UNIVERSITY OF ALASKA

FIELD INVESTIGATION OF HYDROCYCLONES FOR THE RECOVERY OF FINE GOLD
PHASE III

BY
P.D. Rao, D.R. Maneval and D.E. Walsh

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APPENDIX E

FIELD INVESTIGATION OF HYDROCYCLONES FOR THE RECOVERY OF FINE GOLD

Phase III

By

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and

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July 10, 1984

INTRODUCTION

There has been increased interest from placer miners for improved methods of recovering fine gold from placer material. Mines using sluice boxes may recover gold down to 100 mesh, but recovery of gold finer than this size is a function of particle shape factor, sluice box design and operating parameters. It is felt that a concentrating device is needed to recover gold finer than 100 mesh that may not be recoverable in a sluice box. The device should be capable of processing a large volume of water and solids discharged from the sluice box. Compound water cyclones (CWC), successfully used in the coal processing industry, seem to offer solutions. It is not intended to produce a finished product with cyclones, but to reduce bulk so that the reduced concentrate, free of slimes, could further be treated by flotation, gravity methods, or cyanidation to isolate the gold.

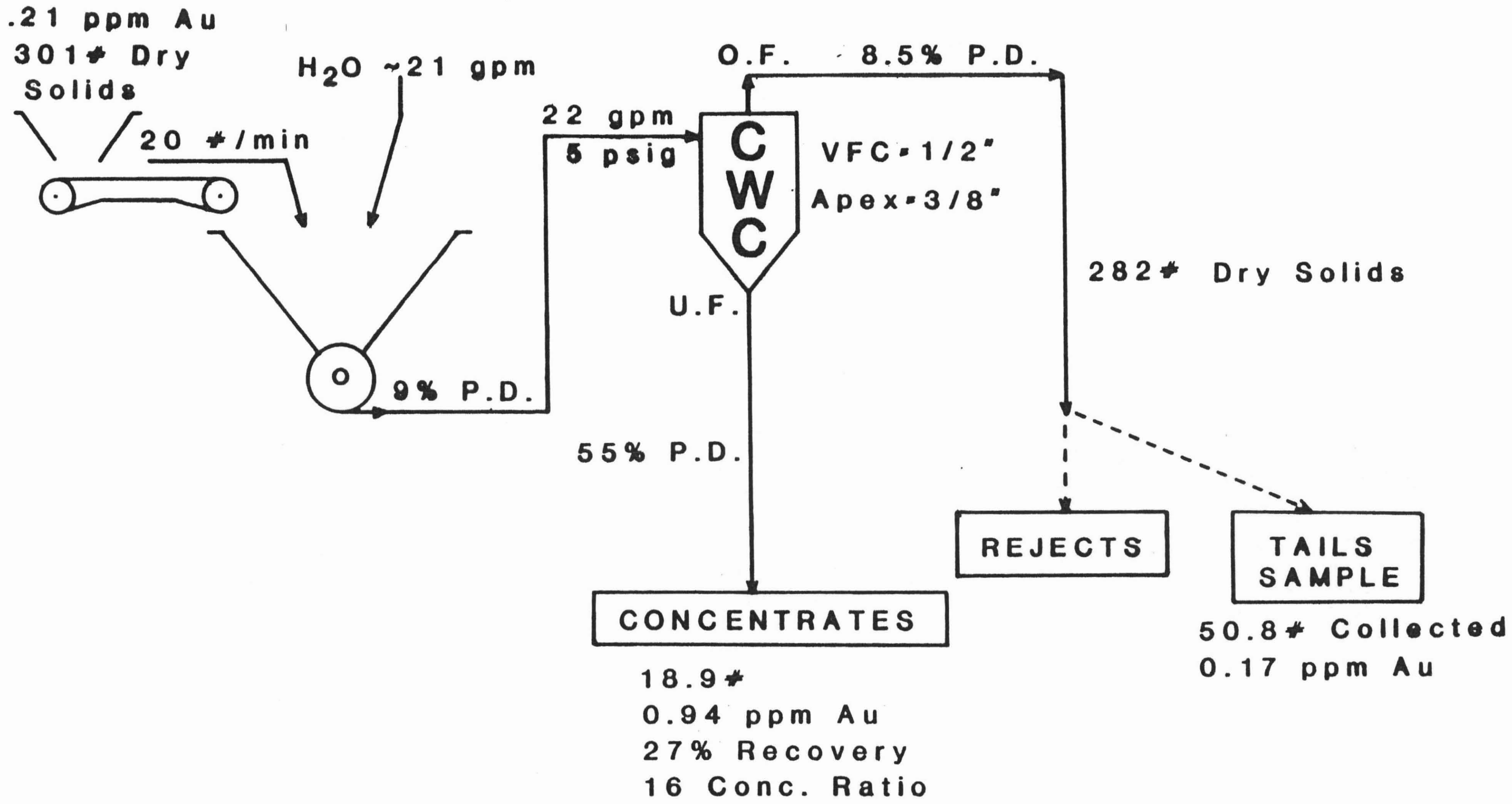
In 1980 the Mineral Industry Research Laboratory (MIRL) of the University of Alaska, Fairbanks began a project to investigate the effectiveness of compound water cyclones for the recovery of fine free gold. Fine gold here is defined to mean not only that gold finer than 40 mesh but also free gold whose low shape factor decreases sluice box recovery of even the coarser size fractions.

