance efficiencies of a wedge-wire static screen, a Pan-American jig, a Reichert Mark VII spiral, and a 12" compound water cyclone. This work was conducted at EVECO, Inc.'s placer gold operation near Fox, Alaska, and funded by the State of Alaska Department of Natural Resources. The Mineral Industry Research Laboratory of the University of Alaska-Fairbanks performed the test work.

Laboratory testing of a 1 ft^2 section of wedge-wire screen with 2.0 mm slot dimensions showed that despite gold's high specific gravity and often flattened nature it was not preferentially screened as compared to gangue particles. On site, a 22" x 60" wedge-wire screen panel acted primarily as a sample splitter ahead of the spiral and cyclone and no screening efficiency tests were run in the field.

For gold recovery evaluation of the three concentrators, field samples of the concentrators' products were collected. These samples were later tabled in the laboratory for free gold recovery using a Gemeni table, a highly efficient free gold separator. Subsequent froth flotation test work involving Gemeni table products showed that the table recovered, in the free gold split, 96% to 99% of the free gold values and 89% to 95% of the total gold values. Froth flotation's recovery (~30%-40%) of gold from the table black sand concentrate product (5-12 oz/ton) was poor indicating locked and/or coated gold values.

The 12" compound water cyclone showed acceptable gold recoveries (75%-95%) when operated at concentration ratios of 11:1 to 5:1. Operation to achieve concentration ratios no greater than 5:1 is suggested. The cyclone performed well as a thickener ahead of both the jig and the spiral, yielding underflow pulp densities of 61% to 73% (w/w). The cyclone processed 90% minus 12 mesh feed ahead of the spiral and -3/8" feed ahead of the jig.

The 2-cell (42" x 42"), Pan-American jig processed both thickened and unthickened -3/8" screen undersize. Jig hutch products were further concentrated using Knudsen Bowls. Gold recoveries for the jig ranged from 90% to 97%. 84% to 97% of the recovered -100 mesh gold reported to the first hutch product.

The Reichert Mark VII spiral gave trouble free field operation and gold recoveries of 97%-99%. This report presents spiral product flow rates and pulp densities. Gold size distributions for spiral products as well as gold shape factor analyses (Corey's Shape Factor) are also given. Similar concentrator products descriptions are presented for the compound water cyclone and the jig.

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Additional thanks must be given to Mr. Mike Mark Anthony who allowed MIRL free use of his equipment during field testing. His final report (DNR Grant No. 1031) is acknowledged and referenced in this report.

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INTRODUCTION

This project, as originally drafted, focused on solving several operational problems, which became apparent to EVECO during their 1984 mining season. In 1984, EVECO completely rebuilt their processing circuit incorporating spirals for the recovery of gold lost in sluice tailings. In this rebuilt system, the placer material was first scrubbed, and screened at 2" using a trommel. The minus 2" material was processed through a sluice box. The sluice box tailings were screened on a double deck vibrating screen with a 1/2" top deck and 10 mesh bottom deck. Minus 10 mesh material was thickened using cyclones and cyclone underflow was treated using 4 primary triple start spirals followed by one secondary double start spiral. The secondary spiral concentrate was stored for the recovery of gold by amalgamation. The problems encountered were:

a. The vibrating screen did not have sufficient capacity to treat the entire tailings stream from the sluice box, indicating the need for a better, less expensive system of sufficient capacity. (It would be advantageous to screen at 20 mesh, which would provide a superior feed for spirals.)

b. The spirals were overloaded and did not have sufficient capacity. (Screening to 20 mesh would reduce the feed to the spirals. The use of a preconcentrator ahead of the spirals would eliminate part of the barren material and increase plant capacity.)

c. The spiral concentrates were too bulky to permit direct amalgamation. A gallon of concentrate was obtained for every ten cubic yards of feed to the plant. (An additional concentration step was needed prior to, or in place of, amalgamation.)

The flowsheet shown in Figure 1 was proposed by MIRL to remedy the problems noted above. The following changes were suggested:

a. The use of a screen mesh larger than 10 mesh on the existing vibrating screen for sizing the sluice tails. A 1/4" or 3/8" screen was recommended. This would reduce screen blinding problems. The existing screen would then have adequate capacity to process the sluice box tailings.

b. Size the minus 1/4" screen underflow at 20 mesh using a static wedge-wire screen. This would reduce the quantity of feed to the fine gold recovery circuit. A 20 mesh top size feed would benefit subsequent recovery systems.

c. Pump the minus 20 mesh pulp to four to six 12" diameter compound water cyclones (CWCs). A concentration ratio of 10:1 was anticipated. This would eliminate 90% of the barren material.

d. The cyclone underflow (concentrate) would be further concentrated using spirals. EVECO could use their existing spirals.

e. Spiral concentrates should be upgraded further using a Gemeni table and the table's concentrate, middlings and tails checked for gold content using froth flotation.

f. If it appeared economic, froth flotation should be incorporated into the process flowsheet.

These suggestions were incorporated into an "Innovative Gold Recovery Placer Mining Demonstration Grant" proposal, which was submitted to and subsequently approved by the Department of Natural Resources (DNR). However, between the time the proposal was approved and its implementation during the 1986 mining season (EVECO did not operate a gold recovery plant in 1985) major revisions were requested by EVECO and approved by DNR. These revisions consisted of:

a) The scrubbing trommels and the sluice box were dropped from the flowsheet.

b) The Reichert Spiral plant was also cut from the processing circuit.

c) In place of the sluice-spiral recovery system, a single, two cell (42" x 42" /cell), IRD Pan-American jig would process -1/4" feed produced by the screening plant. Because only one jig was to be tested, the screening plant would not be run at full capacity. (Run of mine (ROM) feed to the screen plant was 40 yd^3/hr during the test period, which supplied the jig with approximately 17 yd^3/hr.)

d) In order to comply with the intent of the original proposal to DNR, a single 12" CWC-Reichert Spiral circuit would be tested. Spiral concentrates would be tabled on a Gemeni table at MIRL's laboratory.

The chronology of the actual project, as carried out in 1986, consisted of first lab testing a section of static wedge-wire screen in order to determine its screening efficiency. Next a static screen panel, a 12" CWC, and a Reichert Mark VII spiral were integrated into EVECO's existing gravel screening plant and a series of tests run to determine the gold recovery characteristics of the CWC and the spiral. After

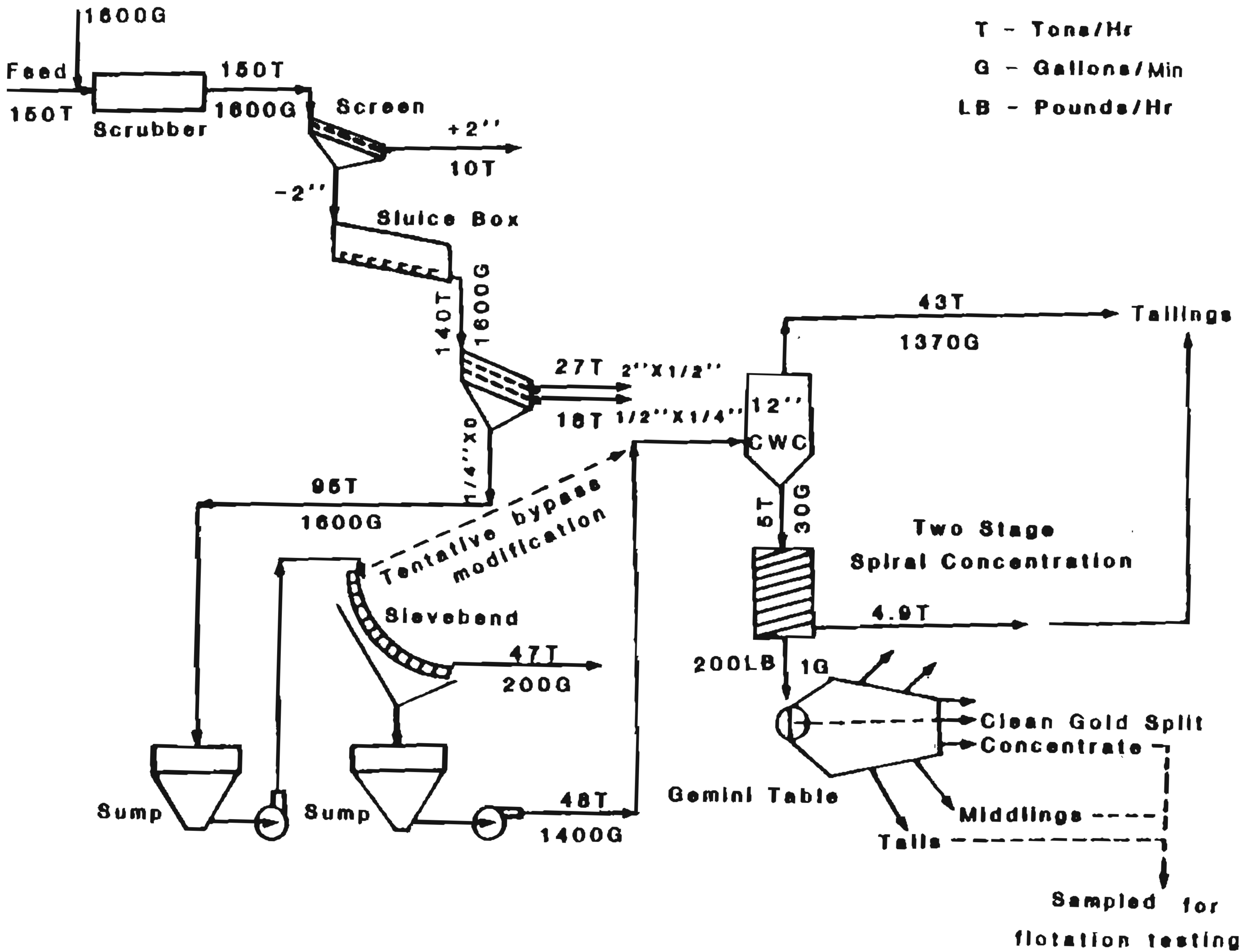

Figure 1. MIRL's proposed flowsheet for EVECO's gold recovery plant.

this series of tests was completed over a two week period, the static screen, CWC, and spiral were removed from the circuit and a Pan-American jig was installed and tested.

Following this field testing, the samples collected were analyzed in MIRL's laboratory. Also at this time, tests were run to evaluate a Gemeni table with respect to its ability to upgrade gold bearing gravity concentrates. The table concentrate, middlings, and tails splits were checked for free gold content using froth flotation.

This project then was directed at answering several questions:

1) Are wedge-wire static screens adaptable to the Alaskan placer mining industry?

2) Are compound water cyclones a viable preconcentrator of placer material?

3) What are the fine gold recovery characteristics of Reichert Mark VII spirals and Pan-American jigs?

4) How may fine gold concentrates be further upgraded by tabling? Are significant amounts of fine gold misplaced on the Gemeni table?

The remaining sections of this report describe the performance of each piece of equipment and/or process in detail. Additionally, a description of EVECO's 1986 plant is included in the following section.

DESCRIPTION OF FIELD TEST SITE

EVECO's "Too Much Gold Hill" placer mine is located near Fox, Alaska, nine miles north of Fairbanks along the Old Steese Highway in Section 1, Township 1 North, Range 1 West, of the Fairbanks Meridian (Figure 2). The mine is located near the junction of Goldstream and Engineer Creeks. Water is drawn from a man-made pond which is fed by ground water. In the early 1960's, the F.E. Company stripped off the overburden and thawed the ground. A portion of EVECO's property was then mined by F.E. company's dredge #8. At the present time EVECO is processing both dredge tailings, that contain residual gold, and the upper gravel of unmined ground.

"The gravel on this property consists of approximately 80 percent quartz; most of the remaining material being birchcreek schist. The amount of heavy minerals per cubic yard was less than two pounds. 85 percent of this was rutile, 14 percent magnetite. The remaining amount was a mixture of pyrite, stibnite, galena and scheelite"[1].

EVECO's plant consisted of a bar grizzly with seven inch spacing located above a hopper. Feed to the grizzly was supplied by an Insley H-1000 backhoe with a 1 1/4 yd^3 bucket. The material from the hopper was fed onto a belt conveyor by a variable speed apron feeder and conveyed to a 4' x 12' double-deck, inclined, vibrating screen. The top deck was 2 1/4" woven wire. The bottom deck was sectioned; the first six feet were 3/8" woven wire screen and the final six feet were 1 1/2" woven wire screen. The screening plant is represented in Figure 3 and produced the following materials:

a) 7" x 2 1/4" rock

b) 2 1/4" x 1 1/2" gravel

c) 1 1/2" x 3/8" gravel, later recombined with -3/8" product

d) -3/8" feed for this projects gold recovery tests.

EVECO modified the lower deck of their vibrating screen to produce -3/8" material specifically for this project in order to supply a -3/8" feed to the equipment being tested. The -3/8" solids and a large percentage of the screen water fell into a sump from which it was pumped by a 4" rubber lined slurry pump.

The screening plant ran at approximately 40 yd^3/hr during the testing period and was capable of processing 90 to 100 yd^3/hr at full capacity. Of the 40 yd^3/hr feed to the screen, approximately 17 yd^3/hr was -3/8".

The power for the plant was supplied by a Caterpillar 150KW generator which consumed approximately four gallons of diesel fuel per hour. The plant's water supply came from two man-made ponds located approximately 150 feet from the plant (Figure 3). The pond farthest from the plant supplied plant water via a 4" diesel-driven pump which used half a gallon of diesel fuel per hour. The nearer pond acted as a pre-settling pond, feeding water back to the feed water pond. Between the two ponds was a barrier of 7" x 2 1/4" rock which acted as a filtering system to reduce the amount of silt reaching the feed water pond. The pre-settling pond was cleaned periodically using a small dragline.

WEDGE-WIRE STATIC SCREEN

Discussion

The fine material from placer gravels needs to be separated and treated using devices specifically suited for the recovery of fine gold. Many of these devices require prior screening of the gravel at fine sizes. Recovery units for the recovery of fine gold include tables, jigs, spirals, hydrocyclones, and froth flotation cells. Of these devices, tables, spirals, and froth flotation cells require removal of

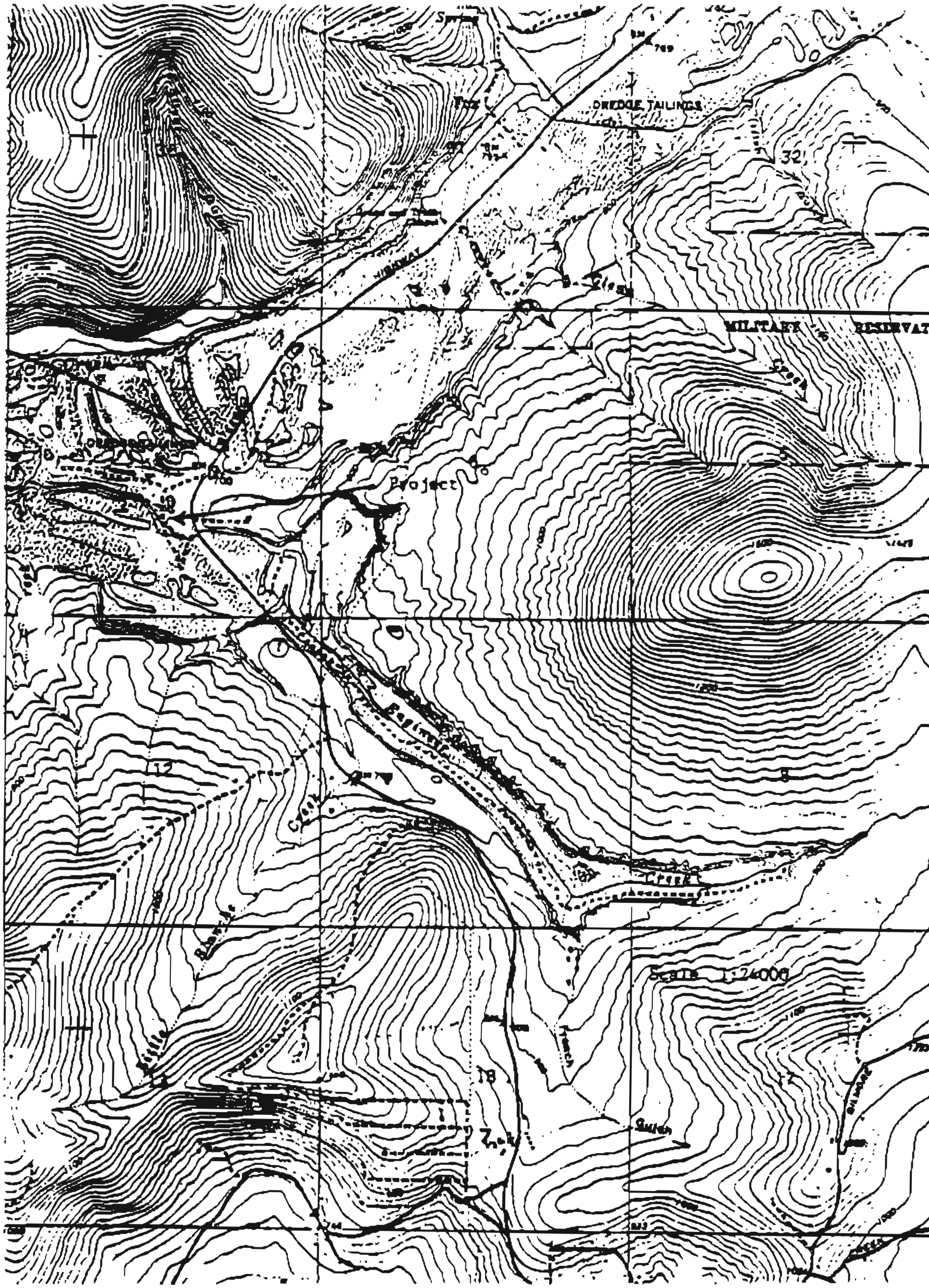

Figure 2. EVECO's mining location.

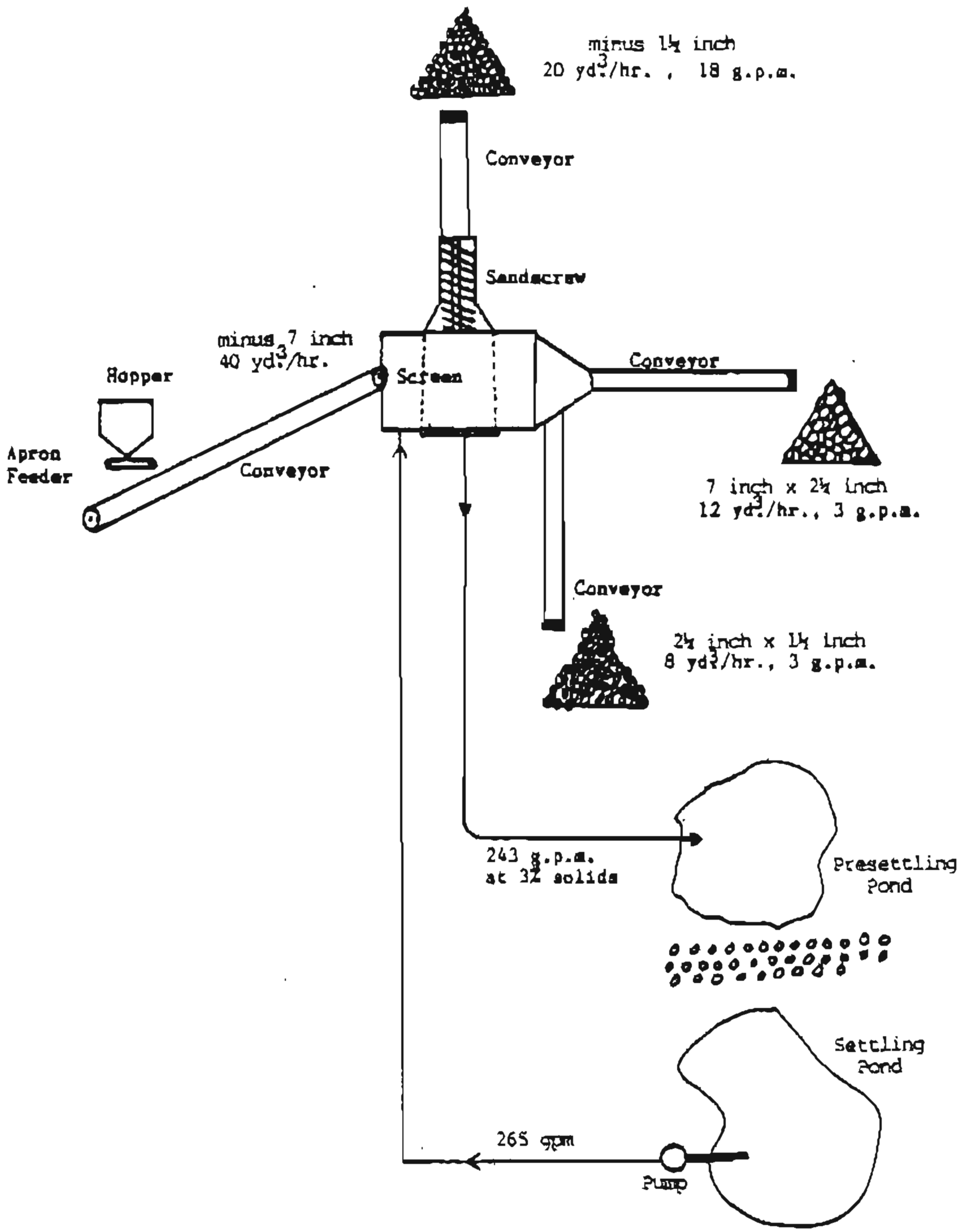

Figure 3. EVECO's screening plant.[1]

coarse material prior to processing the sands for fine gold recovery.

Screens, particularly vibrating screens, normally employed for sizing, require a large screen surface area for 20 mesh separation, making them uneconomic for many placer mining operations. One piece of equipment that has found wide applications in the coal mining industry for desliming coal at 20 mesh (0.84 mm) or for separating heavy medium from washed coal products is the wedge-wire static screen. Static screens have been successfully used for this purpose since the early 1960's and are now standard in every coal washery. Subsequently, they have found numerous applications in the mineral processing industries. Static screens require no power although some models use vibrators for improved performance. Static screens have screen openings larger than the size of separation and problems of screen blinding are few. For example, when properly operated, a wedge-wire static screen at a 45° angle with a 1 mm opening sizes at 1/2 mm (35 mesh).

The influence of the gold's shape on its sizing and the correlation of the sizing of gold particles in relation to the sizing of waste rock needed to be established. These data would aid in the selection of the proper slot dimension and screening area required for placer gold recovery.

Another aspect of the wedge-wire static screen that deserved investigation was the possibility that gold particles would settle to the bottom of the pulp stream on the screen and would readily find their way into the sieve undersize. If true, less than perfect sizing of the placer material could be tolerated. Research was needed in this area to assure that gold was not lost with the misplaced fine material contained in the static screen oversize.

Static screens are high capacity screens which use stationary wedge-bar screening surfaces. The orientation of the screen surface is such that the slots between the wedge-wires are perpendicular to the flow of feed slurry (Figures 4 and 5). A provision is usually incorporated into the functional screening unit to allow the screen surface to be rotated 180° with respect to the flow direction. This allows operators to compensate for the wear of the wedge-wires.