Preliminary investigations were conducted using a 2.75-inch CWC constructed of pyrex glass to test free gold recovery from placer gravels sampled at three mines located in interior Alaska. The results of this work were published in MIRL report no. 55. Free gold recoveries ranged from 84% to 99% using two stages of CWC concentration to attain overall concentration ratios of approximately 25:1. Testing also revealed the CWC performed well for concentrating heavy minerals of density greater than 3.3 and coarser than 270 mesh.

Encouraged by these initial findings it was decided to assemble a pilot scale compound water cyclone recovery test system with which to conduct both laboratory and field studies. Two 4-inch CWC's, one 4-inch classifying cyclone, a 2-inch slurry pump, and associated hardware were purchased and the assembly of the automatic two stage pilot plant was completed in July, 1982. The test system was designed for easy disassembly and transport.

Laboratory testing of the CWC pilot plant included single stage concentration of various feed materials. Figure 1 shows the laboratory flowsheet used in CWC processing a gold bearing beach sand from Yakataga. The entire concentrate was collected. CWC tailings were sampled for 5 seconds every 30 seconds. Gold from both the concentrate and tailings was further concentrated by froth flotation. The frother products were assayed for gold. Portions of the froth products were used to isolate gold particles for determination of their Corey shape factor. The concentrate assayed 0.94 ppm gold while the tailings assayed 0.17 ppm gold giving a recovery of 27%. The concentration ratio was 16:1.

Examination of shape factors of gold from the tailings and concentrates shows no significant difference (Figure 2). Low recoveries point to the need to operate the cyclone so as to achieve lower concentration ratios. Recovery of gold with such low shape factors requires concentration ratios much lower than 8:1; normally