Over time, a rounding of the leading edge of the wedge-wires occurs, which decreases the effective size of separation for the screen. If the surface is reversed at appropriate times, the new flow direction then sharpens the rounded edge and rounds the new leading edge. Timely reversals of a wedge-wire panel will allow for a near constant size of separation to be achieved. However, as a significant portion of the wedge-bar surface is worn away, the spacing between bars increases. As the useful life of a screen surface nears its end, the separation size will increase.

Laboratory Testing

A one square foot section of wedge-wire screen was tested at MIRL. Space between the wedge-bars was set at 2.0 mm and the screen was operated at an angle of 50° from the horizontal. The screen was placed in a sheetmetal housing which served to direct the slurry flow onto the screen surface and also to separate the screen's oversize and undersize products. Figures 6 and 7 show the test equipment. Feed to the screen was provided by a 2" slurry pump. Minus 4 mesh material from EVECO's ground was used for the feed solids and the tests were run in closed circuit. Flow rates of 35 gpm and 45 gpm were combined with feed pulp densities of 10% and 20% to give 4 test combinations.

During each test, simultaneous samples were taken of the oversize and undersize products. Screen analyses were run on both products and an effective size of separation (d_{50}) calculated for each test. These screen analyses are shown in appendix A (A1-A5) along with the size partition curves for each test (A6-A9). The screen's size of separation seems little affected by either flow rate or pulp density over the ranges used. D_{50}, the size at which particles have an equal probability of reporting to the screen oversize or undersize is approximately 12-16 mesh. The partition plots also show that ≥ 95% of particles of size 2.5-3.0 mm or larger report to the oversize. At least 95% of particles of size 20-50 mesh or smaller report to the undersize.

In the second stage of static screen testing run at MIRL, it was desired to observe the screening behavior of gold particles of various sizes and shapes. Neutron activated gold was used during this series of tests. Such gold gives off a characteristic radiation which is easily detected with the help of gamma ray detection equipment. Gold particles of known shape and size were introduced into the closed circuit screen test system and the products were passed by detectors before recycling (Figure 6). Activated gold particles which passed a detector were recorded as a pulse on a chart recorder. The number of pulses distributed between the screen products yielded the gold distribution directly.

Table 1 shows the results of this test work. These tests were run to test the hypothesis that because of gold's density and its often flattened nature it would preferentially report to the screen underflow as compared to less dense and more spherical gangue particles. This appears not to be the case. If anything, the results suggest that gold is screened slightly less efficiently on the wedge-wire static screen than the gangue minerals, whose screening behavior was previously described by the size partition curves of appendix A. These discrepancies between gold and gangue screening efficiencies are likely due to the sampling and counting limitations imposed by the scope of this study. The authors doubt that a true significant difference exists. The authors wish to suggest that addition of water to the mid and lower screen

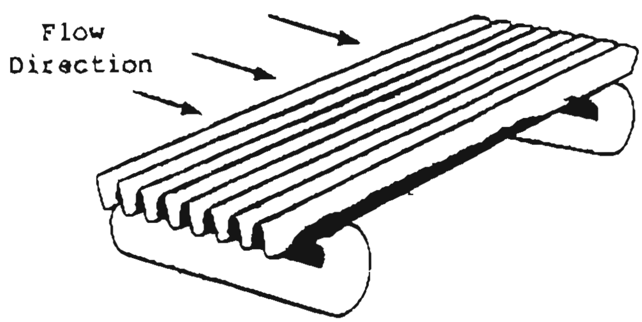

Figure 4. A section of wedge-wire screen.

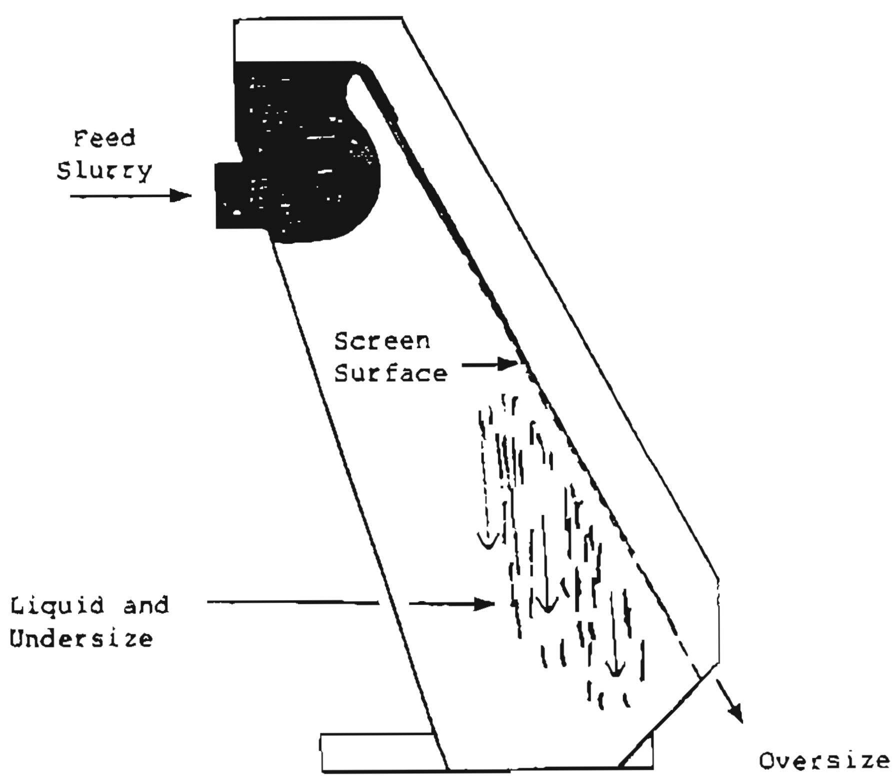

Figure 5. Static-screening unit.

Figure 6. Laboratory setup for testing a wedge-wire static screen.

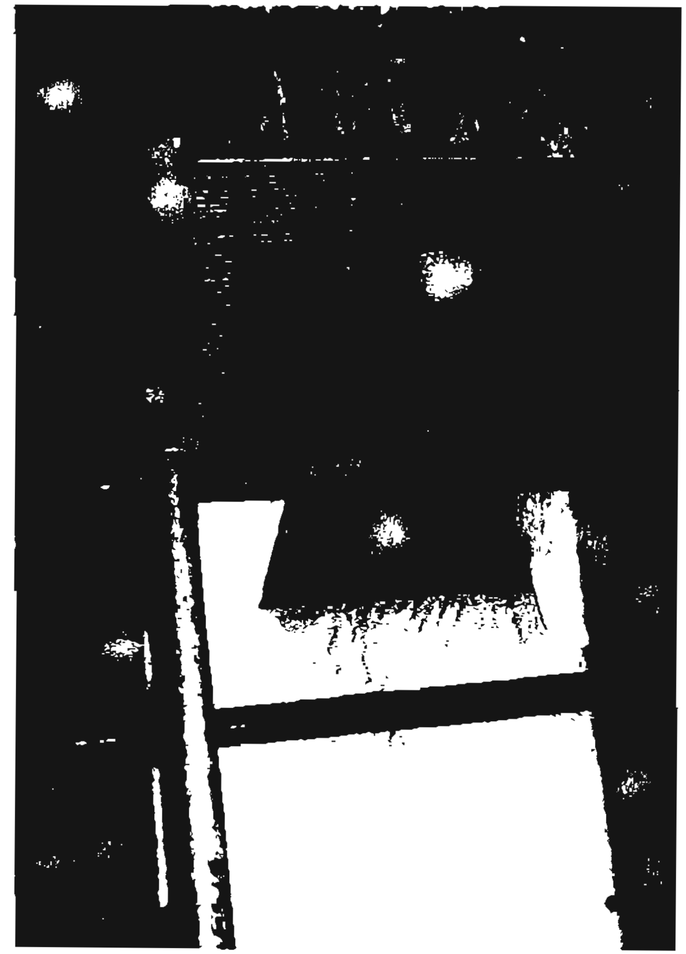

Figure 7. Plan view of laboratory tested wedge-wire screen panel (2.0 mm openings).

TABLE 1

GOLD SCREENING CHARACTERISTICS OF LABORATORY TESTED WEDGE-WIRE SCREEN

% of Gold Reporting to Screen Undersize

Gold Characteristics Size (ASTM mesh) x Shape*	Wedge-Wire Screen Feed Conditions			
	10% Pulp Density		20% Pulp Density	
	35 gpm	45 gpm	35 gpm	45 gpm
10# x 0.1	13%	8%	13%	18%
14# x 0.7	9%	8%	13%	17%
14# x 0.1	31%	18%	22%	30%
20# x 0.3	13%	—	—	—
35# x 0.3	63%	—	—	—
80# x 0.3	83%	—	—	—

* As described by Coreys Shape Factor (CSF)

$$CSF = t/\sqrt{l \cdot w}$$

t = particle thickness
l = particle length
w = particle width

area by spray bars may improve screening efficiency. Vibration could also help. Such remedial measures should be studied.

The test results from MIRL's laboratory work with the static screen make it very obvious that definitive information concerning the size distribution of gold in a feed material be considered if a static screen is to be used. Obviously, a static wedge-wire screen would be most applicable where:

a) the material to be screened does not contain a significant quantity of gold near or above the effective size of separation of the screen.

b) the material to be screened has been previously processed to remove gold near and above the effective size of separation of the screen.

c) it is considered economic to rescreen and/or retreat the static screen oversize to recover lost gold values.

An example of case (a) above would be the treatment of a gold bearing beach sand: perhaps from Cape Yakataga, Alaska. Work by Cook and Rao[2] showed Yakataga beach sand samples they investigated had gold values distributed as 100% minus 30 mesh, 85% minus 70 mesh and 42% minus 200 mesh. Looking at the partition curves (Appendix A) generated by MIRL's test work using a 2.0 mm wedge-wire spacing, shows that such a screen could be expected to screen to the undersize approximately 95% of 30 x 40 mesh gold, and +99% of -70 mesh gold.

Case (b) was represented by the unmodified version of this study where the static screen was to receive and process -1/4" sluice box tailings. A well operated sluice box should recover a significant percentage of the +70 mesh gold. The wedge-wire static screen would therefore be effective in recovering to the screen undersize a very large percentage (+99%) of the gold remaining in the sluice box tailings.

In discussing case (c), imagine a -1/4" feed slurry which was to be screened to 20 mesh but which contained perhaps 20% of total gold values in the 12 x 30 mesh range. Obviously, a wedge-wire static screen with a 2.0 mm wire spacing would not be effective in screening this coarser gold to the undersize. It would, however, remove a large percentage of material from the -1/4" feed and perhaps make the remaining oversize material amenable to rescreening, say at 12 mesh, on a vibrating screen. The resulting -12 mesh solids might then be treated separately or recombined with the static screens undersize product. Economics and scale would dictate the feasibility of such a flowsheet.

Field Installation

Due to the modifications to the originally proposed flowsheet as described earlier, the static wedge-wire screen installed at EVECO's screening plant received -3/8" feed slurry, which contained gold in the 3/8Z" x 0 size range, instead of -1/4" sluice box tailings.

Figure 8 shows where the screen fits into the process flowsheet. Based on MIRL's laboratory test work a 22" x 60" wedge-wire panel with 1.2 mm wire spacing was borrowed from the Usibelli Coal Mine (Healy, Alaska) for field testing. This panel was anticipated to process approximately 350-400 gpm of -3/8" slurry of 10-20% pulp density. The actual field installation is seen in Figure 9, which shows the panel in place with its long dimension and wedge-wire perpendicular to the flow direction. The screen panel is preceded by a length of steel slick plate which serves to more evenly distribute the slurry over the screen surface. Feed to the slick plate was via a 4" slotted pipe.

The slick plate should have been placed on the same angle as the screen panel (50^{0} from the horizontal) for best screen performance, but because of a mix-up during fabrication it was not. In this instance, since screen performance was no longer a factor due to the coarse gold in the screen feed, the initial fabrication was not changed. As operation of the flowsheet shown in Figure 8 began, it was obvious that the 4" Gorman slurry pump was delivering to the screen and the screen passing to the undersize, far more water than the 3" Sala pump could handle. Because of this, a 6" portion along each edge of the static screen was blocked off with steel plate to reduce its throughput capacity.

Thus, as the static screen was operated at EVECO, it

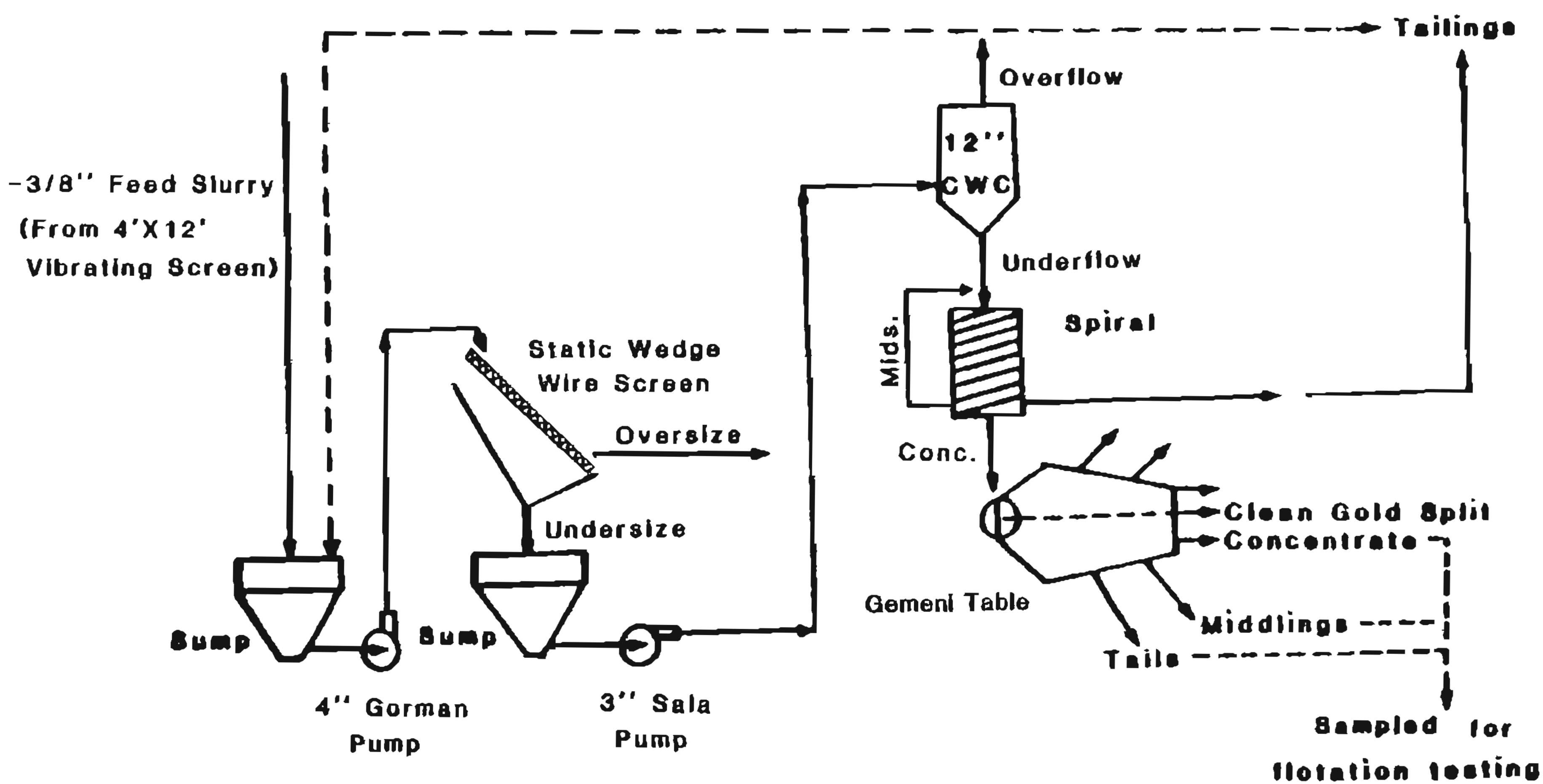

Figure 8. Static screen - CWC - spiral field test flowsheet.

Figure 9. Wedge-wire static screen unit in the field.

acted primarily as a sampler ahead of the CWC-spiral circuit rather than as a screening unit of which efficient sizing was required. The screen was operated for about 20 days between 4 and 6 hours per day. The surface showed no signs of significant wear. Some areas of screen blinding were observed. However, these seemed isolated to areas of the screen surface where flow over the screen was not uniform due to the plated off sides of the screen and the low lead plate (slick plate preceding screen) angle.

COMPOUND WATER CYCLONE

Discussion

The cyclone is a simple yet versatile device used in the treatment of fluid-solid and fluid-fluid suspensions for the purpose of separating one phase from another. Cyclones are used in both processing and pollution control, including food processing, dust collection, sludge removal from petroleum crude, and the mineral processing industry, where cyclones are extensively used in mineral and coal preparation. Historically the main use of hydrocyclones in mineral processing has been as classifiers and they have proven extremely efficient at fine separation sizes. They are used increasingly in closed circuit grinding operations but have many other uses, such as desliming and thickening.

Their basic structure is that of a top cylindrical section with a tapering hollow cone as the bottom section (Figure 10). The fluid stream is introduced tangentially through a peripheral inlet and is transformed into a spiral flow moving from the inlet to the apex. The taper induces a back flow along a central core which spirals toward the vortex finder, while the high centrifugal accelerations of the vortex cause the particles to separate and move in the direction of the apex[4]. Strong centrifugal accelerations are induced, from as few as 10 G's for the average cyclone to as high as 4000 G's[5], the number of G's produced being inversely proportional to cyclone diameter.

The centrifugal force developed accelerates the settling rate of the particles. There is evidence to show that Stoke's law applies with reasonable accuracy to separations in cyclones of conventional design, thereby separating particles according to size and specific gravity[6]. The tangential velocity which reaches its maximum a short distance from the center decays towards the wall. The faster settling particles move to the wall and are discharged through the apex with a small percentage of the feed water. The remainder of the feed slurry is carried out the vortex finder to the overflow discharge.

After a certain residence time, the solid grain is discharged to either the overflow or underflow products. The particle's size and specific gravity exert a major influence on this separation. The cyclone's "cut point" or separation size (generally given in ASTM mesh units, millimeters, or

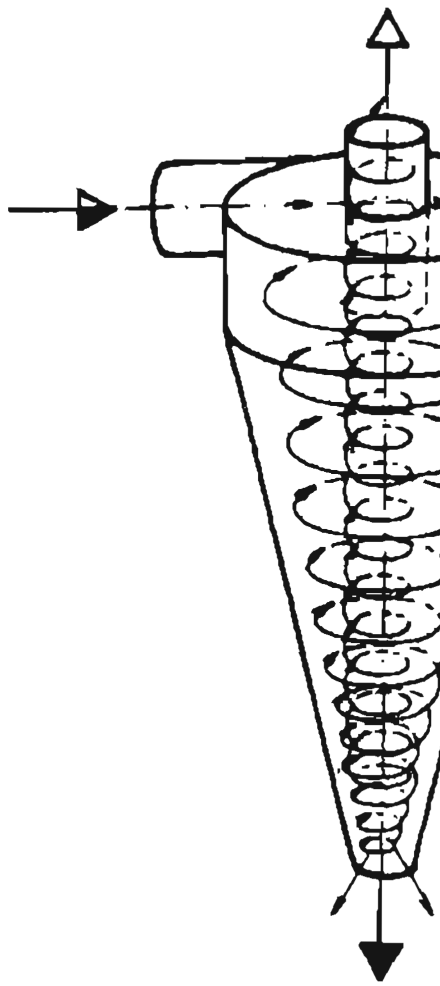

Figure 10. Simplified perspective view of the hydrocyclone showing the "spiral within a spiral" flow pattern[3].

microns) refers to that size of a specific mineral (generally quartz) at which 50% of the grains report to each of the cyclone products. This size is often termed the d_{50} size.

The most important application of cyclones in the mineral beneficiation industry has been for classifying. Classifying cyclones being distinguished by a short vortex finder and small included angle 10-30°, as compared to the concentrating cyclone, which has a large included angle of 60°-180°, and a long vortex finder. Figure 11 shows the design differences between the two.

Recent years have seen the development of various cyclones specifically for concentrating purposes. Their physical design is such that classification effects are suppressed and the influence of particle specific gravity is maximized. These are not heavy-medium cyclones, which have been in use in the mineral processing industry for some years, but true hydrocyclones. They were developed largely as a result of work in the coal industry, where cyclones operating with a water medium are now in wide use for upgrading fine coal.

In contrast, concentrating water hydrocyclones are of squat design, with wide cone angles and long vortex finders. They are called compound water cyclones because of the compound slopes of their basal cones (Figure 12). They are operated to suppress classification phenomena in favor of gravity concentration effects.

The compound water cyclone is not a new wet concentrator. It was developed in the late 1950's by Dr. Jan Visman through research sponsored by Canada's Department of Energy, Mines, and Resources. In the early 1960's Cyclone Engineering Sales Ltd. (CES) of Edmonton, Alberta, Canada, was granted the licensee privileges to the Visman Compound Water Cyclone and subsequently sold the device's U.S. patent rights to McNally Pittsburgh

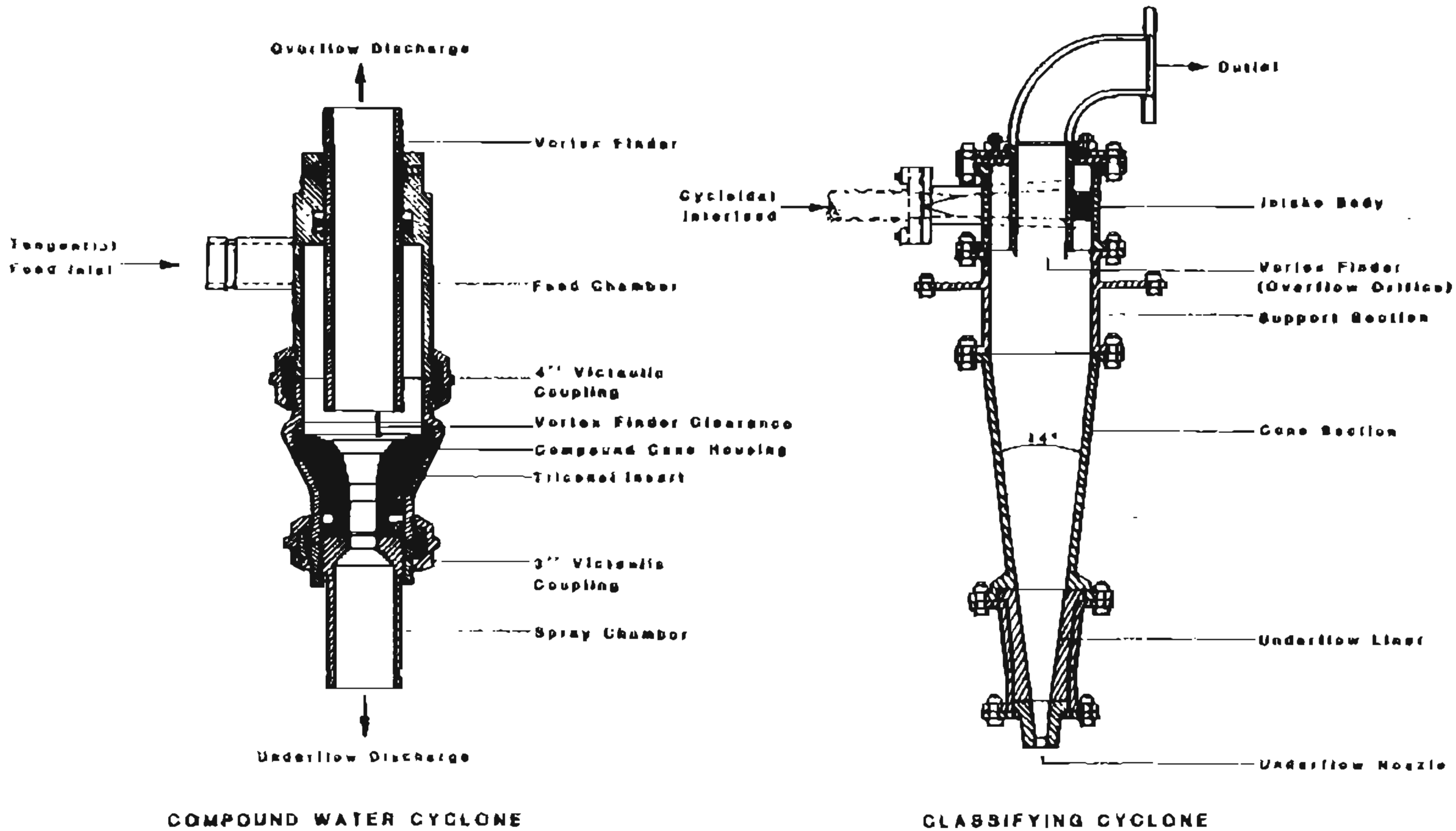

Figure 11. Comparison of design features between the compound water cyclone and the classifying cyclone[7].