O.F. = Overflow

U.F. = Underflow

P.D. = Pulp Density

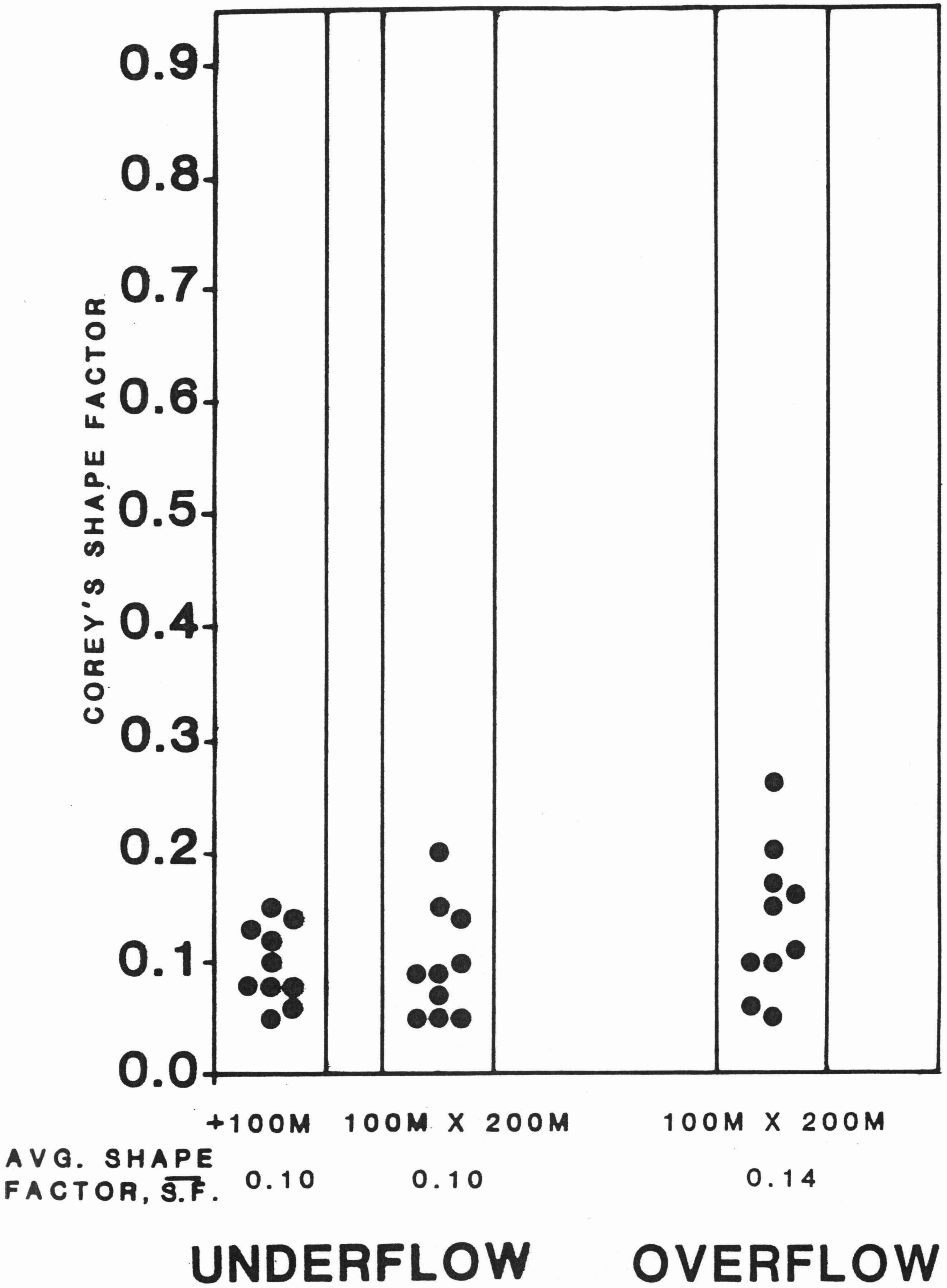
VFC = Vortex Finder Clearance

C.W.C. SINGLE STAGE TEST OF -14M YAKATAGA BEACH SANDS

FIGURE 1

FIGURE 2

CHARACTERISTICS OF GOLD PARTICLES FROM C.W.C. UNDERFLOW AND OVERFLOW
(YAKATAGA BEACH SAND)



considered good practice in mineral beneficiation systems. The fact that the CWC did recover gold with shape factors as low as .05 is very encouraging.

A synthetic sample was prepared by mixing 65 x 200 mesh placer gold with the tailings from the Yakataga CWC laboratory test. Measured shape factors for the gold used ranged from 0.25 to 0.89 (Figure 3). Figure 4 shows the flowsheet used in processing the sample. Concentrate and tailings were assayed for gold. The concentration ratio for the single stage system was 31:1. Concentrates assayed 28 ppm Au while the tailings assayed 0.6 ppm Au. Again use of a lower concentration ratio should improve recovery.

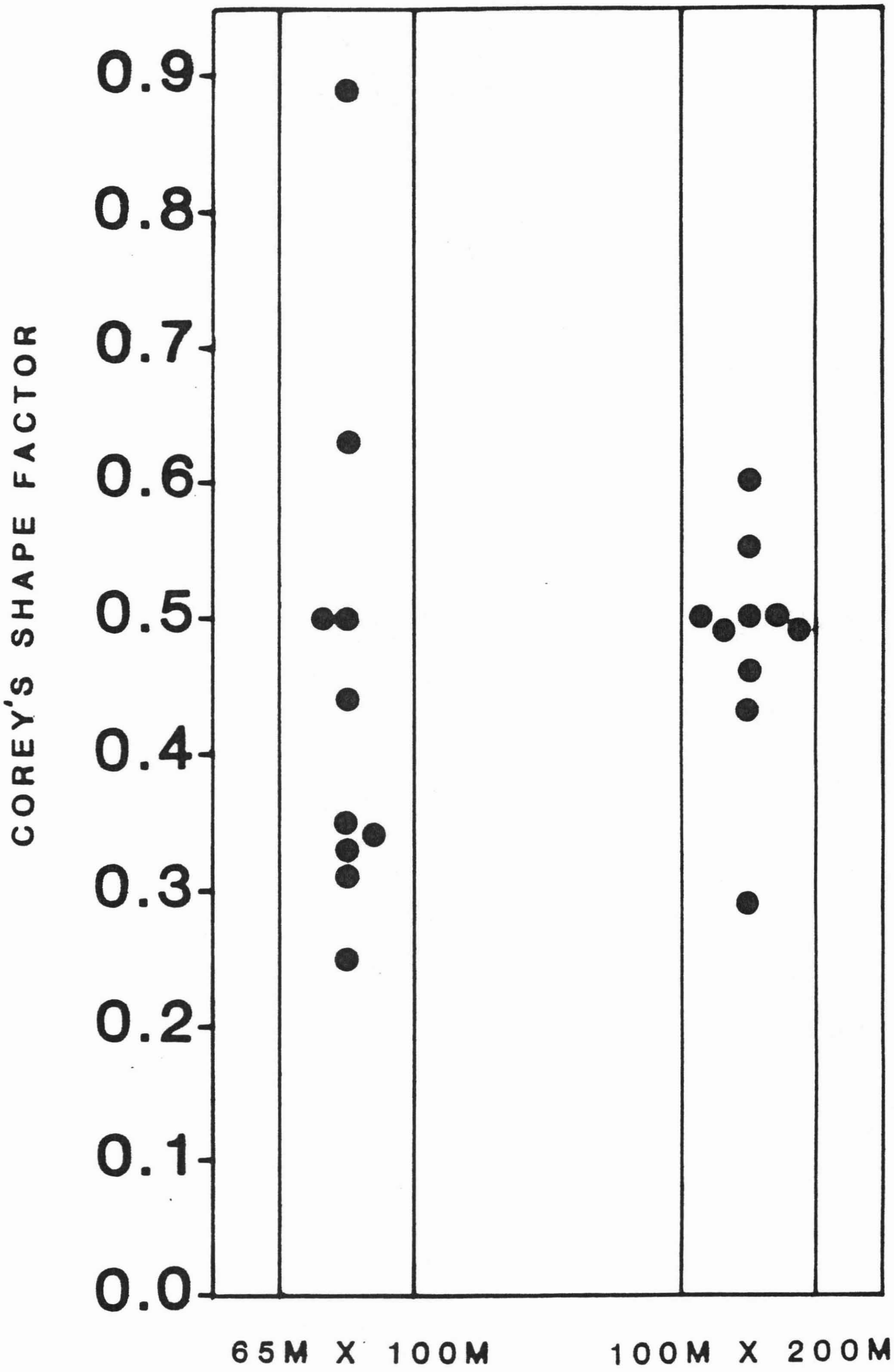
The Yakataga beach sand test with a concentration ratio of 16:1 yielded a gold recovery of 27%. The synthetic sample gave a higher gold recovery, 61%, at a concentration ratio of 31:1, which is attributable to the more favorable shape factor. Recoveries desired and the shape factor of the gold will dictate practicable concentration ratios per stage.