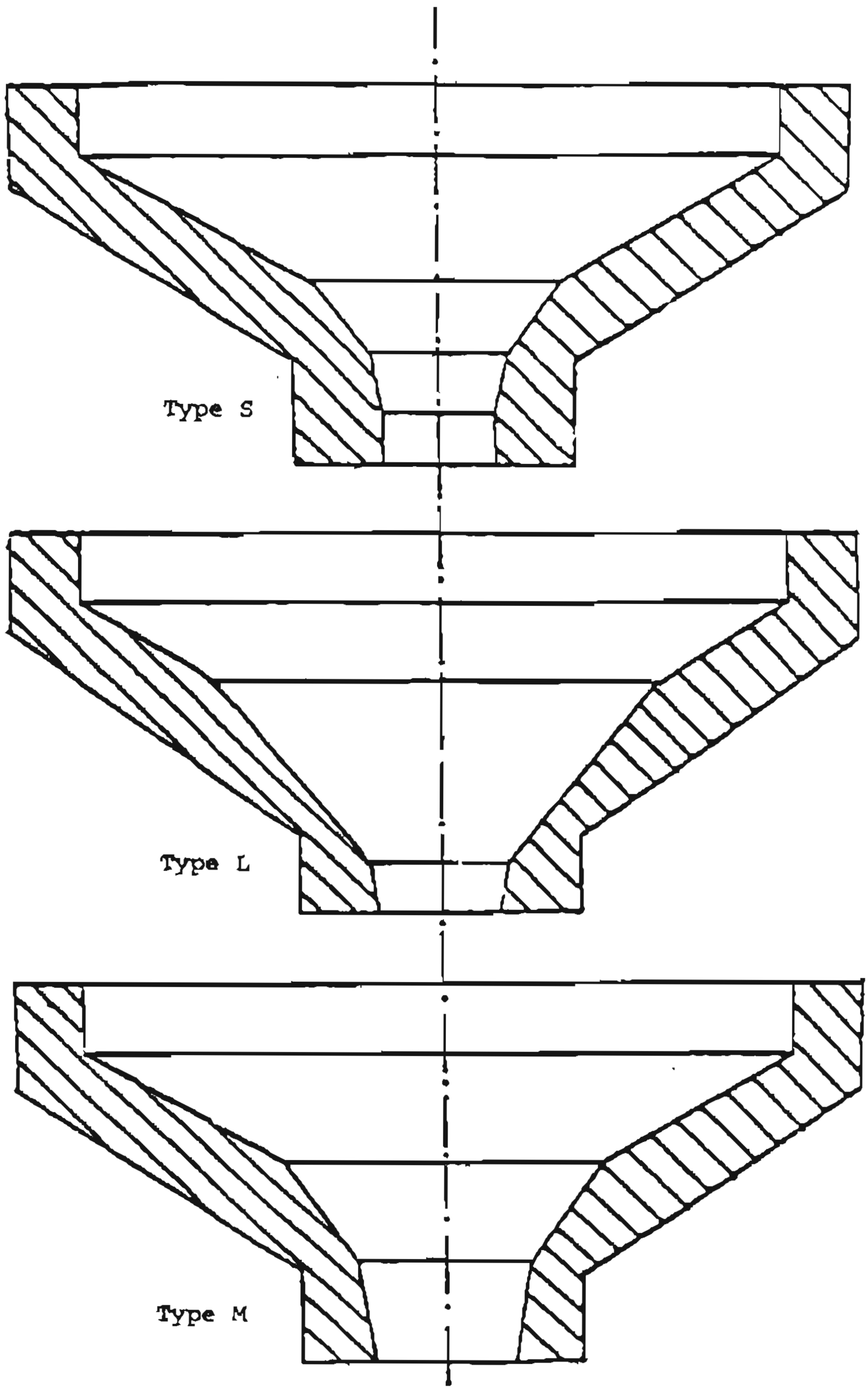

Figure 12. Types of compound cones used in the compound water cyclone[8].

Manufacturing Corporation (M-P), a large coal washery design firm. The following description of the operating principles of the CWC is a synthesis of the views developed from the research and development efforts of Dr. Jan Visman, CES, and M-P.

The compound water cyclone has a short cylindrical section fitted with one of the three compound cones (Figures 12 and 13). Each of the compound cones has three sections, with included angles of 120°, 75° and 20°. The three cones differ with respect to the relative area of their inner cone surfaces. Type "L" is used for lightweight materials such as coals, where a low specific gravity cut-point is required. Type "S" is used for high density materials (e.g., iron ore), where a high specific gravity cut-point is required. Type "M" is used for a variety of materials and covers the medium range or cut-points.

Particles of different sizes and specific gravity form a hindered settling bed in section I of the compound cone. Light, coarse particles are prevented from penetrating the lower strata of this bed by the coarse, heavy fractions and by the fine particles filling the interstices of the bed. Consequently, the water passing from the periphery of the cyclone chamber towards its main outlet (the vortex finder) erodes the top of the stratified bed, removing the light, coarse particles via the "central current" around the air core.

The remainder of the bed is forced into conical section II, by new feed entering the cyclone, without losing its stratified character. Here, the central current is much stronger, further eroding the top of the bed, where the middlings are now exposed. Light middlings are swept up and discharged through the vortex finder.

The heavy middlings that spiral upward in the central current may bypass the orifice of the lower vortex finder owing to their higher specific gravity and the high centrifu-

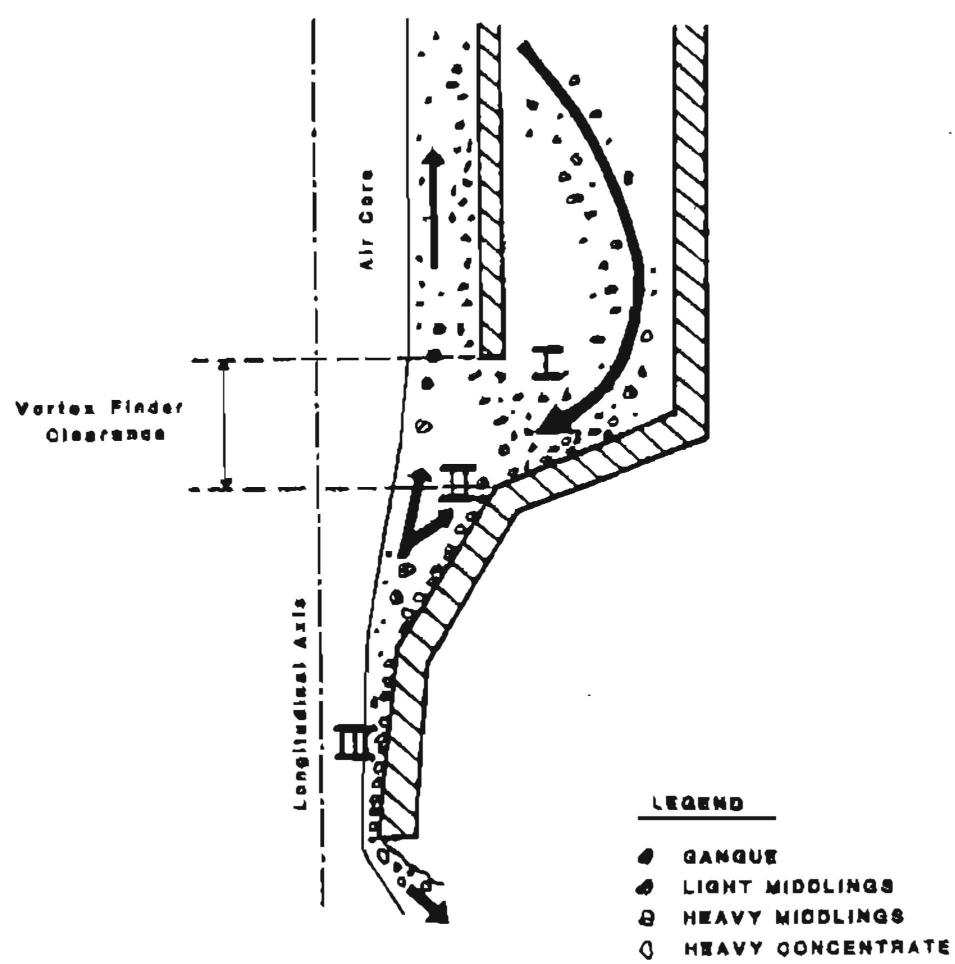

Figure 13. Separating process in the compound water cyclone[9].

gal forces in this region. Consequently, the coarse heavy middlings fraction tends to recirculate to the stratified bed. Finally, in section III, the bed is destroyed as coarse particles fan out along the cyclone wall in a single layer, exposing the fine particles which had been shielded. The central current in Section III is relatively weak. The upward current that remains separates the small particles from the remainder of the material, with preference for those of low specific gravity. Thus the fine, light particles are finally discharged through the vortex finder by a process of elutriation. The heavy particles, fine as well as coarse, are discharged through the apex. The entire separation process then, is postulated to take place in three steps, one for each of the sections of the compound cone. Table 2 gives the design data for CWC's available from CES.

Field Testing

Figure 8 shows where the 12" compound water cyclone used in this study fit into the process flowsheet. As described earlier, the CWC was intended to act as a preconcentrator and achieve relatively low concentration ratios of less than 10:1. The rationale for applying the CWC stems from the fact that scrubbed and/or screened feed often requires thickening ahead of subsequent concentration steps such as spirals or jigs. If such a thickening step could at the same time accomplish some concentration there are obvious advantages. The CWC is such a device and from a low density pulp feed produces a low density overflow (tailings) and a high density (20%-70% pulp density) underflow for further concentration. At the same time, it reduces the bulk for further treatment. If, for example, a CWC achieves a concentration ratio of only 3:1, this has the effect of reducing by a factor of 3, the capacity requirements for spirals or jigs in the following concentration stages; savings in both capital and operating costs would be realized.

The McNally-Pittsburgh 12" CWC used during the field testing was acquired from the Usibelli Coal Mine and fitted with an S-type compound cone purchased from Cyclone Engineering Sales Limited. The CWC processed the static screen undersize slurry which was delivered at 6 psig by the 3" Sala pump (Figures 14 and 15). Because the feed pressure was held constant by the fixed speed of the Sala pump, only the vortex finder clearance was varied to change the concentration ratios achieved by the CWC. Results from the series of field tests run in June 1986 are presented in Tables 3-8. Screen analyses of the cyclone products from two different tests are found in appendix B (B1-B2).

Simultaneous samples of the CWC overflow and underflow were taken for gold recovery determination during various days of operation. Timed samples were taken independent of the gold determination samples in order to calculate flow rates, pulp densities, and concentration ratios. Gold recovery samples were taken to MIRL and tabled using a Gemeni table (model 60) to recover free gold values which were weighed. These weights were used to calculate the CWC gold recoveries for the various tests. A gold size distribution and a gold shape factor analysis of gold recovered from CWC products during test no. 4 are also found in appendix B (B3-B5).

Because of the limited water supply to the 4' x 12' vibrating screen during CWC tests 1-4, the CWC overflow was recycled back to the 4" Gorman pump sump to provide adequate water. This recycling caused a high level of suspended solids (25,000 mg/liter - 75,000 mg/liter -400 mesh solids) to build up. During tests 5 and 6 this condition did not exist since a larger pump was substituted at the feed water pond to supply the 4' x 12' screen. CWC overflow was not recycled during tests 5 and 6.

High levels of suspended solid may have a detrimental effect on CWC gold recovery despite the high centrifugal force field operating within the cyclone. Walsh[11] concluded, using a kaolinitic base potter's clay, that suspended solids levels up to 17,000 mg/liter did not effect the recovery of 40 x 50 mesh gold by a 4" CWC. Higher suspended solids levels were not investigated. In another study by Walsh and Rao[12] it was concluded that high suspended solids levels of montmorillonite have a pronounced effect on the settling velocity of gold particles. This effect was proportional to viscosity increases in the clay bearing slurry. Hence it seems reasonable that if high suspended solids levels are accompanied by increased viscosity, gold recovery will suffer. Unfortunately, viscosity measures were not taken during the EVECO test work.

Tests 1 and 2 were conducted under similar operating conditions. The gold recovery observed in test 1 is significantly less than that for test 2. This difference is most likely due to sampling irregularity caused by the particulate nature of the gold and sample timing. Probably an intermediate value of gold recovery (50-60%) for test 1 and 2 is nearer a true recovery value given the high concentration ratios (49:1) achieved. Walsh[8] found similar gold recovery values for a 4" CWC when operated at high concentration ratios. In all 6 tests, note that the 12" CWC performs its thickening function very well.

Tests 3-5 were all conducted at the same CWC settings of feed pressure and vortex finder clearance. What varied between tests was the suspended solids level in the CWC feed due to overflow recycling in tests 3 and 4 but not during test 5. This is the most likely reason for the change observed in concentration ratios. The higher gold recovery in test 5 may be in part due to the difference in suspended solids levels or it may be a variation due to sampling. Gold recoveries are seen to range from 74% to 94% and seem to indicate the need for operation at lower concentration ratios,

Table 2. Design data for compound water cyclones and classifying cyclones[10].

DESIGN DATA OF COMPOUND WATER CYCLONES AND CLASSIFIER CYCLONES

Approximate Flow Characteristics of Single C.W.C. or CL. C.		Top size of feed mm	Top size of feed mesh/in	Dry feed, tph metric*	Dry feed, tph long* (gross)	Dry feed, tph short* (net)	Average Flowrate of Water cu m/h*	Average Flowrate of Water usgpm	Average Flowrate of Water igpm*	Inlet Pressure (minimum) Kg/Sq cm (atmos.)	Inlet Pressure (minimum) psi	Inlet Pressure (minimum) ft Head	Maximum % Solids Wt %	Maximum % Solids Vol. %	Average Spec. Gravity Solids	Average Spec. Gravity Pulp
Multiple 2" C.W.C.-2M CL.C.-2M	coal			3 6**	3 6**	3 7**	31 62**	174 348**	145 290**	0.4 1.6	6 - 25	14 58	7	5	1.5	1.03
	sand	1.5	10 m.	6 - 12	6 12	7 14	36 71	200 - 400	167 334	0.6 1.6	8 25	18 - 58	12	5	2.5	1.08
	ore			8 16	8 16	9 18	36 71	200 400	167 334	0.6 1.6	8 25	18 58	10	5	3.5	1.13
4 in. C.W.C.-4 CL.C.-4	coal			0.5	0.5	0.6	6	27	23	0.2	3	8	7	5	1.5	1.03
	sand	5	3/16	0.8	0.8	0.9	6	27	23	0.3	4	8	12	5	2.5	1.08
	ore			1.1	1.1	1.3	6	27	23	0.3	4	9	10	5	3.5	1.13
6 in. C.W.C.-6 CL.C.-6	coal	8		1.3 2.7	1.3 2.7	1.5 3.0	17 16	67 64	56 53	0.4	5	12	7 14	5 10	1.5	1.02 1.06
	sand	8		2.2 4.5	2.2 4.4	2.5 4.9	17 16	67 64	56 53	0.4	5 6	13 14	12 22	5 10	2.5	1.08 1.15
	ore	8		3.1 6.2	3.1 6.8	3.4 6.9	18 - 16	72 64	60 53	0.4	6	13 15	16 28	5 10	3.5	1.12 1.24
8 in. C.W.C.-8 CL.C.-8	coal			3 6	3 6	3 - 6	36	154	128	0.5	7	16	7 14	5 10	1.5	1.03 - 1.06
	sand	10	3/8	8	9	10	33	146	122	0.6	8	18	22	10	2.5	1.16
	ore			13	13	14	33	146	122	0.6	9	20	18	10	3.5	1.25
12 in. C.W.C.-12 CL.C.-12	coal			16	16	17	92	403	335	0.8	11	26	14	10	1.5	1.06
	sand	19	¾	25	25	28	92	403	336	0.8	12	27	22	10	2.5	1.15
	ore			36	35	38	92	403	336	0.9	13	29	28	10	3.5	1.25
24 in. C.W.C.-24 CL.C.-24	coal			86 - 129	85 - 127	95 142	518 - 489	2279 2153	1898 1792	1.5	21 22	50 51	14 - 21	10 15	1.5	1.05 1.08
	sand	38	1½	143 - 218	141 212	158 238	518 - 489	2280 2153	1898 1792	1.6	24 - 25	54 - 58	22 - 31	10 - 15	2.5	1.15 - 1.23
	ore			201 - 301	198 - 296	222 - 332	518 - 489	2279 2154	1898 1793	1.8 2.0	26 - 28	59 - 65	28 - 38	10 - 16	3.5	1.26 - 1.38

* Figures apply to C.W. Cyclones and CL. Cyclones with wide vortex finder.
· When using narrow vortex finder, estimates of dry feed rates and flow rates are to be reduced by 1/3

** The lower feed and flow rates correspond to minimum pressures given in the table. The higher feed rates correspond with inlet pressure of 25 psi (1.76 Kg/sq. cm., 58 ft. head)

Figure 14. Photograph of 3" Sala slurry pump. Static screen above and left of pump. 12" CWC top-right. Reichert Mark VII spiral top-left. Feed sump for spiral sets below CWC underflow outlet.

Figure 15. 12" CWC installed at EVECO screening plant.

Table 3
CWC FIELD TEST NUMBER 1.

Date: 6/6/86
Function: Preconcentration, Thickening Ahead of Spiral
Vortex Finder Clearance: 3-7/8 Inches
Feed Pressure: 6 PSIG
Cone Type: S
Concentration Ratio Achieved: 49:1

RESULTS

CWC Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)
Feed	36.2	272.7	31.88	0.0008	100
Overflow	36.0	270.0	31.23	0.0005	66
Underflow	61.0	2.7	0.65	0.013	34

Table 4
CWC FIELD TEST NUMBER 2

Date: 6/9/86
Function: Preconcentration, Thickening Ahead of Spiral
Vortex Finder Clearance: 3-7/8Inches
Feed Pressure: 6 PSIG
Cone Type: S
Concentration Ratio Achieved: 49:1

RESULTS

CWC Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)
Feed	36.2	272.7	31.88	0.0025	100
Overflow	36.0	270.0	31.23	0.0003	12
Underflow	61.0	2.7	0.65	0.107	88

Table 5
CWC FIELD TEST NUMBER 3

Date: 6/10/86
Function: Preconcentration, Thickening Ahead of Spiral
Vortex Finder Clearance: 5 Inches
Feed Pressure: 6 PSIG
Cone Type: S
Concentration Ratio Achieved: 11:1

RESULTS

CWC Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)
Feed	20.9	265.4	16.0	0.002	100
Overflow	20.0	260.0	14.5	0.0006	26
Underflow	65.0	5.4	1.5	0.017	74

Table 6
CWC FIELD TEST NUMBER 4

Date: 6/11/86
Function: Preconcentration, Thickening Ahead of Spiral
Vortex Finder Clearance: 5 Inches
Feed Pressure: 6 PSIG
Cone Type: S
Concentration Ratio Achieved: 11:1

RESULTS

CWC Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)
Feed	20.9	265.4	16.0	0.004	100
Overflow	20.0	260.0	14.5	0.001	22
Underflow	65.0	5.4	1.5	0.033	78

Table 7
CWC FIELD TEST NUMBER 5

Date: 7/9/86
Function: Preconcentration Thickening Ahead of Spiral
Vortex Finder Clearance: 5 Inches
Feed Pressure: 6 PSIG
Cone Type: S
Concentration Ratio Achieved: 7:1

RESULTS

CWC Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)
Feed	18.2	280.0	14.4	0.0015	100
Overflow	16.2	273.3	12.3	0.0001	6
Underflow	69.9	6.7	2.1	0.01	94

Table 8
CWC FIELD TEST NUMBER 6

Date: 7/18/86
Function: Preconcentration Thickening Ahead of Jig (-3/8 inch feed)
Vortex Finder Clearance: 3 Inches
Feed Pressure: 7 PSIG
Cone Type: S
Concentration Ratio Achieved: 5:1

RESULTS

CWC Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)
Feed	23.0	364.0	24.8	-	-
Overflow	20.0	349.0	19.7	-	-
Underflow	73.0	15.0	5.1	-	-

perhaps less than 5:1.

A final test, number 6, used the 12" CWC in a different capacity than tests 1-5. Where the CWC had been processing static screen undersize in tests 1-5, in test 6 it was fed -3/8" material directly from the 4" Gorman slurry pump (Figure 16). The CWC acted as a thickener and preconcentrator ahead of a Pan-American jig in test 6. No CWC samples for gold content determination were taken during test 6. This test was run after a series of jig tests had been completed and total gold recovered was used as a general measure of CWC performance. This will be discussed in the jig section of this report.

As a concentrator and thickener, the 12" CWC gave trouble free field operation over a two week period. No signs of excessive internal wear were obvious upon dismantling the cyclone. In anticipation of severe vortex finder wear (from previous work with 4" CWC's) the 12" CWC vortex finder was coated with Flexane 94, a DEVCON urethane compound. The Flexane 94 surfaces showed no signs of excessive wear after CWC operation and performed as anticipated in protecting the vortex finder.

REICHERT MARK VII SPIRAL

Discussion[13]

Spirals have been used for gravity concentration for many years. The Reichert spirals were initially developed for the alluvial tin industries of Australia and Southeast Asia. Each of over twenty different Reichert spiral designs is contoured to separate materials of a given specific gravity range. The Mark VII has been on the market since 1982 and is designed to recover tin with specific gravity of 6 or 7. On the opposite end of the spectrum, the Mark X separates heavier waste shale from coal.