In June, 1983, the pilot plant was transported to and operated at a placer gold mine located in the Circle mining district, Alaska. The feed to the CWC pilot plant was a split from the operations sluice box tailings. Splits from both the main channel and one side channel of the sluice box were processed in single and double stage concentration circuits at a rate of 0.8 tons dry solids per hour.

The above paragraphs summarize MIRL's research with the CWC to the date following receipt of funding from the U.S. Department of Interior, Office of Surface Mining, for Phase III of "Field Investiga-

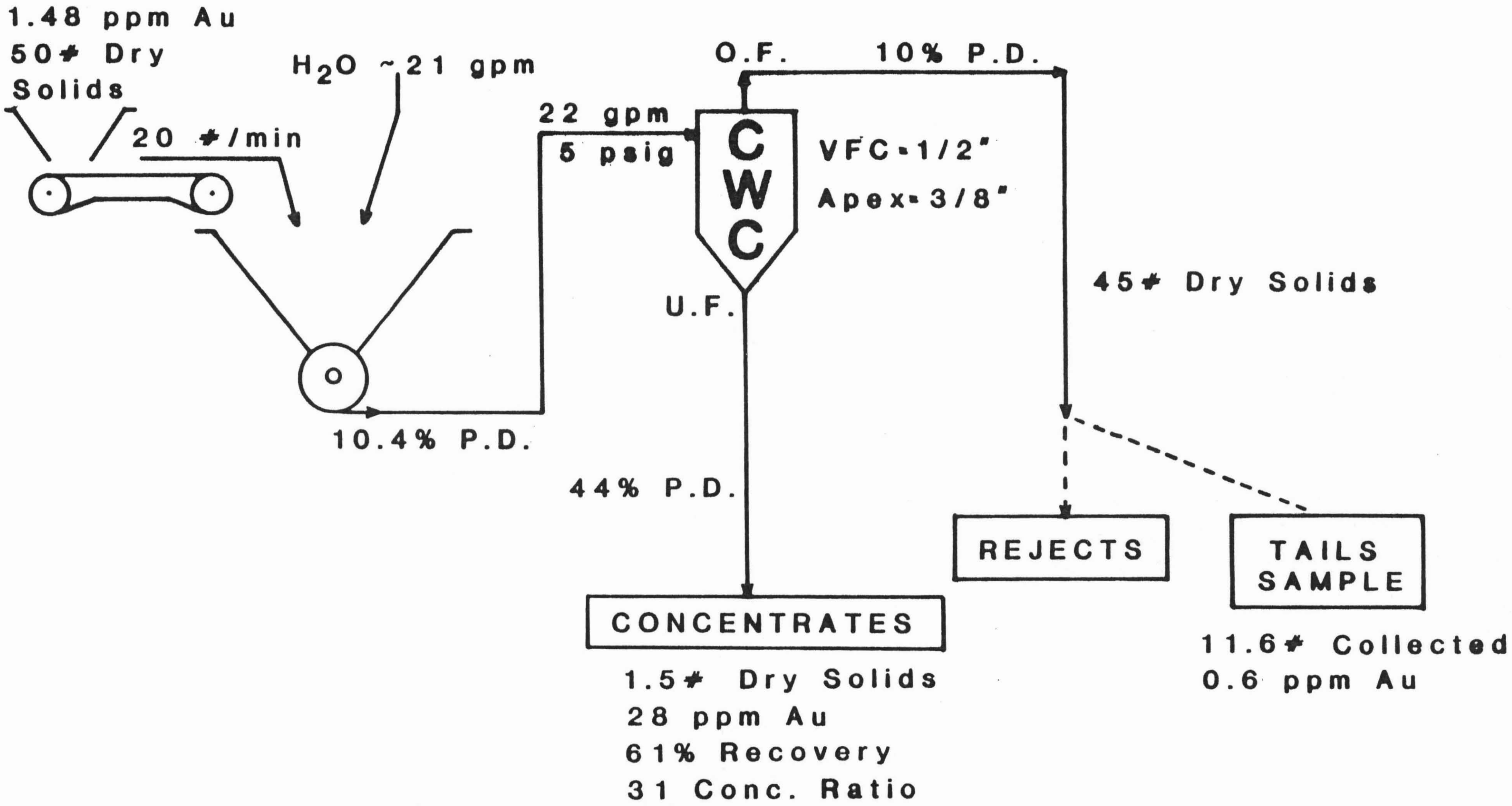
FIGURE 3

CHARACTERISTICS OF GOLD PARTICLES FROM C.W.C. SYNTHETIC FEED



AVG. SHAPE FACTOR, $\overline{S.F.}$	0.45	0.48

C.W.C. TEST USING SYNTHESIZED FEED



O.F.=Overflow

U.F.=Underflow

P.D.=Pulp Density

VFC=Vortex Finder Clearance

FIGURE 4

tions of Application of Hydrocyclones for the Recovery of Fine Gold". Phase III of this project has three main objectives, which are listed below.

1. Complete the analyses of the CWC field test work conducted in the Summer of 1983.
2. Perform additional field test(s) in Summer 1984.
3. Fund a graduate student to investigate the ability of the CWC to recover fine free gold of various size and shape factors and to determine the influence of the CWC's operating parameter on this gold's recovery.

The first two of these objectives have been met. The third is presently under way. The remainder of this report describes MIRL's Phase III work with the compound water cyclone.

FIELD TEST

Summer 1983

FIELD TEST WORK-SUMMER 1983

In the summer of 1983, the pilot plant was transported to and operated at a placer gold mine located in the Circle mining district, Alaska. The feed to the CWC pilot was a split from the operations sluice box tailings. Splits from both the main channel and one side channel of the sluice box were processed in single and double stage concentration circuits at a rate of 0.8 tons dry solids per hour. The data from the summer's field work was