The cross-sectional shape of the Mark VII spiral changes from top to bottom. Material fed to the top of the spiral is progressively concentrated over its full length. Fine grained, high specific gravity solids are concentrated at the inside of the spiral's turns. The concentrate is separated from the middlings, which may be recirculated, and the tailings, by splitters at the bottom of the spiral (Figure 17). Depending upon the nature of the feed material, one usually obtains concentration ratios of 50:1 to 100:1.

The Mark VII Reichert spiral is a lightweight and low cost fiberglass-plastic unit. It has no moving parts. The spiral is designed to be used 24 hours a day, 365 days per year for many years before wearing out. A single spiral may be mounted on the support column (single start) for test work, or two or three identical spirals mounted on the same column (double or triple start) for production.

The Mark VII spiral is fed a high density (20-60% w/w) solids slurry of minus 10 mesh (or finer) feed. It achieves high efficiency when recovering gold between 40 and 270 mesh in size (420 to 53 microns). A four part split is made at the bottom of the spiral. Concentrates, which can be

Figure 16. 4" Gorman slurry pump processing -3/8" screen undersize.

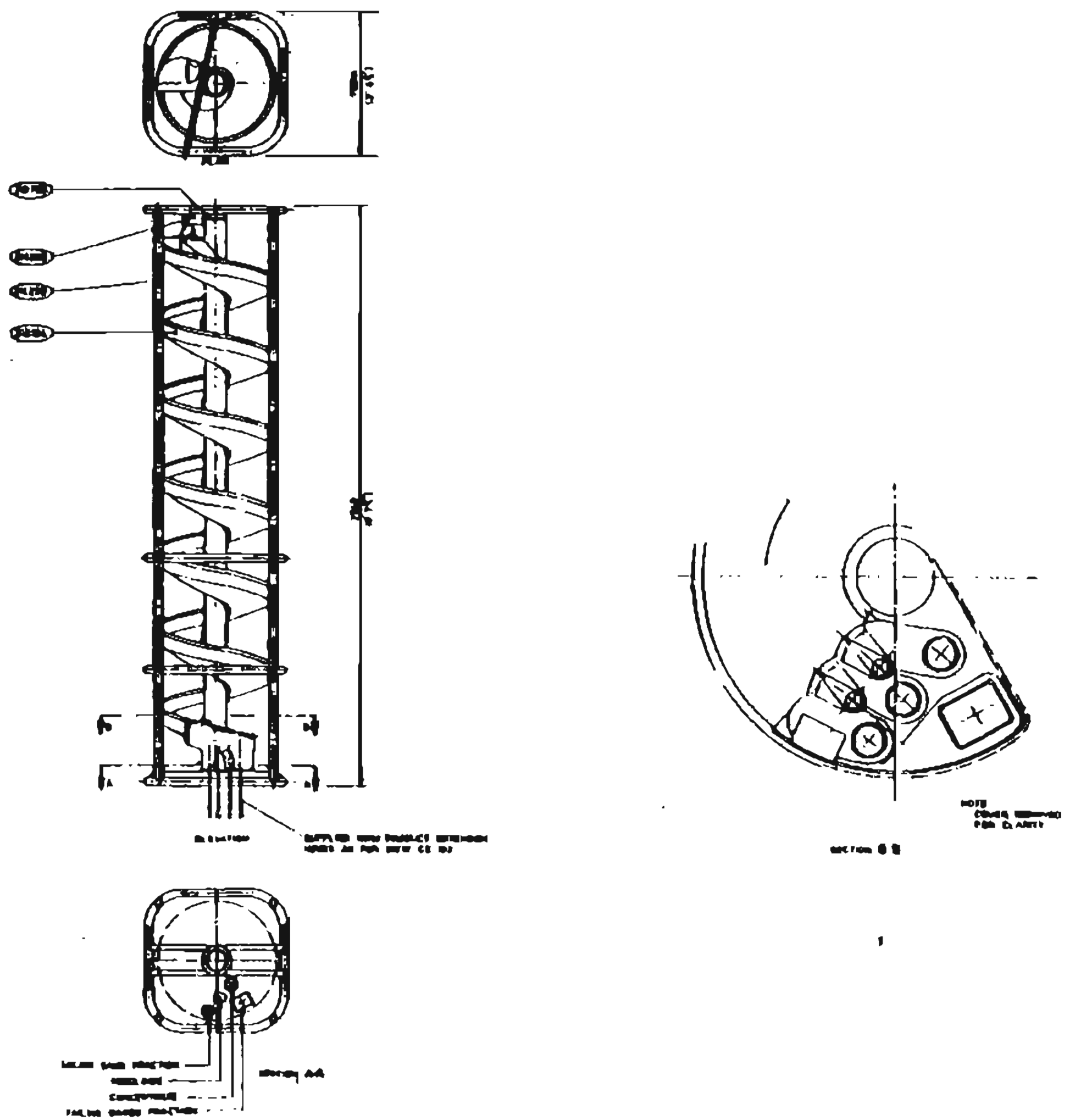

Figure 17. Drawing of Reichert Mark VII spiral[14].

observed as a thin dark line on the inside edge of the spiral, are separated for further processing. The middlings may be recycled and act as a buffer, preventing loss of fine gold should the feed surge or fluctuate. The tailings are discarded. A water split, low in solids, is either discarded or recycled.

Concentrates from the spiral are processed either on a conventional Wifley or Diester table or on the new Gemeni table. Tabling is employed to make the difficult separation of the heavy minerals from the gold.

A single spiral trough accepts a feed of up to three tons/hr of minus 10 mesh material. A triple start spiral can be fed up to nine tons/hr. Table 9 shows some general design data for the Mark VII spiral.

Field Testing

As can be seen from Figure 8, the spiral received and upgraded the 12" CWC underflow and discharged a concentrate which was treated by a Gemeni table. In field practice, the CWC underflow was discharged to a sump to which makeup water was added. A 2" slurry pump then pumped the slurry to the spiral (Figure 14). Spiral products (4) were all discharged separately. Spiral concentrates were continuously collected over a test run period, generally 3 hours. Spiral middlings were not recycled due to the plant layout (another pump would have been required) but were discharged into the sand screw along with the spiral tailings and high water split. Middlings, tailings and water split were sampled periodically throughout a test period. These samples and the continuously collected concentrates were later processed on MIRL's Gemeni table to determine their gold content and calculate spiral gold recovery values. Timed samples of the spiral products were also collected during each test to determine pulp densities, flow rates and concentration ratios.

TABLE 9 DESIGN DATA FOR REICHERT MARK VII SPIRAL

Head Feed (per start)

Capacity:	up to 3TPH solids depending on application
Pulp Density (w/w):	20 - 60% solids
Size Range:	0.03 mm - 2 mm
Pulp Volume (max):	22 gpm

Concentrate Removal (per start)

Rate:	up to 0.3TPH solids
Pulp Density/(w/w):	30-60% solids

Tables 10-13 show the results of the four spiral tests. A size distribution of the spiral feed and the four spiral products is presented in appendix C (C1). A size distribution and shape factor analysis of gold recovered from spiral products of spiral test no. 4, are also presented in appendix C (C2-C4).

It is apparent from tables 10-13, that the spiral was operated to produce excessive concentration ratios, i.e. the concentrate splitter cut too narrow a concentrate band. This accounts for the high percentage of gold in the middlings products. A concentration ratio of nearer 50:1 would have been more appropriate. However, in a spiral plant, these middlings would be recycled and no gold loss should be attributed to them. Tables 10-13 show that the middlings comprise from 5%-12% of the total feed solids to the spiral and as such, their recycling would not significantly increase the load to the spiral.

Considering both concentrates and middlings, the spiral gold recoveries are exceptionally good, ranging from 97% to +99%. The concentration ratios of 11:1, 12:1 and 19:1, considering both concentrates and middlings, for test 2-4, approach concentration ratios observed for a single stage of jigging, as will be seen later in this paper.

The operation of the Mark VII spiral during field testing was relatively trouble free. The sump feeding the spiral experienced occasional plugging. The cause of this was traced to two sources:

a) Insufficient makeup water due to fluctuations in plants feed water pressure.

b) Blockage of the sumps outlet by coarse pebbles. These pebbles occasionally entered the sump after bouncing off the 4' x 12' screen surface.

After these two trouble areas were remedied, no further problems were experienced.

GEMENI TABLING AND FROTH FLOTATION

Discussion

The shaking table concentrator, or concentrating table, is a flowing film separator and perhaps the most efficient form of gravity concentrator. Tables are however, low capacity concentrators and if applied to large tonnage applications, require considerable floor space to achieve the desired throughput. For this reason, they are most widely applied in the treatment of low volume slurry streams which are difficult metallurgically. Tables most commonly produce finished concentrates from the products of gravity concentrators appearing earlier in the process flowsheet.

Table 10
REICHERT MARK VII SPIRAL TEST NUMBER 1

Date: 6/9/86

Concentration Ratio (Feed/Conc): 169:1

Concentration Ratio (Feed/Conc + Mids): 7:1

RESULTS

Spiral Product	Pulp Density (% Solids)	Flow Rates: Slurry (gpm)	Flow Rates: Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)	
Feed	16	18.9	0.82	0.026	100.0	
High Water Split	3	9.6	0.06	0.0008	0.2	
Tails	25	8.8	0.65	0.0008	2.5	
Middlings	59	0.5	0.11	0.088	45.7	
						97.2
Concentrate	48	0.03	9.8 lbs/hr	2.21	51.5	

PERCENT GOLD RECOVERY BY SIZE

SPIRAL PRODUCT

GOLD SIZE	Conc.	Mids.	Tails	High H_2O	Feed
+30	1.7	98.3	0.0	0.0	100
30x100	65.7	31.1	3.2	0.0	100
-100	88.0	6.4	4.5	1.1	100

Table 11
REICHERT MARK VII SPIRAL TEST NUMBER 2

Date: 6/10/86

Concentration Ratio (Feed/Conc): 280:1

Concentration Ratio (Feed/Conc + Mids): 11:1

RESULTS

Spiral Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)	
Feed	21	21.6	1.3	0.007	100.0	
High Water Split	3	10.7	0.09	nil	nil	
Tails	34	10.4	1.1	0.0002	1.9	
Middlings	59	0.5	0.1	0.029	38.3	98.1
Concentrate	44	0.03	9.5 lbs/hr	1.26	59.8	

PERCENT GOLD RECOVERY BY SIZE

SPIRAL PRODUCT

GOLD SIZE	Conc.	Mids.	Tails	High H_2O	Feed
+30	15.4	84.6	0.0	0.0	100
30x100	52.3	46.7	1.0	0.0	100
-100	93.3	1.5	5.2	0.0	100

Table 12
REICHERT MARK VII SPIRAL TEST NUMBER 3

Date: 6/11/86

Concentration Ratio (Feed/Conc): 275:1

Concentration Ratio (Feed/Conc + Mids): 12:1

RESULTS

Spiral Product	Pulp Density (% Solids)	Flow Rates: Slurry (gpm)	Flow Rates: Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)	
Feed	20	22.6	1.3	0.025	100.0	
High Water Split	4	11.5	1.1	0.0004	0.35	
Tails	33	10.6	0.1	0.0001	0.15	
Middlings	59	0.5	0.1	0.08	26.3	
						99.5
Concentrate	43	0.03	9.6 lbs/hr	5.04	73.2	

PERCENT GOLD RECOVERY BY SIZE

SPIRAL PRODUCT

GOLD SIZE	Conc.	Mids.	Tails	High H_2O	Feed
+30	2.5	97.5	0.0	0.0	100
30x100	76.2	23.8	0.0	0.0	100
-100	97.0	0.7	1.7	0.5	100

Table 13
REICHERT MARK VII SPIRAL TEST NUMBER 4

Date: 7/9/86

Concentration Ratio (Feed/Conc): 408:1

Concentration Ratio (Feed/Conc + Mids): 19:1

RESULTS

Spiral Product	Pulp Density (% Solids)	Flow Rates: Slurry (gpm)	Flow Rates: Dry Solids (tph)	Gold Grade (oz/ton)	Gold Recovery (%)	
Feed	30	22.0	2.0	0.014	100.0	
High Water Split	4	10.0	0.1	0.0001	0.0	
Tails	45	11.6	1.8	0.0001	0.7	
Middlings	60	0.4	0.1	0.12	44.2	99.3
Concentrate	50	0.02	9.9 lbs/hr	3.15	55.1	

PERCENT GOLD RECOVERY BY SIZE

GOLD SIZE	SPIRAL PRODUCT: Conc.	Mids.	Tails	High H_2O	Feed
+30	4.2	95.8	0.0	0.0	100
30x100	56.8	42.8	1.0	0.0	100
-100	99.1	0.4	0.3	0.2	100

This is exactly the application of the Gemeni table in this project's flowsheet, where it acts as a final gold separator, processing the Reichert Mark VII spiral concentrate.

Of the common shaking tables (Diester, Wifley, James, ...) the Gemeni table exceeds all others in its ability to separate free placer gold from a heavy mineral concentrate. Its primary advantages are its numerous free gold pick up grooves and water adjustments which allow gold to be selectively separated from heavy sands. The dressing water flow rates are adjusted to supply enough water at the points of separation to cause the more spherical heavy minerals to miss entering the gold pick-up grooves. The flaky placer gold, which extends less into the flowing water film, enters the pick up grooves and is collected separately. The tables are generally fed a minus 12 mesh feed, though they perform better with minus 20 mesh solids. If extremely fine gold is present (-270 mesh), additional screening may be required to achieve optimal results.

The table gold product is typically plus 90%-95% gold by weight and directly smeltable. Where the table processes minus 12 mesh feed, screening the gold product at 20 mesh will typically remove coarse gangue particles (and some coarse gold), and upgrade the through screen material.

Over the past 5 years of the Gemeni table's manufacture, their deck design has been modified several times, but their basic operating principle remains unchanged. Models #60, #250, and #1000 are manufactured and designed to process feed rates of 60, 250, and 1000 lbs/hr respectively. When treating extremely heavy mineral concentrates for gold removal, these capacities should prudently be halved for design purposes. Basic operating instructions, table description, and sales information is included in appendix D (D1-D3).

As part of this study, the efficiency of a Model 60 Gemeni Table was evaluated. To this end, it was decided to use the froth flotation process to treat the table's concentrate, middlings, and tailings products to determine gold not reporting to the free gold split.

Flotation is a process used to separate mineral particles by virtue of differences in their surface properties. These properties can be altered by the addition of various chemicals, commonly called flotation reagents. The froth flotation process basically involves making the surface of one or more mineral types present in a solid-water pulp receptive to air bubble attachment, which causes the minerals to be lifted to the pulp surface by a buoyant force. Once at the surface the particles become trapped in a froth and are mechanically scraped off and collected. The pulp is agitated by a mechanically driven impeller, which also acts to draw air into the pulp and disperse it as fine bubbles. For placer gold flotation, reagents most commonly used are:

a) Xanthates, which attach to the surface of the gold particles and promote bubble attachment. Such chemicals are known as collectors.

b) Pine oil or Cresylic acid base frothers, which aid in the stabilization of a froth at the surface of the pulp, which facilitates entrapment of gold particles floated to the surface.

c) pH modifiers, which are used to control the pH of the pulp for optimum collector-surface interaction.

Cell pulp densities vary from 20% to 35% solids by weight. The fewer slimes in the pulp the better will be the flotation recovery and concentration ratio. If the gold has a compact and chunky nature, it is unlikely to respond favorably to flotation at sizes above 65 mesh. However, flaky placer gold (Corey Shape Factors ≤ 0.15) may float at sizes up to 20 mesh.

In general then the flotation of a placer gold bearing material involves the following processes:

a) Screening; generally to -10 or -20 mesh.

b) Attritional scrubbing to clean the gold surfaces. This step may not be required.

c) Pulp density adjustment.

d) Conditioning. Agitating the pulp for a period of time with the required flotation reagents.

e) Flotation and froth removal.

f) Froth treatment and tailings disposal.

Laboratory Testing

Though the Gemeni table was used throughout this project to process field samples for the recovery of their free gold values, this section discusses its use only in relation to the processing of Reichert Mark VII spiral concentrates. The spiral concentrates were tabled in a manner to approach plant operation, i.e. at the highest feed rate which allowed efficient gold separation. The table concentrates, middlings, and tailings were saved and later processed using froth flotation in batch flotation cells.

Tables 14-17 show the results of these tests. These results indicate that the table free gold recovery values range from 96% to 99% while its total gold recoveries range from 89% to 95%. Of the gold not recovered to the free gold split,

Table 14
GEMINI TABLE - FLOTATION TEST NUMBER 1

Feed Description: Spiral Test No. 1 Concentrate

Table Feed Rate: 38 lbs / hr.

Froth Flotation Conditions:

Frother - Aerofloat 15 (0.1 lb/ton)
Dow Froth 250 (0.1 lb/ton)

Collector - Aeroxanthate 325 (0.2 lb/ton)
Aerofloat 208 (0.2 lb/ton)

Scrubbing Time - 5 minutes

Conditioning Time - 5 minutes

Froth Collection Time - 2 minutes

Pulp Density - Variable

RESULTS

	Gold Wts. (mg)		Gold Percent	
Product	Total Gold	Free Gold	Total Gold	Free Gold
Table Gold Split	974.1	974.1	91.0	96.4
Table Con x Froth Con	36.6	35.8	3.4	3.6
Table Con x Froth Tails	57.6	nil	5.4	0.0
Table Mids x Froth Con	1.9	nil	0.2	0.0
Table Mids x Froth Tails	nil	nil	0.0	0.0
Table Tails x Froth Con	--	--	--	--
Table Tails x Froth Tails	--	--	--	--

Table 15
GEMINI TABLE - FLOTATION TEST NUMBER 2

Feed Description: Spiral Test No. 2 Concentrate

Table Feed Rate: 38 lbs / hr.

Froth Flotation Conditions:

Frother - Aerofloat 15 (0.1 lb/ton)
Dow Froth 250 (0.1 lb/ton)

Collector - Aeroxanthate 325 (0.2 lb/ton)
Aerofloat 208 (0.2 lb/ton)

Scrubbing Time - 5 minutes

Conditioning Time - 5 minutes

Froth Collection Time - 2 minutes

Pulp Density - Variable

RESULTS

	Gold Wts. (mg)		Gold Percent	
Product	Total Gold	Free Gold	Total Gold	Free Gold
Table Gold Split	360.1	360.1	89.0	96.0
Table Con x Froth Con	14.8	14.8	3.6	3.9
Table Con x Froth Tails	28.9	nil	7.1	0.0
Table Mids x Froth Con	0.9	0.2	0.2	0.1
Table Mids x Froth Tails	nil	nil	0.0	0.0
Table Tails x Froth Con	--	--	--	--
Table Tails x Froth Tails	--	--	--	--

Table 16
GEMINI TABLE - FLOTATION TEST NUMBER 3

Feed Description: Spiral Test No. 3 Concentrate

Table Feed Rate: 38 lbs / hr.

Froth Flotation Conditions:

Frother - Aerofloat 15 (0.1 lb/ton)
Dow Froth 250 (0.1 lb/ton)

Collector - Aeroxanthate 325 (0.2 lb/ton)
Aerofloat 208 (0.2 lb/ton)

Scrubbing Time - 5 minutes

Conditioning Time - 5 minutes

Froth Collection Time - 2 minutes

Pulp Density - Variable

RESULTS

	Gold Wts. (mg)		Gold Percent	
Product	Total Gold	Free Gold	Total Gold	Free Gold
Table Gold Split	2238.8	2238.8	95.0	98.8
Table Con x Froth Con	28.7	28.2	1.2	1.2
Table Con x Froth Tails	81.5	nil	3.4	0.0
Table Mids x Froth Con	1.8	1.2	0.1	trace
Table Mids x Froth Tails	2.9	nil	0.1	0.0
Table Tails x Froth Con	2.2	nil	0.1	0.0
Table Tails x Froth Tails	--	--	--	--

Table 17
GEMINI TABLE - FLOTATION TEST NUMBER 4

Feed Description: Spiral Test No. 4 Concentrate

Table Feed Rate: 38 lbs / hr.

Froth Flotation Conditions:

Frother - Aerofloat 15 (0.1 lb/ton)
Dow Froth 250 (0.1 lb/ton)

Collector - Aeroxanthate 325 (0.2 lb/ton)
Aerofloat 208 (0.2 lb/ton)

Scrubbing Time - 5 minutes

Conditioning Time - 5 minutes

Froth Collection Time - 2 minutes

Pulp Density - Variable

RESULTS

	Gold Wts. (mg)		Gold Percent	
Product	Total Gold	Free Gold	Total Gold	Free Gold
Table Gold Split	1309.0	1309.0	89.5	95.2
Table Con x Froth Con	66.2	65.7	4.5	4.8
Table Con x Froth Tails	81.8	nil	5.6	0.0
Table Mids x Froth Con	1.5	0.4	0.1	trace
Table Mids x Froth Tails	nil	nil	0.0	0.0
Table Tails x Froth Con	4.0	nil	0.3	0.0
Table Tails x Froth Tails	--	--	--	--

nearly all is found in the table concentrate.

Froth flotation of the table concentrate product yielded froth concentrate grades ranging from 370 oz/ton to 1080 oz/ton with recoveries from 24% to 43%. Froth tailings grades ranged from 4.4 oz/ton to 11.5 oz/ton. Concentration ratios achieved during flotation of the table concentrates were 133:1, 332:1, 104:1, and 144:1 for test 1-4 respectively.

Considering the poor gold recoveries by froth flotation and the high grade of the flotation tails it seems likely that locked gold and/or severely coated gold are present. Froth flotation is probably not a viable treatment alternative for the table concentrate produced from EVECO spiral concentrate, the only table product warranting possible retreatment. However, limited flotation testwork was conducted during this project and further study should be given to investigate ways to improve gold recovery by flotation. Other possible treatment routes which could be investigated include:

a) Retabling after grinding.

b) Direct cyanide leaching.

c) Cyanidation after grinding.

PAN-AMERICAN JIG

Discussion

In the jigging process, a mixture of ore particles, which are supported by a screen or perforated plate within a solid sided enclosure, are subjected to a pulsating flow (rising and falling) of water. The objective is to affect the stratification of the ore mixture grading from high specific gravity particles at the bottom to low specific gravity particles at the top of the particulate "bed." In practice, a layer of "ragging," coarse, heavy particles, is added to the jig and lies between the supporting screen and the mineral bed. The feed enters the feed end of the jig, flows across the ragging during which time separation occurs due to the pulsing water current. High specific gravity grains pass through the ragging and, if fine enough, penetrate the supporting screen passing into the "hutch" where they are drawn off. The light grains are transported through the jig by incoming feed and exit the jig as tailings (Figure 18).

Jigs are used to process material of size range 25 mm to 75 micron; the particular size depending upon a specific application. In placer gold processing the jig typically processes run of mine ore which has been screened to minus 1/2"-1/4" and can be expected to yield good gold recoveries.

The pulsating water action can be induced by several means. In the Pan-American jig, the hutch, which is attached to the lower end of the jig box by a rubber diaphragm, is alternately lifted and lowered by mechanical means. On the pulsion stroke (upward flow) the mineral bed is lifted as a mass, then as the upward flow velocity decreases the bed begins to open, the bottom particles falling first until the entire bed is dilated. On the suction stoke (downward flow) the bed closes again and awaits the next pulsion stroke. In practice, the severity of the suction stroke is often reduced by adding "hutch water," a constant upward flow of water rising through the supporting screen. Severe compaction of the mineral bed, when using adequate hutch water, is eliminated and the separation process improved.

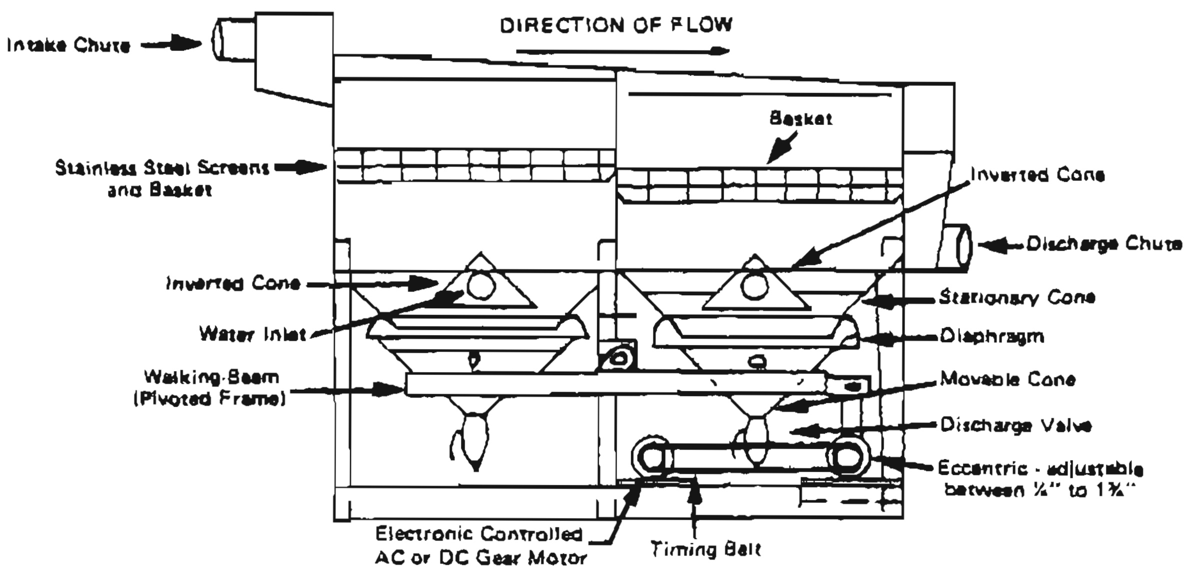

Figure 18. A Pan-American Jig[16].

A number of parameters of the Pan-American jig are adjustable to modify jig performance. These are listed below with typical ranges for placer gold ores. These figures pertain to 42" x 42" jig cells.

a) ragging - 425 lbs/cell, 3/16 inch steel shot

b) feed pulp density - 30%-60% (w/w)

c) feed rate - 20-30 yd^3/hr

d) hutch water - 50-100 gpm/cell

e) stroke length - 3/4"-1 1/2"

f) stroke frequency - 120-200 cycles/minute.

The Pan-American jig used by EVECO was an IRD (International Resource Development, Inc.) Gold Placer Jig manufactured in Carson City, Nevada. It was of a two cell (42"x42"), end flow configuration as depicted in Figure 18.

Field Testing

The flowsheet shown in Figure 19, illustrates where the jig was placed in EVECO's processing circuit. Minus 3/8" feed was pumped to the jig via the 4" Gorman slurry pump. At the jig the feed slurry was either, (1) fed to the jigs feed box without thickening or, (2) thickened using a 10" Krebs cyclone prior to entering the jig, depending upon test conditions. Hutch water was also varied between tests; 44 gpm per cell and 84 gpm per cell were the two flow rates used. The stroke length was held constant at 1 inch, as was the stroke frequency of 135 cycles/minute. Approximately 425 pounds of 3/16" steel shot was used per cell as ragging.

Each jig hutch product reported to a Knudsen Bowl. These concentrators were previously tested by Mike Mark Anthony[1]. The bowls were run at the optimum condition described by Mark Anthony excepting the feed pulp densities were lower than 22% solids. Jig tests were conducted over a 1 hr period so as not to overload the Knudsen Bowls with heavy minerals and decrease their gold recovery. At the end of each test, the bowl products were collected separately and each was later tabled on MIRL's Gemeni table for recovery of their gold values. The jig tailings were also sampled throughout the 1 hr test and later tabled for gold recovery. Tables 18-22 show the results of the five jig tests. A size distribution and shape factor analysis of the gold recovered from the jig products of test no. 2 are presented in appendix E (E1-E3).

The gold recovery results show the jig performs very well. The lower gold recoveries in test #1 are probably the result of the combination of excessive feed water, too much hutch water, and a high feed rate. Concentration ratios from 16:1 to 39:1 were achieved while gold recoveries ranged from 93.3% to 99.7%. Of the gold recovered by the jig, approximately 98% was recovered by the first cell, though this percentage varied with gold size.

Test number 5 was run in order to observe the operation of the 12" CWC processing -3/8" feed solids and acting as thickener and a preconcentrator ahead of the jig (Figures 20 and 21). During this test no jig tailings samples were taken nor were hutch products sampled for pulp densities and flow rates. Total gold weight recovered in test 5 indicates that the 12" CWC was not rejecting significant quantities of gold to the overflow (tailings) product. Gold distribution between hutches also seems in line with previous jig tests.

During jig field testing no serious operational problems were encountered. The jig mechanics are simple and provide low maintenance operation. The 10" Krebs cyclone used to thicken the jig feed in tests 2 and 3 was slightly undersized for the job, but was used due to its availability from Mike Mark Anthony's previous test work on site. It experienced occasional plugging at the apex (underflow) opening and rejected some sand size material to the overflow. The 12" CWC showed no indication of being under capacity in this same application. It produced a 73% solids underflow which was diluted with makeup water to 53% solids for jig feed. It also rejected 80% of the feed solids, yielding a concentration ratio of 5:1.

CONCLUSIONS

In testing the equipment (static screen, jig, spiral, CWC) studied during the course of this project, no significant operational or maintenance problems were encountered. This at least suggests their suitability for application in Alaska's placer gold mining industry. It is difficult to argue with the effectiveness and economics of a well operated sluice recovery system for the majority of Alaska's interior alluvial gold deposits, where the significant percentage of free gold lies above 65 mesh. However, there will certainly be circumstances where greater sophistication in gravity concentration is required and where some of those units studied in the project will prove applicable, efficient, and economic. Some plausible situations are:

1) Where placer ores contain significant quantities of heavy minerals and require continuous gravity concentrators rather than a batch unit.

2) Where gravels are processed for their industrial value with gold recovery as an additional though not primary revenue source. Here, more efficient recovery systems may not demand a major increase in plant complexity and/or operational costs, since such plants typically screen gravel to fine sizes (-1/4").

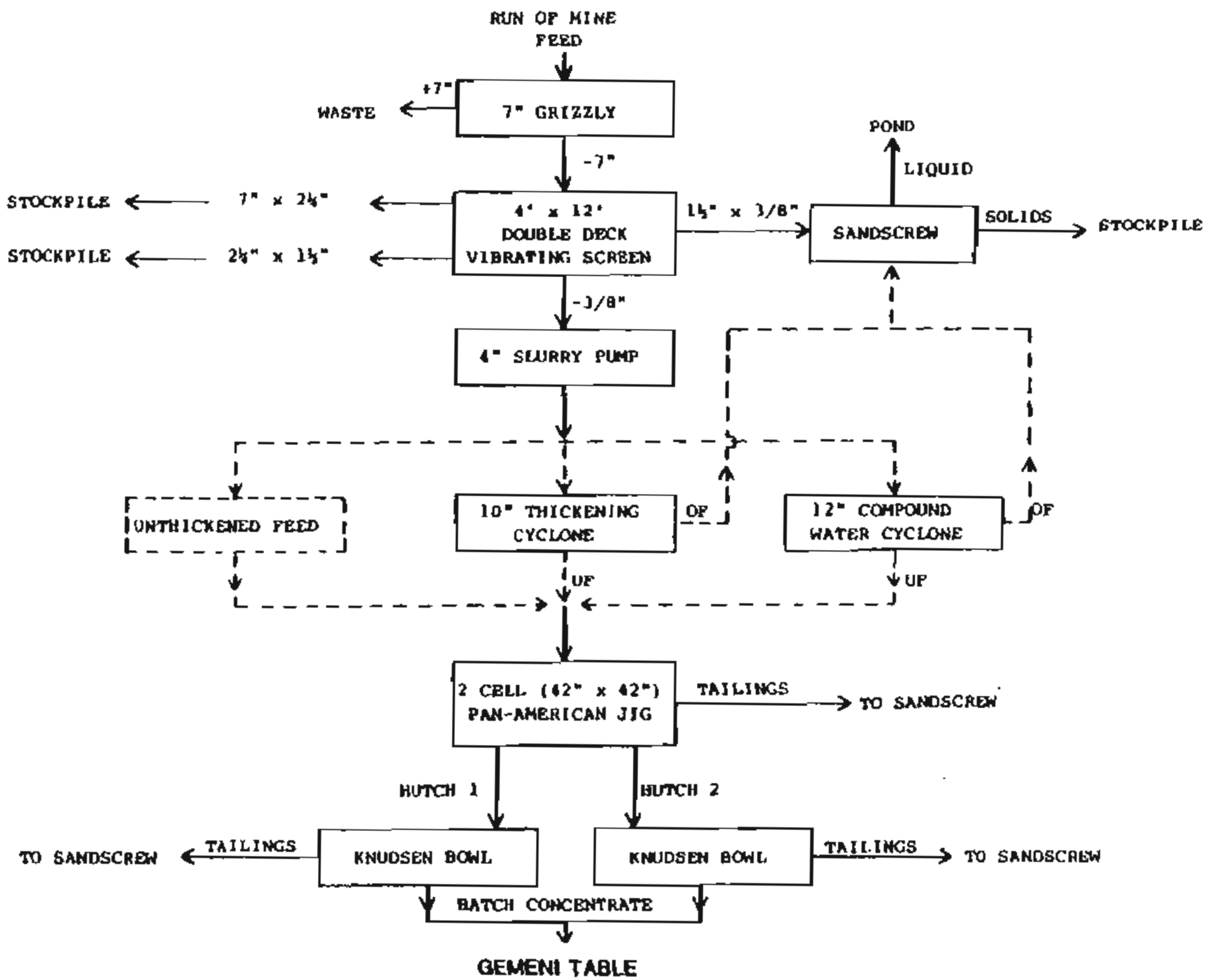

Figure 19. Flowsheet showing EVECO's jig test plant.

Table 18
JIG TEST NUMBER 1

Date: 7/16/86

Hutch Water Flowrate: 84 gpm/cell

Feed Thickened w/ 10" KREBS Classifying Cyclone (yes/no): no

Concentration Ratio: 39:1

RESULTS

Jig Product	Pulp Density (% Solids)	Flow Rates: Slurry (gpm)	Flow Rates: Dry Solids (tph)	Through Screen Gold Wt. (mg)	Through Screen Gold Recovery (%)
Feed	37	265	31.2	3220.1	100.0
Primary Hutch	10	19	0.5	2925.6	90.8
Secondary Hutch	13	8	0.3	79.5	2.5
Tails	25	405	30.6	215.0	6.7

PERCENT THROUGH SCREEN RECOVERY BY SIZE

GOLD SIZE	JIG PRODUCT: Hutch 1	Hutch 2	Tails	Feed
+30	100	0	0	100
30x100	86	2	12	100
-100	69	13	18	100

Table 19
JIG TEST NUMBER 2

Date: 7/16/86

Hutch Water Flowrate: 44 gpm/cell

Feed Thickened w/ 10" KREBS Classifying Cyclone (yes/no): yes

Concentration Ratio: 18:1

RESULTS

Jig Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Through Screen Gold Wt. (mg)	Through Screen Gold Recovery (%)
Feed	41	187	25.6	3150.0	100.0
Primary Hutch	15	19	0.8	3025.3	96.0
Secondary Hutch	27	6	0.6	97.4	3.1
Tails	32	248	24.2	27.3	0.9

PERCENT THROUGH SCREEN RECOVERY BY SIZE

JIG PRODUCT

GOLD SIZE	Hutch 1	Hutch 2	Tails	Feed
+30	99.0	1.0	0.0	100
30x100	94.3	4.4	1.3	100
-100	86.3	9.4	4.2	100

Table 20
JIG TEST NUMBER 3

Date: 7/17/86

Hutch Water Flowrate: 84 gpm/cell

Feed Thickened w/ 10" KREBS Classifying Cyclone (yes/no): yes

Concentration Ratio: 26:1

RESULTS

Jig Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Through Screen Gold Wt. (mg)	Through Screen Gold Recovery (%)
Feed	32	213	21.0	2490.0	100.0
Primary Hutch	10	19	0.5	2407.2	96.7
Secondary Hutch	13	8	0.3	75.9	3.0
Tails	20	353	20.2	6.9	0.3

PERCENT THROUGH SCREEN RECOVERY BY SIZE

JIG PRODUCT

GOLD SIZE	Hutch 1	Hutch 2	Tails	Feed
+30	98	2	0	100
30x100	98	2	0	100
-100	82	15	3	100

Table 21
JIG TEST NUMBER 4

Date: 7/17/86

Hutch Water Flowrate: 44 gpm/cell

Feed Thickened w/ 10" KREBS Classifying Cyclone (yes/no): no

Concentration Ratio: 16:1

RESULTS

Jig Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Through Screen Gold Wt. (mg)	Through Screen Gold Recovery (%)
Feed	28	265	22.0	3549.1	100.0
Primary Hutch	15	19	0.8	3459.6	97.5
Secondary Hutch	27	6	0.6	76.7	2.1
Tails	22	326	20.6	12.8	0.4

PERCENT THROUGH SCREEN RECOVERY BY SIZE

GOLD SIZE	JIG PRODUCT Hutch 1	Hutch 2	Tails	Feed
+30	98.8	1.2	0.0	100
30x100	96.8	3.2	0.0	100
-100	94.1	2.4	3.4	100

Table 22
JIG TEST NUMBER 5

Date: 7/18/86

Hutch Water Flowrate: 44 gpm/cell

Feed Thickened and preconcentrated using a 12 inch CWC (CR = 5:1)

RESULTS

Jig Product	Pulp Density (% Solids)	Flow Rates Slurry (gpm)	Flow Rates Dry Solids (tph)	Through Screen Gold Wt. (mg)	Through Screen Gold Recovery (%)
Feed	53	25	5.0	--	--
Primary Hutch	--	--	--	3831.8	--
Secondary Hutch	--	--	--	29.2	--
Tails	16	68	3.0	--	--

PERCENT THROUGH SCREEN RECOVERY BY SIZE

GOLD SIZE	JIG PRODUCT Hutch 1	Hutch 2	Tails	Feed
+30	98.8	1.2	--	--
30x100	95.6	4.4	--	--
-100	90.1	9.9	--	--

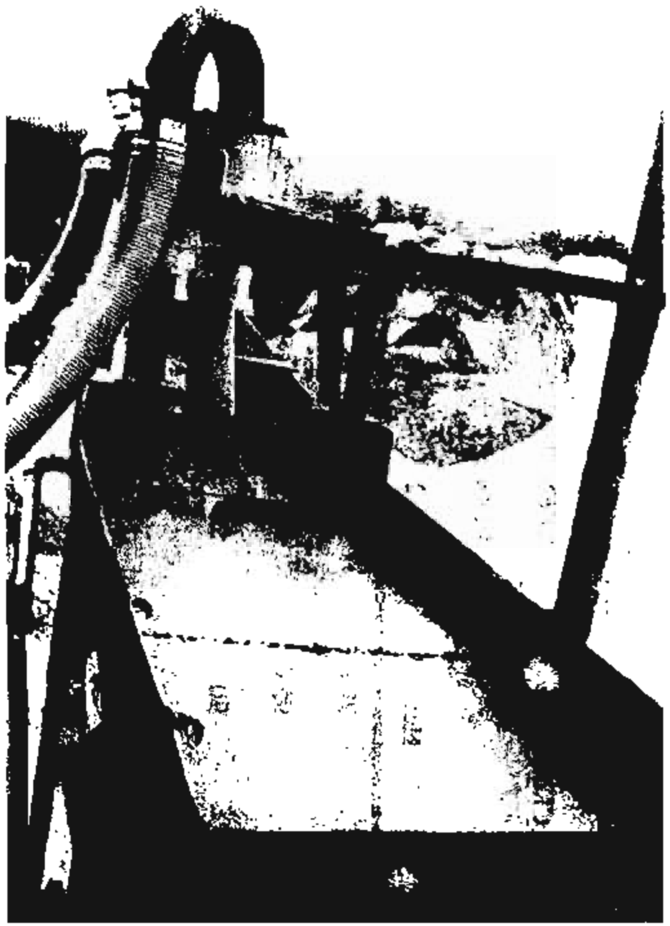

Figure 20. 12" CWC thickening and preconcentrating -3/8" screen undersize ahead of Pan American jig.

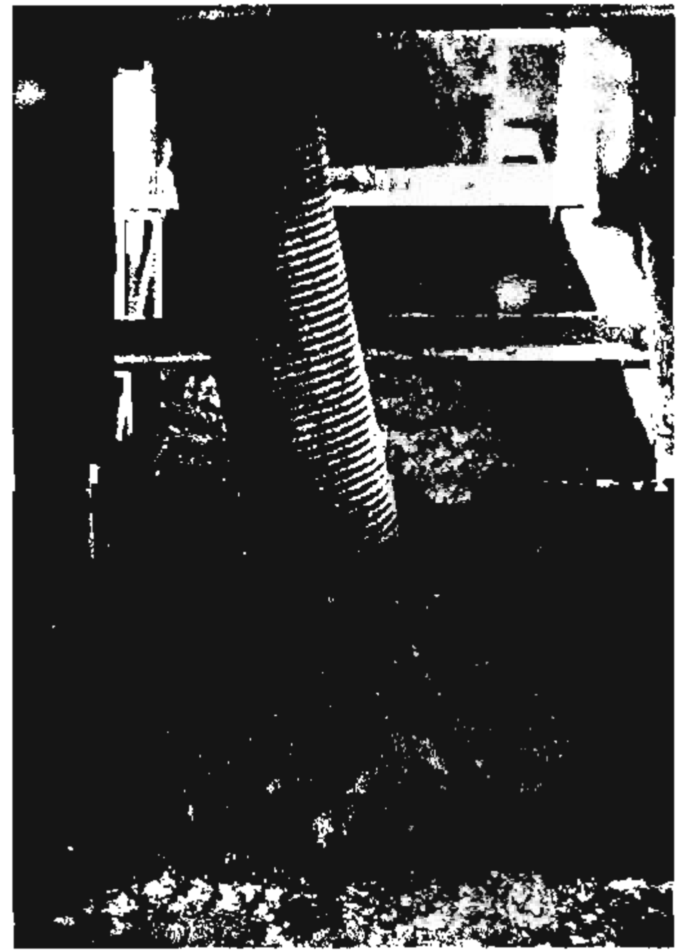

Figure 21. 12" CWC underflow discharging to jig feed.

3) Onshore or offshore mining operations where hydraulic and/or mechanical-hydraulic mining methods necessitate dewatering the run of mine slurry prior to processing.

4) Where significant quantities of fine gold (-65 mesh) exist.

Of the devices tested, the jig seems to present the best combination of simplicity and efficiency. Fine sizing is not required, and with attention given to the washing-scrubbing-screening section of a jig flowsheet, thickening jig feed may perhaps be avoided. However, given the necessity for thickening jig feed, the CWC seems a well suited unit. The test work here suggests that concentration ratios of 5:1 should not be exceeded for efficient gold recovery. However, even at a 2:1 concentration ratio, the thickened feed from a CWC will require only half the jig capacity as compared to a thickening cyclone underflow rate.

At a concentration ratio of 3:1, CWC gold (-100 mesh) recoveries should approach, if not exceed, 90%. A well regulated Pan-American jig should recover +90% of the gold in the CWC underflow and achieve a concentration ratio near 20:1. For the combined CWC-jig circuits, a concentration ratio of 60:1 and gold (-100 mesh) recoveries of +81% are estimated. Coarser gold (30 x 100 mesh) recoveries could reach +95%. Thus, an operation processing 120 yd^3/hr could reasonably produce 60 yd^3/hr of -1/4" CWC feed and 1 yd^3/hr from the jig hutches. After thickening, this hutch product would be upgraded by a secondary jig (or perhaps a spiral) and the secondary concentrate tabled for final gold separation. Batch concentrators are not suggested for secondary concentration.

The spiral seems to show no significant advantages over the jig in the gold recoveries observed and requires more intensive feed preparation. Though not addressed in the study, such factors as floor space and head room requirements for various plant capacities and capital and operating costs may show advantages of one concentrator over the other. Spiral concentration ratios may slightly exceed those of jigs for similar recoveries, and the spiral concentrate can be directly tabled without an intermediate thickening step. Where an economic percentage of gold exists in the 1/4" x 10 mesh fraction, jigs seem the likely choice over spirals.

In cases where spirals are presently in operation and/or the preferred concentrator, the CWC is again seen as a complimentary concentrator to increase plant throughput. The CWC-spiral circuit operated in this project worked well, though CWC concentration ratios were in general too high to yield optimal circuit recoveries. CWC-spiral circuits could easily obtain concentration ratios of 90:1 with gold recoveries similar to those quoted earlier for the CWC-jig combination. The CWC-spiral circuit, operating at a conservatively calculated 144:1 concentration ratio in spiral test no. 3, recovered 78% of -20 mesh free gold values. 20.5% of this recovered gold was minus 100 mesh and 60% was minus 40 mesh.

The static screen, in field operation, was not optimized for screening efficiency due to its primary role as a sampler rather than a sizing device. However, no significant operational problems were observed and should fine sizing be required, static screens should be a viable option. Gold particles are screened no more efficiently than gangue particles as shown by the laboratory test work completed. Screening efficiency may perhaps be improved with added spray water and vibration.

The Gemeni table was shown to be an extremely efficient unit for separating free gold from black sand concentrate. Testing showed that the table recovered to its free gold split, 96% to 99% of the free gold values and 89% to 95% of the total gold values. Of the gold not recovered to the free gold split, +99% reported to the table black sand concentrate product.

Froth flotation of the table black sand concentrate product yielded froth concentrate grades ranging from 370 oz/ton to 1080 oz/ton with recoveries from 24% to 43%. Froth tailings grades ranged from 4.4 oz/ton to 11.5 oz/ton. Concentration ratios achieved during flotation of the table concentrates were 133:1, 332:1, 104:1, and 144:1. Considering the poor gold recoveries by froth flotation and the high grade of the flotation tails it seems likely that locked gold and/or severely coated gold are present. Further study of froth flotation of EVECO's heavy mineral concentrate is suggested.

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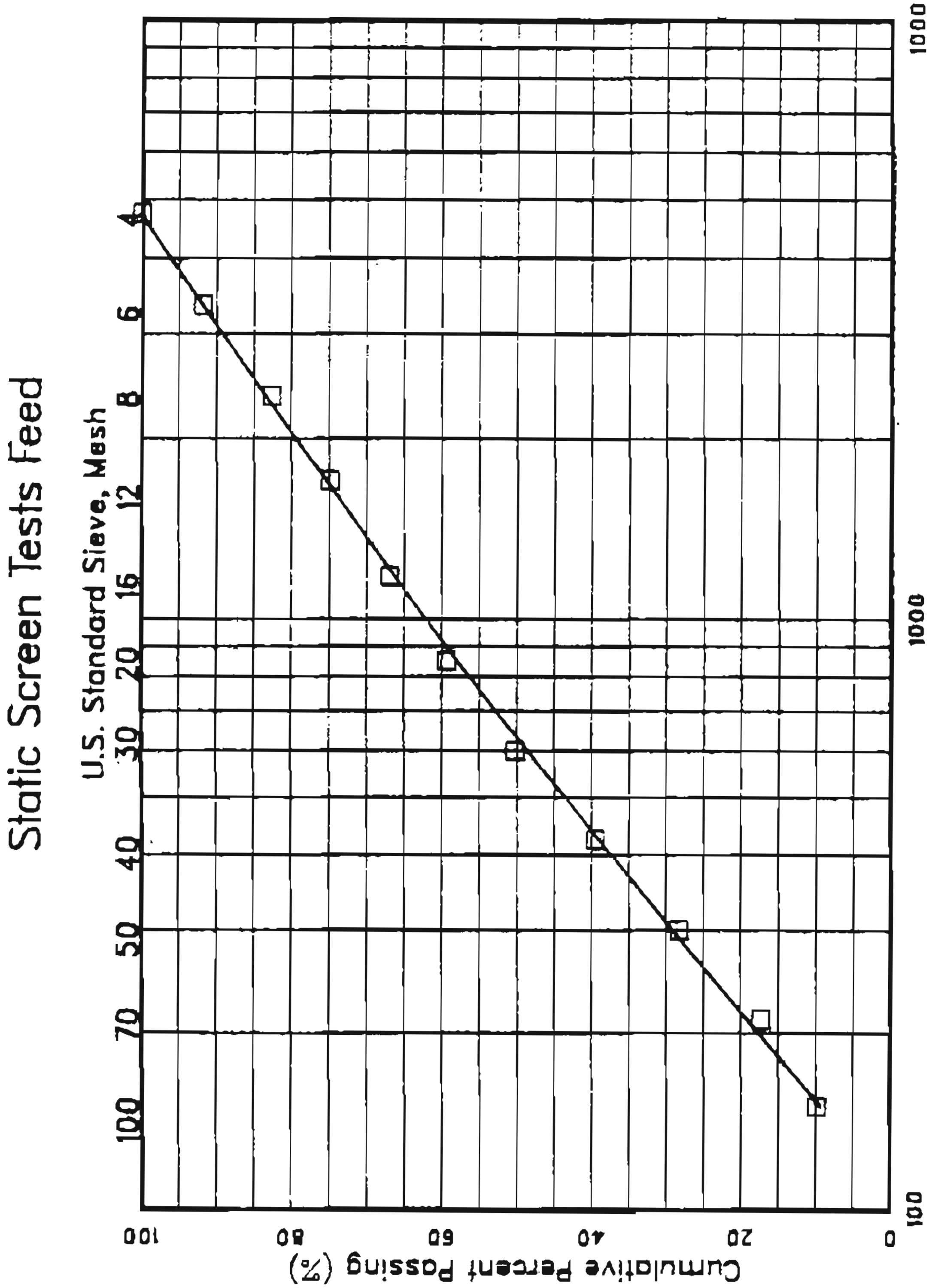
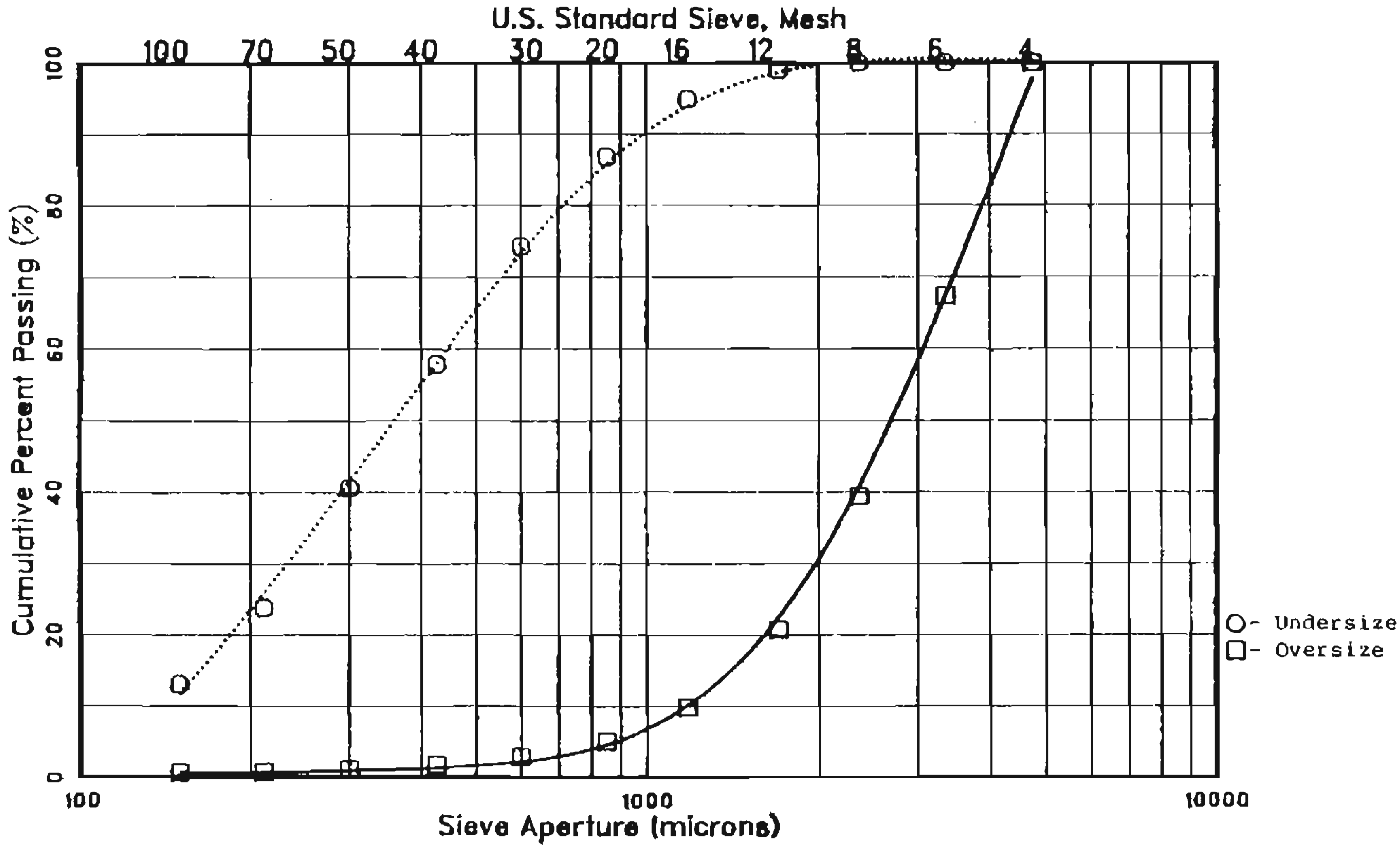
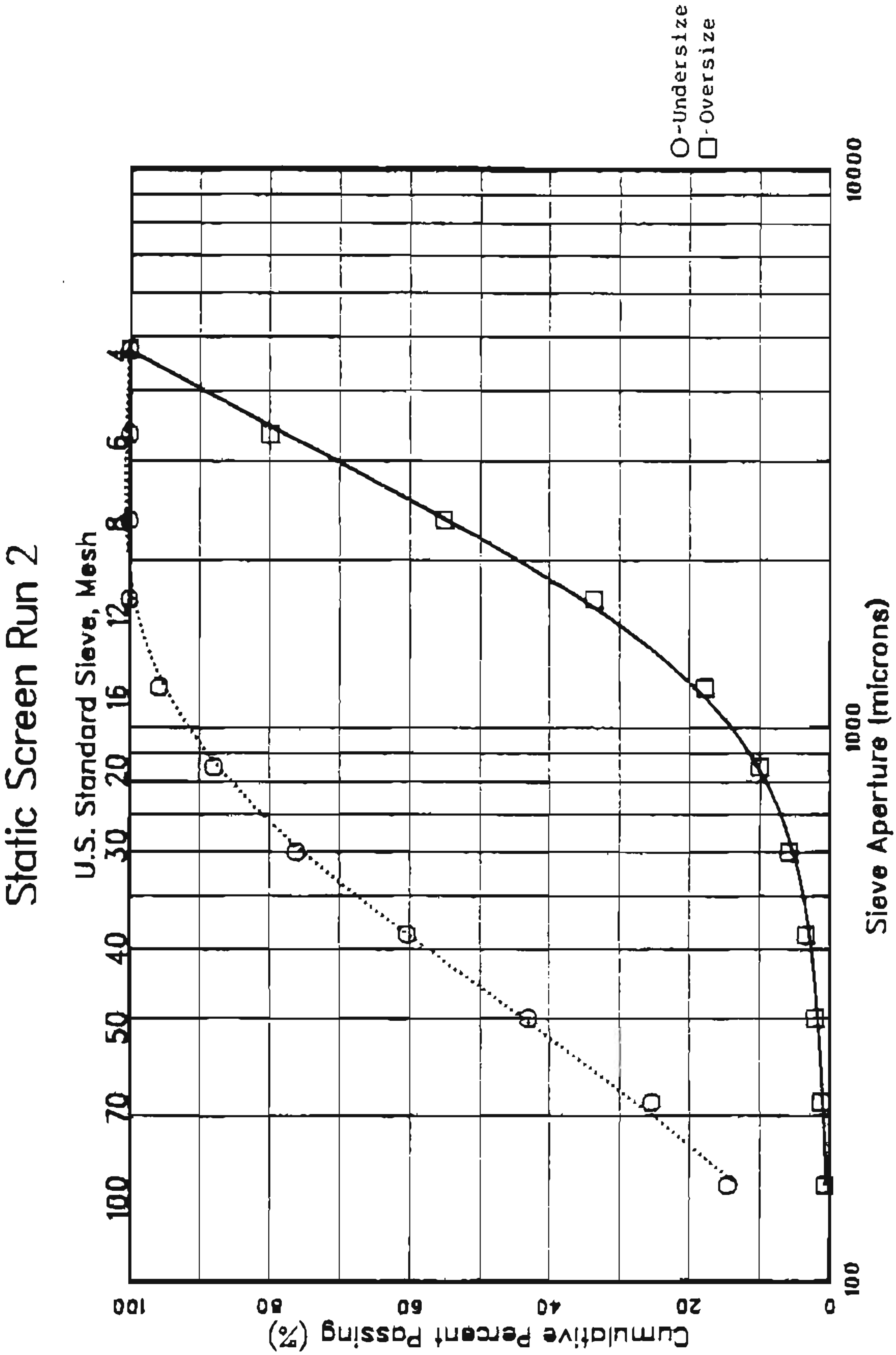
APPENDIX



Static Screen Tests Feed
U.S. Standard Sieve, Mesh
4
6
8
12
16
20
30
40
50
70
100
Sieve Aperture (microns)
100
1000
10000
Cumulative Percent Passing (%)
0
20
40
60
80
100

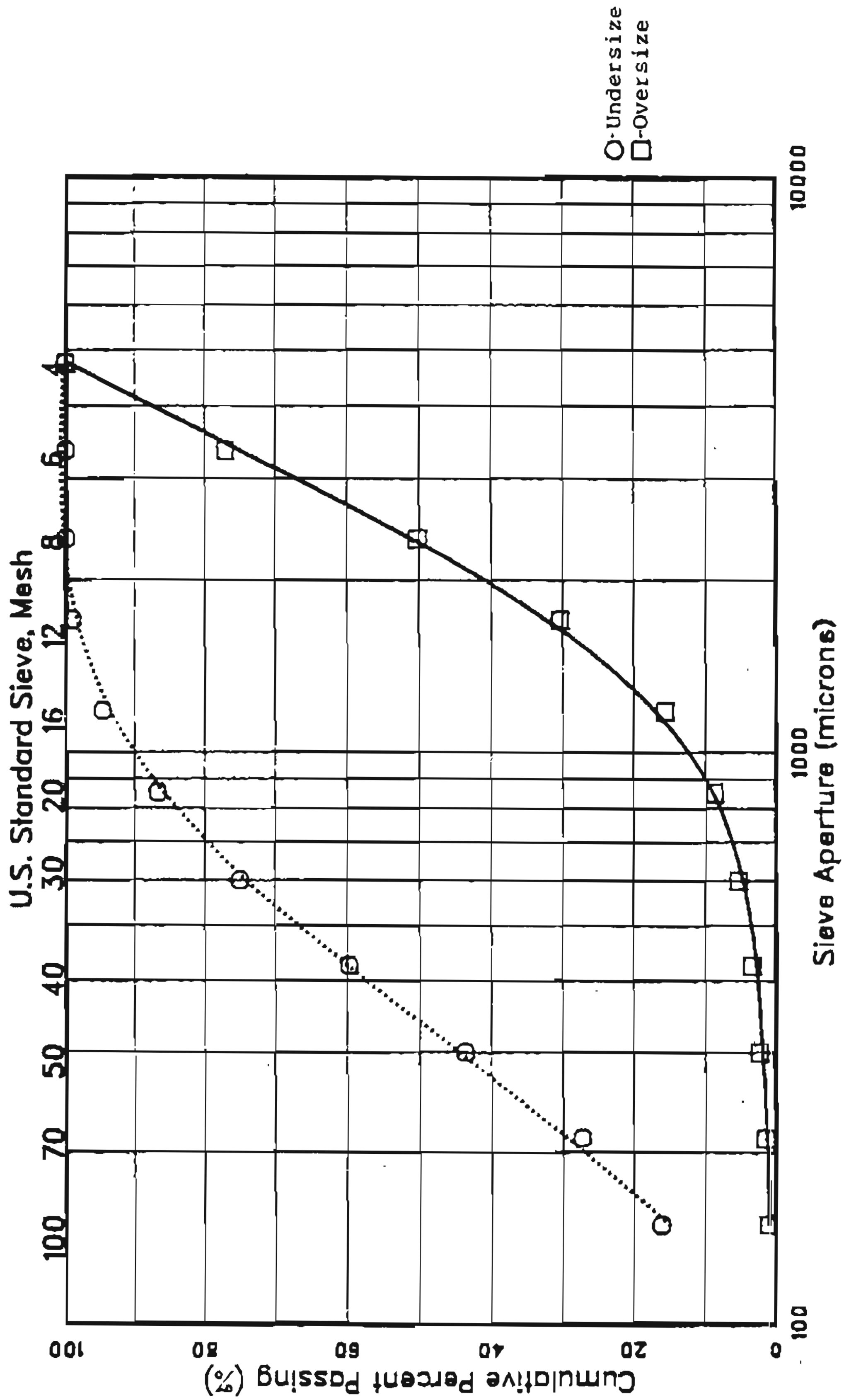
Static Screen Run 1

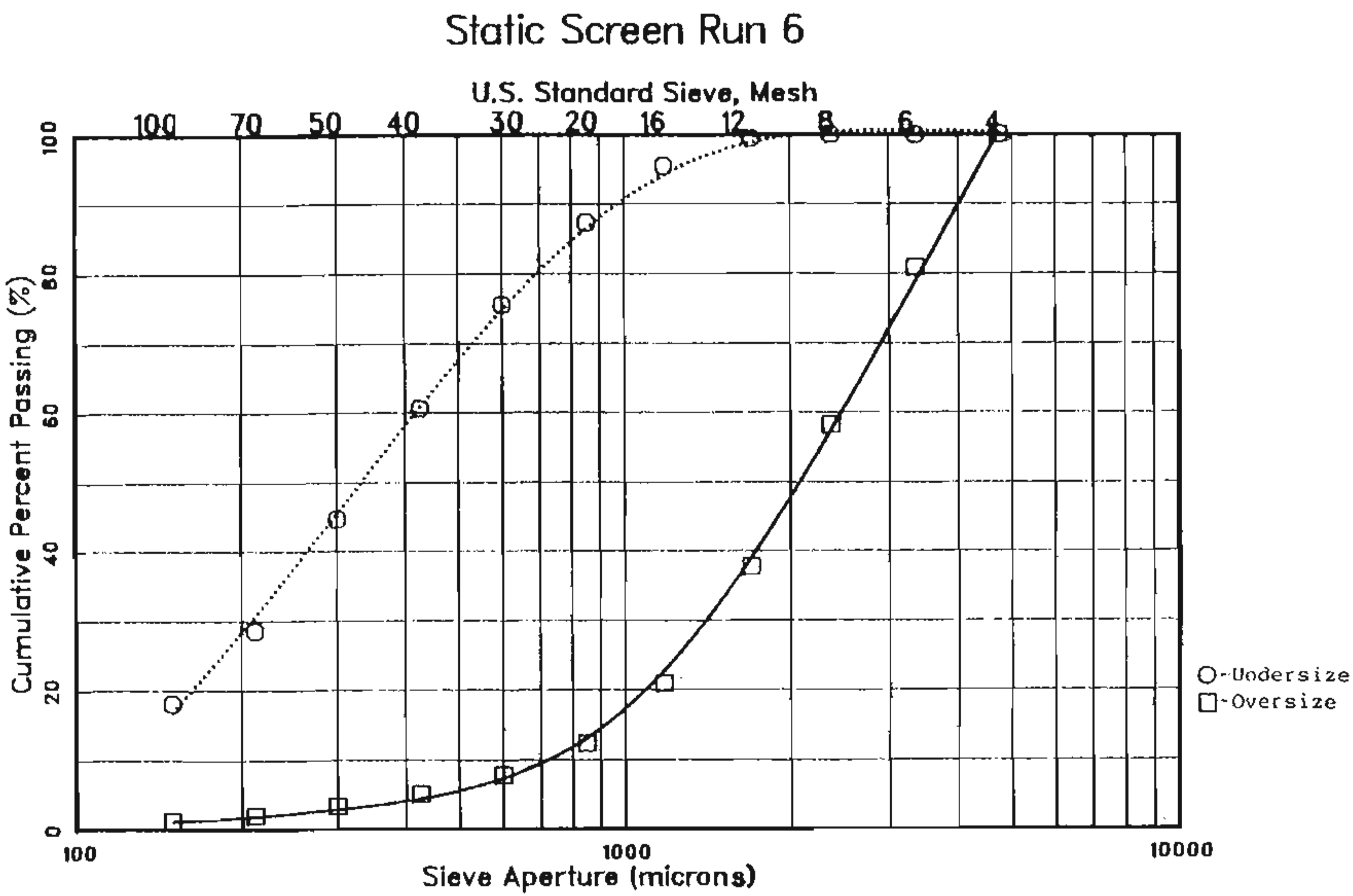




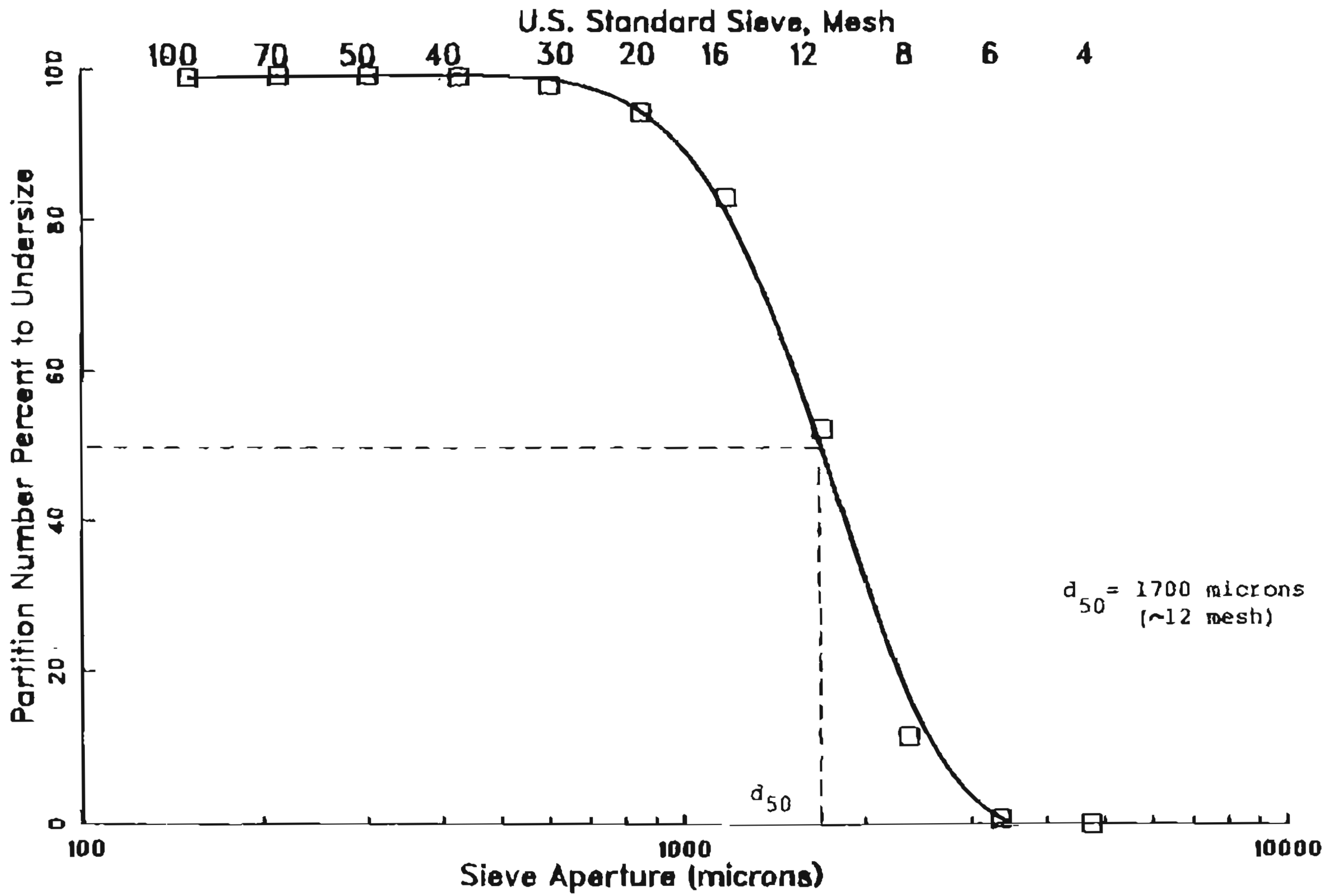
Static Screen Run 2
U.S. Standard Sieve, Mesh
4
6
8
12
16
20
30
40
50
70
100
Sieve Aperture (microns)
100
1000
10000
Cumulative Percent Passing (%)
0
20
40
60
80
100
O-Undersize
□-Oversize

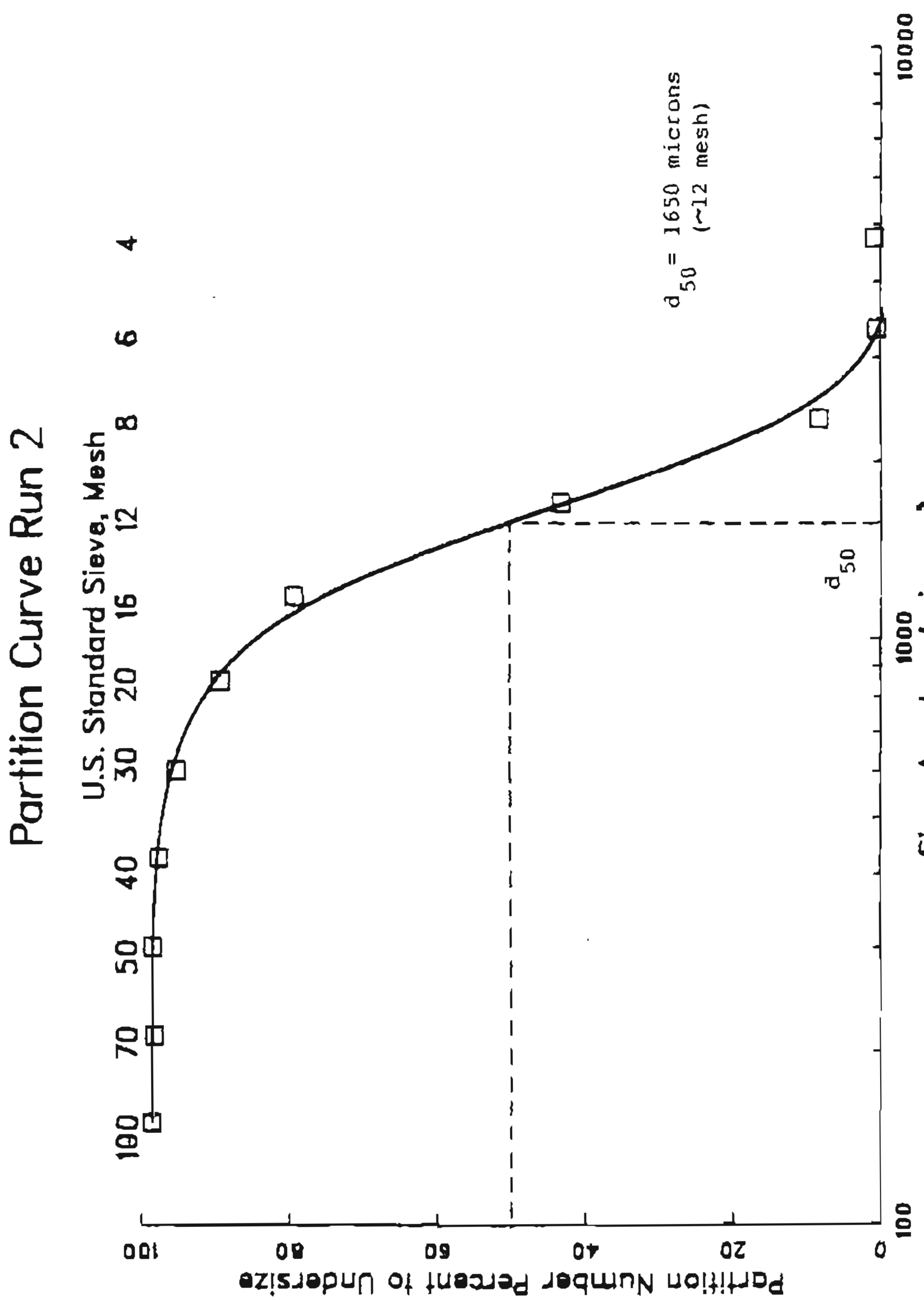
Static Screen Run 5

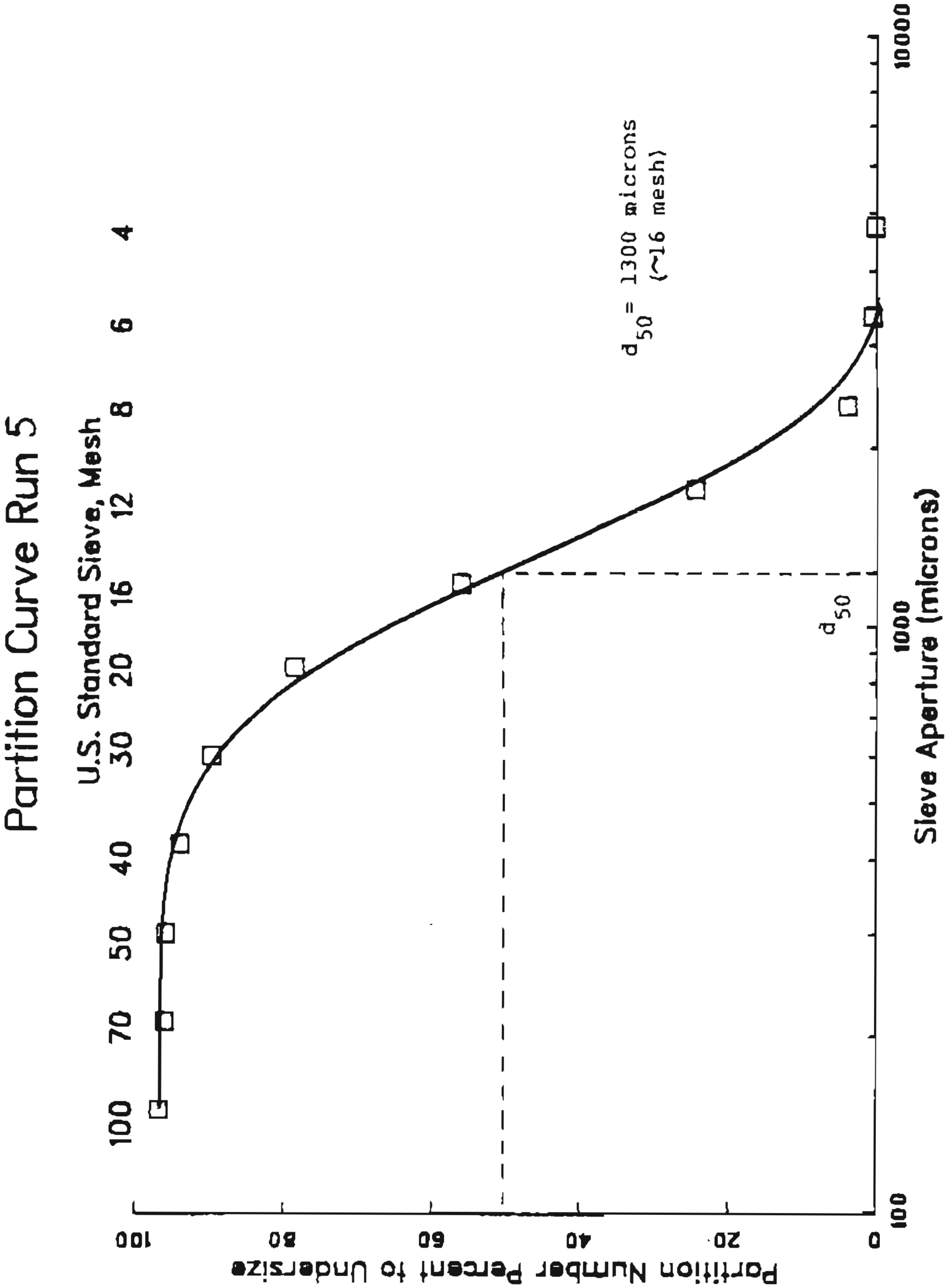



Static Screen Run 6
U.S. Standard Sieve, Mesh
100 70 50 40 30 20 16 12 8 6 4
Cumulative Percent Passing (%)
0
20
40
60
80
100
100
1000
10000
Sieve Aperture (microns)
O-Undersize
□-Oversize

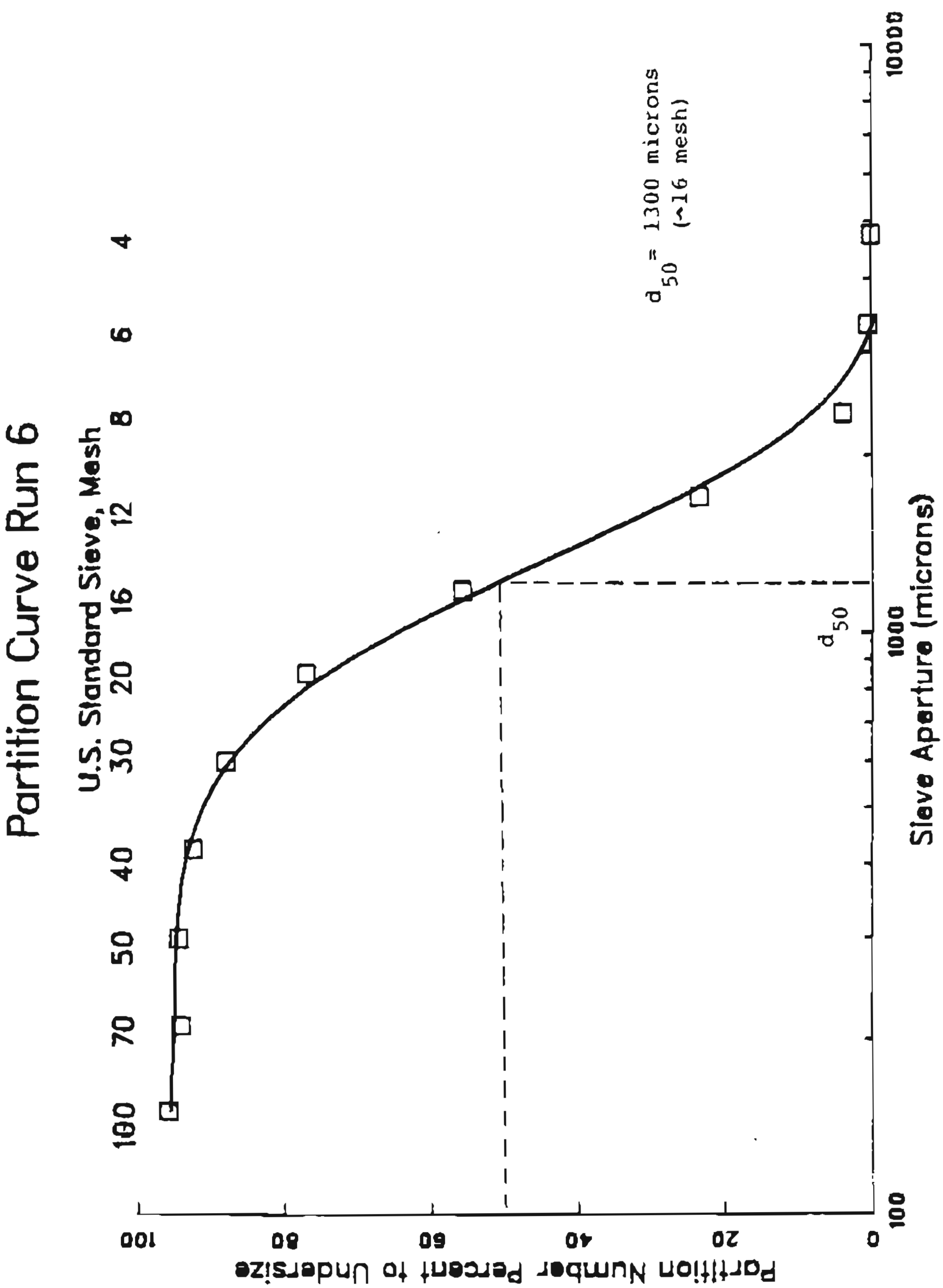
Partition Curve Run 1




Partition Curve Run 2
U.S. Standard Sieve, Mesh
100 70 50 40 30 20 16 12 8 6 4
Partition Number Percent to Undersize
0 20 40 60 80 100
Sieve Aperture (microns)
100 1000 10000
d_{50}
d_{50} = 1650 microns
(~12 mesh)

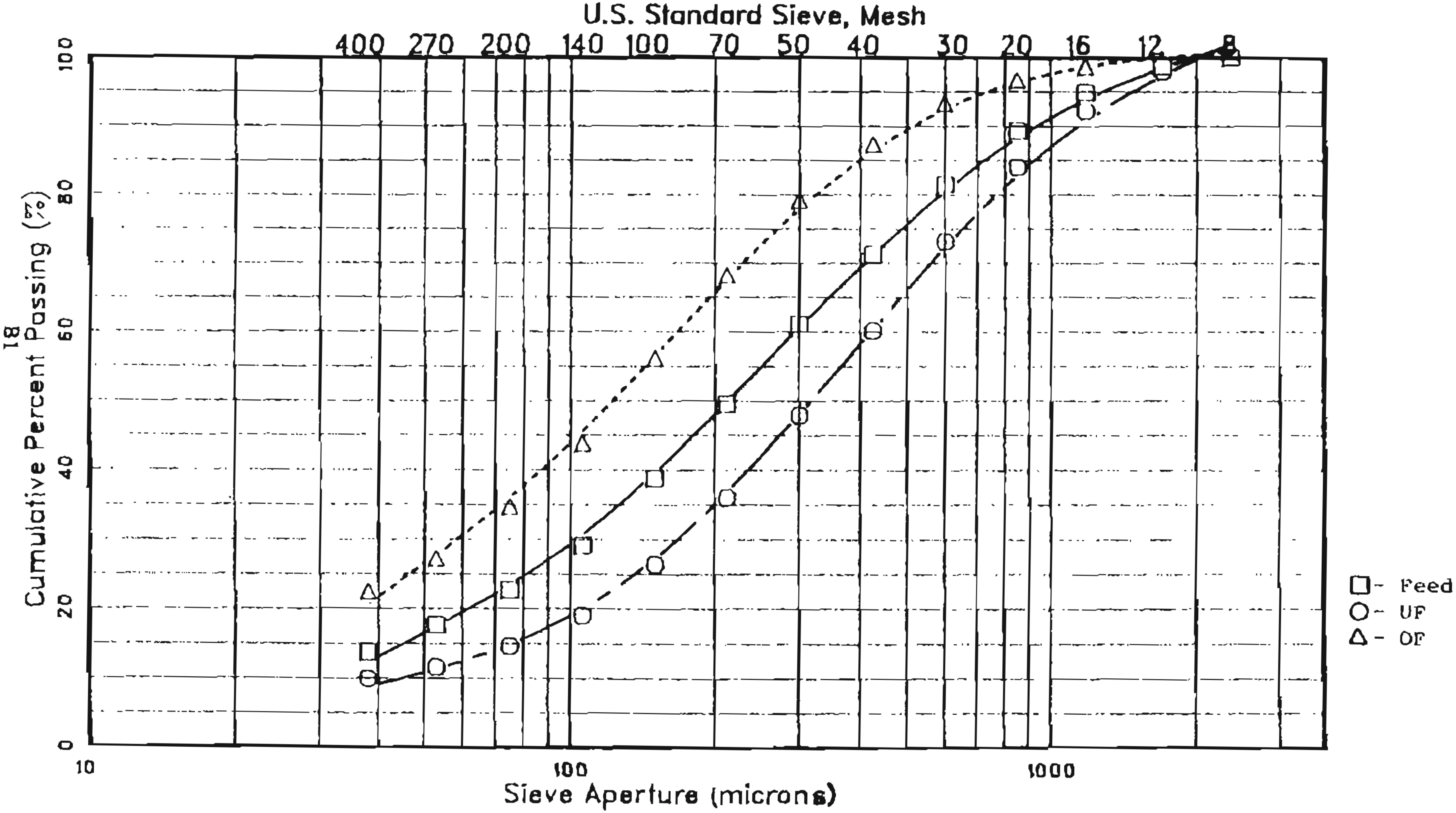


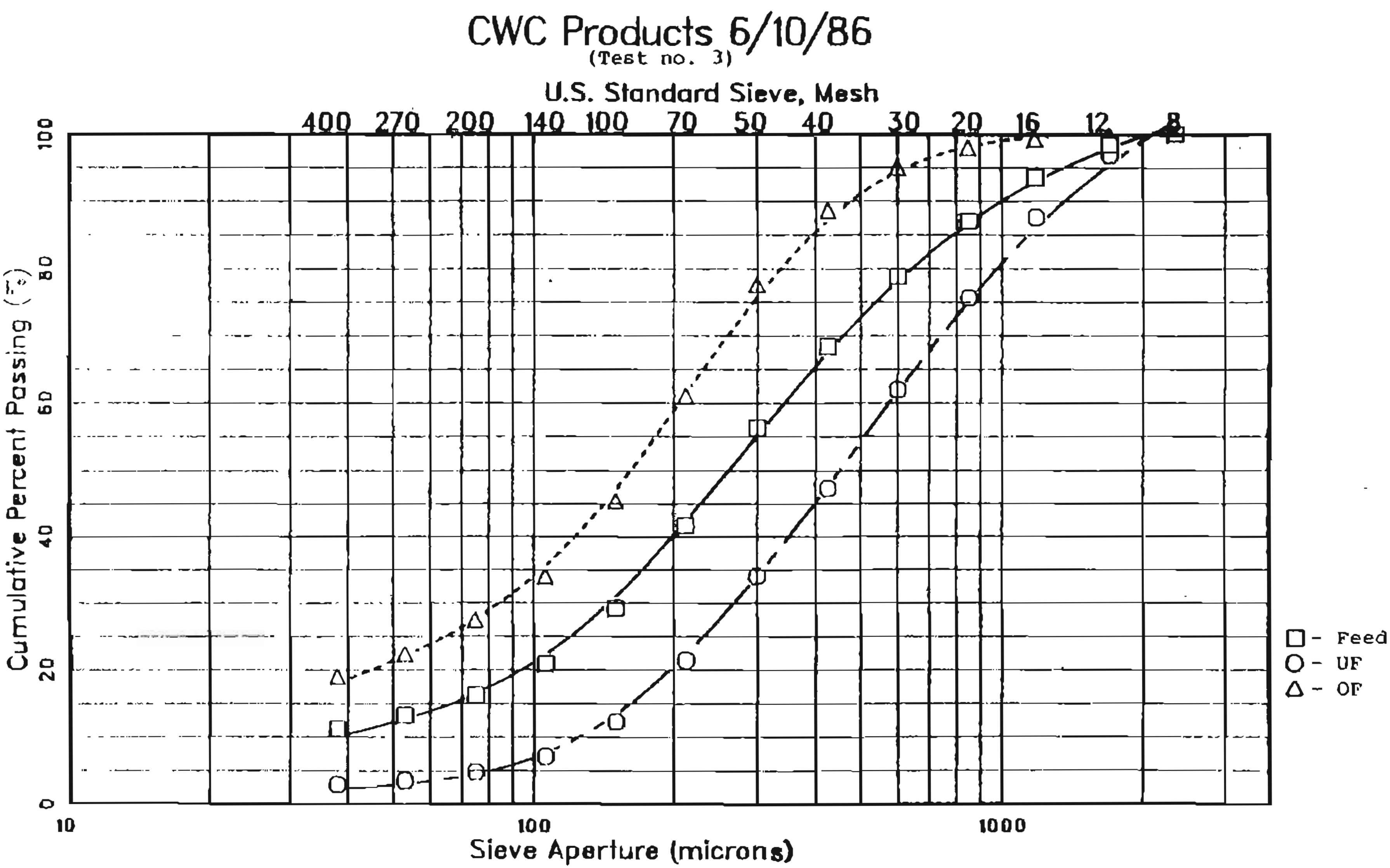
Partition Curve Run 5
U.S. Standard Sieve, Mesh
100
70
50
40
30
20
16
12
8
6
4
d_{50} = 1300 microns
(~16 mesh)
d_{50}
Partition Number Percent to Undersize
0
20
40
60
80
100
Sieve Aperture (microns)
100
1000
10000


Partition Curve Run 6
U.S. Standard Sieve, Mesh
100
70
50
40
30
20
16
12
8
6
4
Partition Number Percent to Undersize
100
80
60
40
20
0
d_{50} = 1300 microns
(~16 mesh)
d_{50}
100
1000
10000
Sieve Aperture (microns)

CWC Products 6/6/86

(Test no. 1)





CWC Products 6/10/86
(Test no. 3)
U.S. Standard Sieve, Mesh
400 270 200 140 100 70 50 40 30 20 16 12 8
Cumulative Percent Passing (%)
0 20 40 60 80 100
10 100 1000
Sieve Aperture (microns)
□ - Feed
○ - UF
△ - OF

SIZE DISTRIBUTION OF GOLD RECOVERED FROM CWC UNDERFLOW (TEST NO. 4)

Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
20 x 30	12.7	16.5	83.5
30 x 40	18.3	23.7	59.8
40 x 50	11.1	14.4	45.4
50 x 70	13.2	17.1	28.3
70 x 100	10.0	13.0	15.3
100 x 150	6.5	8.4	6.9
150 x 200	4.3	5.6	1.3
-200	1.0	1.3	---
TOTAL	77.1	100.0	

SIZE DISTRIBUTION OF GOLD RECOVERED FROM CWC OVERFLOW (TEST NO. 4)

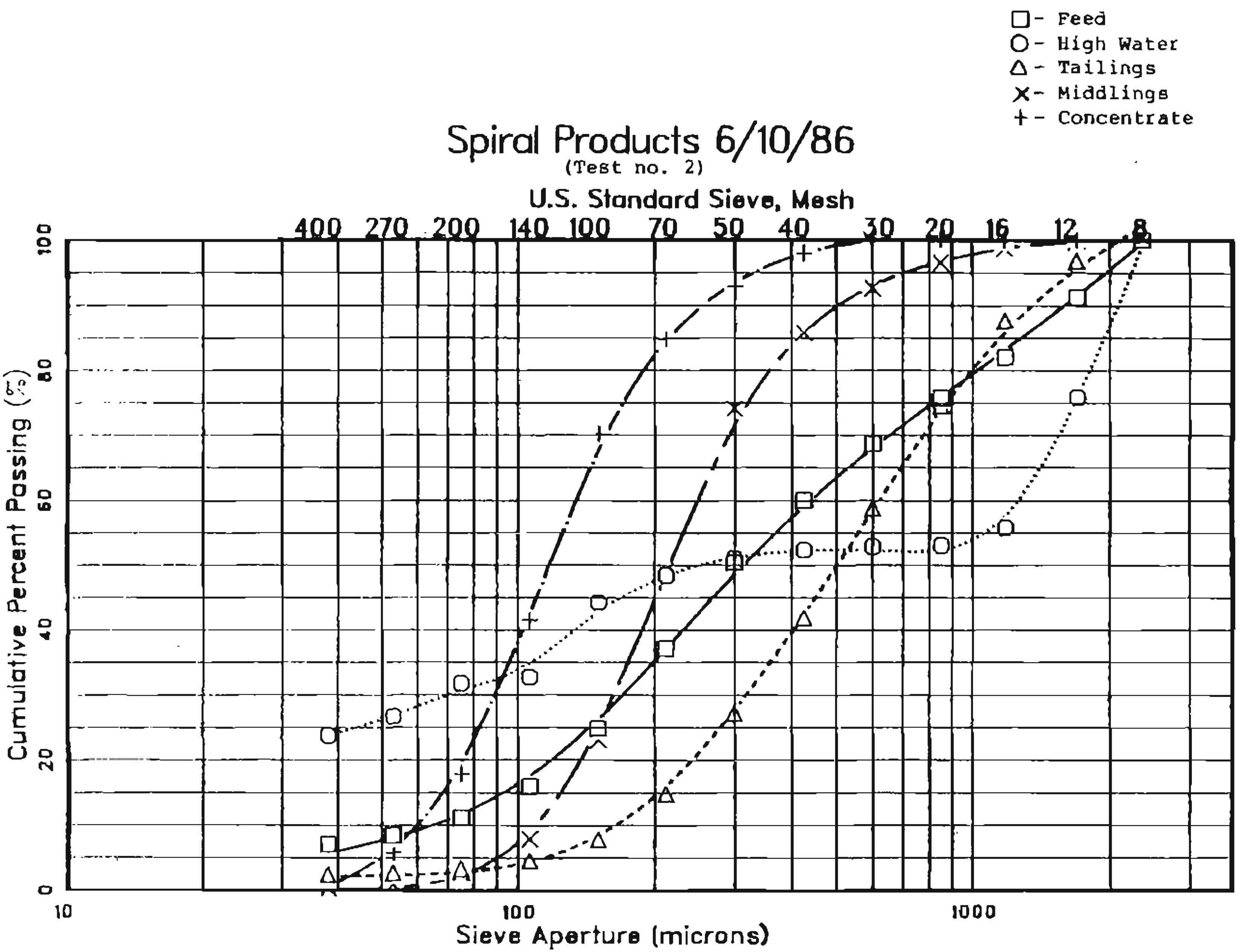
Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
20 x 30	0.0	---	---
30 x 40	0.0	---	---
40 x 50	0.0	---	100
50 x 70	0.16	9.6	90.4
70 x 100	0.22	13.2	77.2
100 x 150	1.0	59.9	17.3
150 x 200	0.26	15.6	1.7
-200	0.03	1.7	---
TOTAL	1.67	100.0	

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM 12" CWC UNDERFLOW (TEST NO. 4)

	ASTM Mesh Size						
Particle Number	20x30	30x40	40x50	50x70	70x100	100x150	150x200
1	0.22	0.10	0.14	0.13	0.22	0.24	0.10
2	0.24	0.15	0.15	0.15	0.23	0.25	0.20
3	0.27	0.16	0.15	0.16	0.27	0.27	0.22
4		0.20	0.19	0.22	0.30	0.27	0.23
5		0.20	0.21	0.24	0.30	0.36	0.37
6		0.22	0.23	0.24	0.31	0.37	0.37
7		0.24	0.23	0.26	0.39	0.38	0.40
8		0.25	0.24	0.28	0.44	0.40	0.42
9		0.26	0.28	0.32	0.55	0.42	0.57
10		0.31	0.42	0.32	0.60	0.42	0.57
Statistics:							
Mean	0.24	0.21	0.22	0.23	0.36	0.34	0.34
Median	0.24	0.21	0.22	0.24	0.30	0.36	0.37
Standard Deviation	0.02	0.06	0.08	0.07	0.13	0.07	0.16
Range:							
Min.-	0.22	0.10	0.14	0.13	0.22	0.24	0.10
Max.-	0.27	0.31	0.42	0.32	0.60	0.42	0.57

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM 12" CWC OVERFLOW (TEST NO. 4)

	ASTM Mesh Size		
Particle Number	70x100	100x150	150x200
1	0.21	0.23	0.24
2	0.23	0.25	0.31
3	0.23	0.26	0.32
4	0.27	0.27	0.38
5	0.42	0.31	0.38
6		0.35	0.44
7		0.41	0.45
8		0.43	0.52
9		0.43	0.54
10		0.45	0.54
11			0.57
12			0.58
13			0.63
Statistics:			
Mean	0.27	0.34	0.45
Median	0.23	0.33	0.45
Standard Deviation	0.08	0.08	0.12
Range:			
Min.-	0.21	0.23	0.24
Max.-	0.42	0.45	0.63


Spiral Products 6/10/86
(Test no. 2)
U.S. Standard Sieve, Mesh
400 270 200 140 100 70 50 40 30 20 16 12 8
Cumulative Percent Passing (%)
0 20 40 60 80 100
10 100 1000
Sieve Aperture (microns)
□ - Feed
○ - High Water
Δ - Tailings
X - Middlings
+ - Concentrate

SIZE DISTRIBUTION OF GOLD RECOVERED FROM SPIRAL CONCENTRATE (TEST NO. 4)

Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
20 x 30	20.7	1.6	98.4
30 x 40	53.7	4.1	94.3
40 x 50	165.7	12.7	81.6
50 x 70	278.8	21.3	60.3
70 x 100	295.8	22.6	37.7
100 x 150	224.4	17.1	20.6
150 x 200	207.9	15.9	4.7
-200	62.0	4.7	---
TOTAL	1309.0	100.0	

SIZE DISTRIBUTION OF GOLD RECOVERED FROM SPIRAL MIDDLINGS (TEST NO. 4)

Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
20 x 30	18.9	42.7	57.3
30 x 40	16.0	36.2	21.1
40 x 50	8.0	18.1	3.0
50 x 70	1.2	2.7	0.3
70 x 100	0.1	0.2	0.1
100 x 150	0.03	0.1	---
150 x 200	nil	---	---
-200	nil	---	---
TOTAL	44.23	100.0	

SIZE DISTRIBUTION OF GOLD RECOVERED FROM SPIRAL TAILINGS (TEST NO. 4)

Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
20 x 30	0.0	---	100
30 x 40	0.0	---	100
40 x 50	0.0	---	100
50 x 70	0.3	78.1	21.9
70 x 100	0.08	20.8	1.1
100 x 150	0.004	1.1	---
150 x 200	nil	---	---
-200	nil	---	---
TOTAL	0.384	100.0	

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM SPIRAL CONCENTRATE (TEST NO. 4)

Particle Number	ASTM Mesh Size 20x30	30x40	40x50	50x70	70x100	100x150	150x200
1	0.07	0.15	0.11	0.15	0.14	0.16	0.22
2	0.10	0.18	0.12	0.16	0.15	0.20	0.28
3	0.14	0.21	0.14	0.19	0.16	0.21	0.28
4	0.14	0.22	0.15	0.21	0.18	0.28	0.36
5	0.16	0.23	0.16	0.24	0.22	0.34	0.36
6	0.17	0.25	0.18	0.25	0.22	0.35	0.37
7	0.25	0.25	0.18	0.26	0.24	0.36	0.37
8	0.31	0.28	0.26	0.28	0.25	0.36	0.39
9		0.33	0.32	0.28	0.27	0.39	0.44
10		0.39	0.33	0.35	0.46	0.40	0.48
Statistics:							
Mean	0.17	0.25	0.20	0.24	0.23	0.30	0.36
Median	0.15	0.24	0.17	0.24	0.22	0.34	0.36
Standard Deviation	0.08	0.07	0.08	0.06	0.09	0.09	0.08
Range:							
Min.-	0.07	0.15	0.11	0.15	0.14	0.16	0.22
Max.-	0.31	0.39	0.33	0.35	0.46	0.40	0.48

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM SPIRAL MIDDLINGS (TEST NO. 4)

Particle Number	ASTM Mesh Size 20x30	30x40	40x50	50x70	70x100
1	0.09	0.13	0.14	0.12	0.25
2	0.15	0.18	0.15	0.13	0.34
3	0.16	0.22	0.15	0.13	
4	0.17	0.22	0.17	0.18	
5	0.19	0.22	0.18	0.24	
6	0.20	0.23	0.19	0.26	
7		0.24	0.27	0.35	
8		0.25	0.28	0.36	
9		0.30		0.36	
10		0.31		0.41	
Statistics:					
Mean	0.16	0.23	0.19	0.25	0.30
Median	0.16	0.22	0.18	0.25	0.30
Standard Deviation	0.04	0.05	0.05	0.11	0.06
Range:					
Min.-	0.09	0.13	0.14	0.12	0.25
Max.-	0.20	0.31	0.28	0.41	0.34

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM SPIRAL TAILINGS (TEST NO. 4)

Particle Number	ASTM Mesh Size 50x70	70x100	100x150	150x200
1	0.22	0.22	0.31	0.21
2	0.27	0.24	0.31	0.23
3		0.27	0.34	0.23

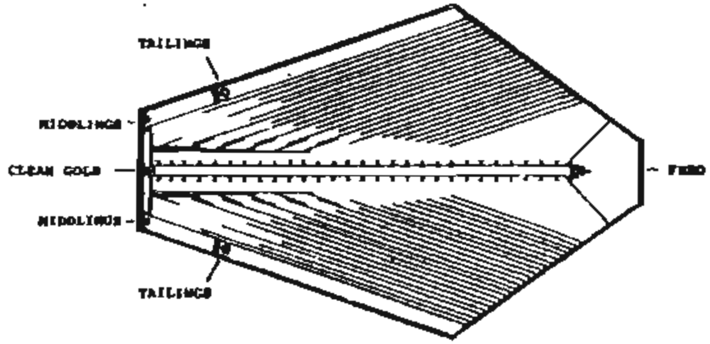
GOLD HARVESTERS, INC.
Recovery • Sales • Service

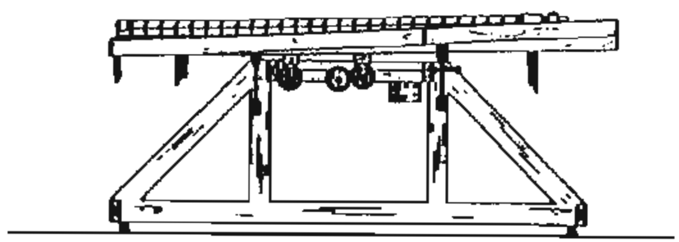
(303) 232-7166

[illegible] Lakewood, Colo. [illegible]

RODGERS *GEMINI GOLD TABLES

United States and Foreign Patents Pending





BASE FRAME CUTAWAY

Thank you for your interest. We invite you to test your material using our equipment. Please call for an appointment.

Wendell Rodgers
President

RODGERS *GEMINI GOLD TABLES

APPLICATION: Final extraction of fine "FREE" gold from concentrates, up grading mineral concentrates, visual testing and sampling. Also, recovers gold, and mercury, lost by amalgamation processing.

ADVANTAGE: A high volume "finisher" that produces a clean gold concentrate, with typical recovery of [illegible]% or more, and saves valuable minerals. The unique compact design does more work than two ordinary tables.

FEED CAPACITY: *GEMINI #1000: [illegible] to [illegible] pounds per hour is typical.

*GEMINI #250: [illegible] to [illegible] pounds per hour is typical.

FEED SIZE: Minus 20 mesh ideal for close gold separation, minus 10 mesh for maximum "rough" and "finish". Minus 1/8" for "rough" concentration. Minus ¼" can be processed, but not recommended.

WATER USE: *GEMINI #1000: up to [illegible] gallons per minute, [illegible] G.P.M. is typical.

*GEMINI #250: up to 10 gallons per minute. [illegible] G.P.M. is typical.

ELECTRIC POWER: 110 V. A.C. [illegible] HZ, variable speed ¼ H.P. D.C. Motor.

HEAD MOTION: Our unique design is centrally located beneath the top. The motor drives a 1" offset crank shaft and a roller bearing rubber wheel, which contacts an adjustable roller bearing rubber wheel attached to the top super structure. A third adjustable roller bearing rubber wheel acts as a bumper post. An adjustable compression spring dampens the action. An electronic speed control is provided for optimum action control.

TABLE TOP: The top is exterior plywood with a microlam super structure which cannot warp or twist. It is completely sealed with polyurethane. Our proprietary top coatings are colored green for high visibility of gold and minerals.

BASE FRAME: Components of heavy duty [illegible] gauge rectangular steel are bolted together, which allows compact shipment and quick assembly.

DIMENSIONS: *GEMINI #1000 - Top: [illegible]"W. x [illegible]"L. x [illegible]"H.
Base: [illegible]"W. x [illegible]"L.

*GEMINI #250 - Top: [illegible]"W. x [illegible]"L. x [illegible]"H.
Base: [illegible]"W. x [illegible]"L.

INSTALLATION: No special foundation is required, however a firm rigid floor is essential. Assembly and set up time is less than [illegible] hours.

MAINTENANCE: Five bearings require lubrication once per week of continuous operation and a periodic check for loose bolts, etc.

INSTRUCTIONS: Operating instructions are provided.

WARRANTY: A 12 month warranty is limited to defective materials and workmanship

PRICES: Rodgers *GEMINI #1000: $[illegible] F.O.B. Denver, Colorado, U.S.A.
Crating Charge: $[illegible] - Shipping Weight:

Rodgers *GEMINI #250: $[illegible] F.O.B. Denver, Colorado, U.S.A.
Crating Charge: $[illegible] - Shipping Weight:

NOTE: Colorado residents add [illegible]% Sales Tax.

TERMS: [illegible]% deposit with order, balance C.O.D.

DELIVERY: Generally [illegible] to [illegible] weeks. Call to confirm.

THE MINERS' COMPANY

Recovery of Fine Gold

[illegible]
[illegible]

[illegible]

RODGERS *GEMENI GOLD TABLES

APPLICATION: Extraction of fine "FREE" gold from concentrates, up grading mineral concentrates, visual testing and sampling for "FREE" gold.

ADVANTAGE: A high volume "finisher" that produces a clean gold concentrate, with typical recovery of 98% or more and saves valuable minerals.

FEED CAPACITY: *Gemeni #1000: 1,000 to 2,000 pounds per hour.
*Gemeni # 250: 250 to 500 pounds per hour.

FEED SIZE: Minus 20 mesh ideal for clean gold separation, minus 10 mesh maximum "rough" and "finish". Minus 1/8" for "rough" concentration only.

WATER USE: *Gemeni #1000: 10 to 20 gallons per minute.
*Gemeni # 250: 5 to 10 gallons per minute.

ELECTRIC POWER: 110 V. 1/4 H.P. D.C. 50/60 cycle motor with speed control.

HEAD MOTION: A unique design, centrally located beneath the top. The motor drives a 1" diameter crank shaft, with a roller bearing wheel attached to the top super structure. A third adjustable, roller bearing wheel acts as a bumper post. An adjustable compression spring dampens and controls the action. An electronic speed control is provided for optimum action control.

CONSTRUCTION: The top is exterior plywood with a microlam super structure which cannot warp or twist. It is completely sealed with polyurethane and our own durable top coatings. They are colored green for high visibility of gold and minerals.

BASE FRAME: Components of heavy duty 11 GA. rectangular steel are bolted together, which allows compact shipment and quick assembly on site.

DIMENSIONS: *Gemeni #1000, top; 66.5" W. x 108" L. x 42" H.
base; 36" W. x 78.5" L. x 39" H.
*Gemeni # 250, top; 51.5" W. x 78.5" L. x 39" H.
base; 27" W. x 72" L. x 39" H.

INSTALLATION: No special foundation is required, however a firm floor or base is essential, for successful operation. Assembly and set up time is less than two hours.

MAINTENANCE: Five bearings require lubrication once per week of continuous operation; a periodic check for loose bolts, etc.

INSTRUCTIONS: Operating instructions are provided.

WARRANTY: 12 month warranty limited to defective materials and workmanship.

PRICES: Crating: $400.00
Rodgers *Gemeni #1000: $9,950.00 F.O.B. Fairbanks, Alaska, U.S.A.
Rodgers *Gemeni # 250: $6,700.00 F.O.B. Fairbanks, Alaska, U.S.A.

TERMS: 50% deposit with order, balance C.O.D.

DELIVERY: Generally 4 to 6 weeks. Call to confirm.

RODGERS GEMENI 12/12 OPERATING INSTRUCTIONS
PLEASE READ AND FOLLOW DIRECTIONS CAREFULLY

Each machine is set up, fully assembled and tested; therefore, we know it operates properly. However, it takes some experience to coordinate the action, rate of feed, and water flow.

1. Place the machine on a solid floor and level it sideways and lengthways. All four feet must be tight and firm on the floor. If necessary place shims under the feet to keep it from rocking.

2. Adjust the Action Control (the wing-nut below the feeder) clockwise for more power, counter-clockwise for less. The sand and gold will "walk" faster, or slower, according to the power applied. There is little or no forward movement of gold when the power is too weak. Too much power creates excessive vibration, causing some gold to be lost in the tailings.

3. Get acquainted with the Action Control by first conducting a "Dry Run", using no water or sand. Place a coin (dime or penny) at the feeder end of the table. A good starting action for processing materials is when the coin "walks" 12" in 15 seconds. Stop the machine and fill the gold containers with water. Attach them to the threaded fittings under the holes beneath the top near the discharge end.

4. The proper pitch is built-in and requires only minor adjustments to balance the top sideways. The balance adjusters are two eyebolts: one on each side, underneath the top.

5. Prepare gold bearing concentrates by pre-screening the sand wet. Use a -20 mesh screen, or a common window screen. When recycling water, flush out as much silt, clay, or trash as you can without losing the gold.

6. Position the Funnel/Feeder slightly above the rubber pad. Put damp -20 mesh sand in the Funnel/Feeder and cover with water to keep it wet. This prevents fine gold from contacting air and floating off.

7. There are two main valves for water control. One controls the amount of water under the Funnel/Feeder spout. The other one controls the water at the center of the table for cleaning the gold. When using needle valves for water control, set both the main valves and all the needle valves open about 50%. With the water on, adjust the main valves until water trickles from each needle valve. Now, the main valves control them all for easier fine tuning. Individual needle valves may be adjusted as required for optimum separation and cleaning. The table top must be completely wet to keep from floating off fine gold.

8. There are three factors that govern the rate of feed: the space allowed under the Funnel/Feeder spout, the amount of water under the Funnel/Feeder spout, and the speed of the table action. The action of the machine will stratify the sand as it leaves the feeder. Adjust the action until the gold separates from the sand. Adjust the water flow to clean the gold as it "walks" into the short pick-up grooves. Always use the least amount of water you can to clean the gold. Heavier than average minerals, super light thin gold, gold in quartz, alloys, amalgam, silver, and lead will work down and collect at the central discharge area. A middling product is discharged on each side.

9. If the rate of feed is too fast, black sands may "bank up" (move as one mass) and carry off some fine gold. Visible gold particles should not be allowed to pass beyond the first set of riffle grooves. Losses may be substantial when the rate of feed is too fast, when too much water is used, or when too much or too little action occurs. Optimum rate of feed, separation and cleaning of the gold can only be determined by experimenting and by careful fine tuning.

SLIGHT adjustments DO make a BIG difference! With a little practice and patience you will soon become an expert operator. We wish you the greatest success and will do our best to help. Please feel free to contact us if you have any questions.

GOLD HARVESTERS, INC., 9725 W. 21st Ave., Lakewood, Colorado 80215

SIZE DISTRIBUTION OF GOLD RECOVERED FROM JIG HUTCH #1 (TEST NO. 2)

Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
+20	1417.5	46.8	53.2
20 x 30	484.9	16.0	37.2
30 x 40	329.0	10.9	26.3
40 x 50	201.1	6.6	19.7
50 x 70	169.1	5.6	14.1
70 x 100	146.2	4.8	9.3
100 x 150	117.5	3.9	5.4
150 x 200	112.0	3.7	1.7
-200	48.0	1.7	---
TOTAL	3025.3	100.0	

SIZE DISTRIBUTION OF GOLD RECOVERED FROM JIG HUTCH #2 (TEST NO. 2)

Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
+20	13.9	17.1	82.9
20 x 30	8.6	10.6	72.3
30 x 40	9.9	12.1	60.2
40 x 50	5.2	6.4	53.8
50 x 70	6.4	7.8	46.0
70 x 100	4.4	5.4	40.6
100 x 150	2.5	3.1	37.5
150 x 200	12.8	15.7	21.8
-200	17.8	21.8	---
TOTAL	81.5	100.0	

SIZE DISTRIBUTION OF GOLD RECOVERED FROM JIG TAILINGS (TEST NO. 2)

Gold Size (ASTM Mesh)	Wt (mg)	Wt (%)	Cummulative Wt % Finer than
+70	0.0	0.0	100
70 x 100	0.05	45.5	54.5
100 x 150	0.027	24.5	30.0
150 x 200	0.019	17.3	12.7
-200	0.014	12.7	---
TOTAL	0.110	100.0	

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM JIG HUTCH NO. 1 (TEST NO. 2)

	ASTM Mesh Size						
Particle Number	20x30	30x40	40x50	50x70	70x100	100x150	150x200
1	0.15	0.15	0.16	0.13	0.16	0.18	0.23
2	0.15	0.16	0.16	0.18	0.19	0.19	0.34
3	0.16	0.16	0.17	0.18	0.22	0.21	0.34
4	0.17	0.19	0.17	0.20	0.22	0.24	0.36
5	0.22	0.21	0.19	0.24	0.24	0.25	0.36
6	0.22	0.21	0.30	0.25	0.29	0.29	0.36
7	0.24	0.23	0.34	0.32	0.31	0.34	0.38
8	0.26	0.24	0.40	0.39	0.38	0.35	0.44
9	0.30	0.28	0.48	0.40	0.42	0.48	0.62
10	0.32	0.36	0.79	0.48	0.46	0.53	0.65
Statistics:							
Mean	0.22	0.22	0.32	0.28	0.29	0.31	0.41
Median	0.22	0.21	0.24	0.24	0.26	0.27	0.36
Standard Deviation	0.06	0.06	0.20	0.11	0.10	0.12	0.13
Range:							
Min.-	0.15	0.15	0.16	0.13	0.16	0.18	0.23
Max.-	0.32	0.36	0.79	0.48	0.46	0.53	0.65

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM JIG HUTCH NO. 2 (TEST NO. 2)

ASTM Mesh Size

Particle Number	20x30	30x40	40x50	50x70	70x100	100x150	150x200
1	0.19	0.19	0.08	0.12	0.13	0.20	0.12
2	0.30	0.19	0.09	0.14	0.13	0.24	0.25
3	0.30	0.28	0.10	0.17	0.16	0.25	0.29
4		0.29	0.11	0.18	0.19	0.29	0.31
5		0.30	0.12	0.20	0.20	0.30	0.34
6		0.38	0.15	0.20	0.21	0.31	0.35
7		0.40	0.17	0.23	0.22	0.31	0.37
8			0.19	0.26	0.22	0.35	0.38
9			0.21	0.26	0.24	0.38	0.57
10			0.25	0.34	0.40	0.40	0.62
Statistics:							
Mean	0.26	0.29	0.15	0.21	0.21	0.30	0.36
Median	0.30	0.29	0.14	0.20	0.20	0.30	0.34
Standard Deviation	0.06	0.08	0.06	0.06	0.08	0.06	0.14
Range:							
Min.-	0.19	0.19	0.08	0.12	0.13	0.20	0.12
Max.-	0.30	0.40	0.25	0.34	0.40	0.40	0.62

COREY SHAPE FACTOR VALUES FOR RANDOM GOLD PARTICLES FROM JIG TAILINGS (TEST NO. 2)

ASTM Mesh Size

Particle Number	70x100	100x150	150x200
1	0.26	0.29	0.45
2			0.53
3			0.35