consolidated and the results evaluated. In October, a paper was prepared and presented at the Alaska Miners Association 1983 convention. This paper described M.I.R.L.'s work to date with the compound water cyclone. The paper was well received and the fifty available copies were quickly acquired by the audience after the presentation. A copy of this report is located in the Appendix of this report and one was supplied with the second quarterly report of January 11, 1984.

Because of the generally low pilot plant feed grades, only one of the 4 field tests yielded definitive results. A wedge wire screen with 1/8" opening was mounted at the sluice box's mid channel discharge. Sampling was restricted to 10 inches of the 30 inch wide mid channel. The minus 1/8" material was further screened on a cross flow screen with 1 mm openings which had an effective screening size of 20 mesh. The -20 mesh material was collected in a 50 gallon sump and pumped to two 4" compound water cyclones in parallel. Total underflow was collected and the overflow was sampled for one minute every fifteen minutes of operation. The concentrate and tailing samples were further concentrated in the laboratory using a Reichert Mark VII spiral. Both the spiral concentrate and tailings were assayed to arrive at a more accurate estimate for the grade of the CWC products.

The Reichert spiral concentrate was upgraded by froth flotation to facilitate hand picking of gold particles for microscopic measurement of their shape factors. The average shape factor for the 20 x 30 mesh particles recovered by CWC was 0.11 which explains their loss by the sluice box. As particle size becomes finer, even particles of higher shape factor report to sluice box tailings. The compound water cyclones achieved a concentration ratio of 13:1, upgrading a feed containing 0.004 oz./T to 003 oz./ton. The froth flotation concentrate had a grade of 44.2 oz./T. There was 92% gold recovery by the cyclone system. The spirals operated at a 19:1 concentration ratio with 91% gold recovery.

LABORATORY TESTS

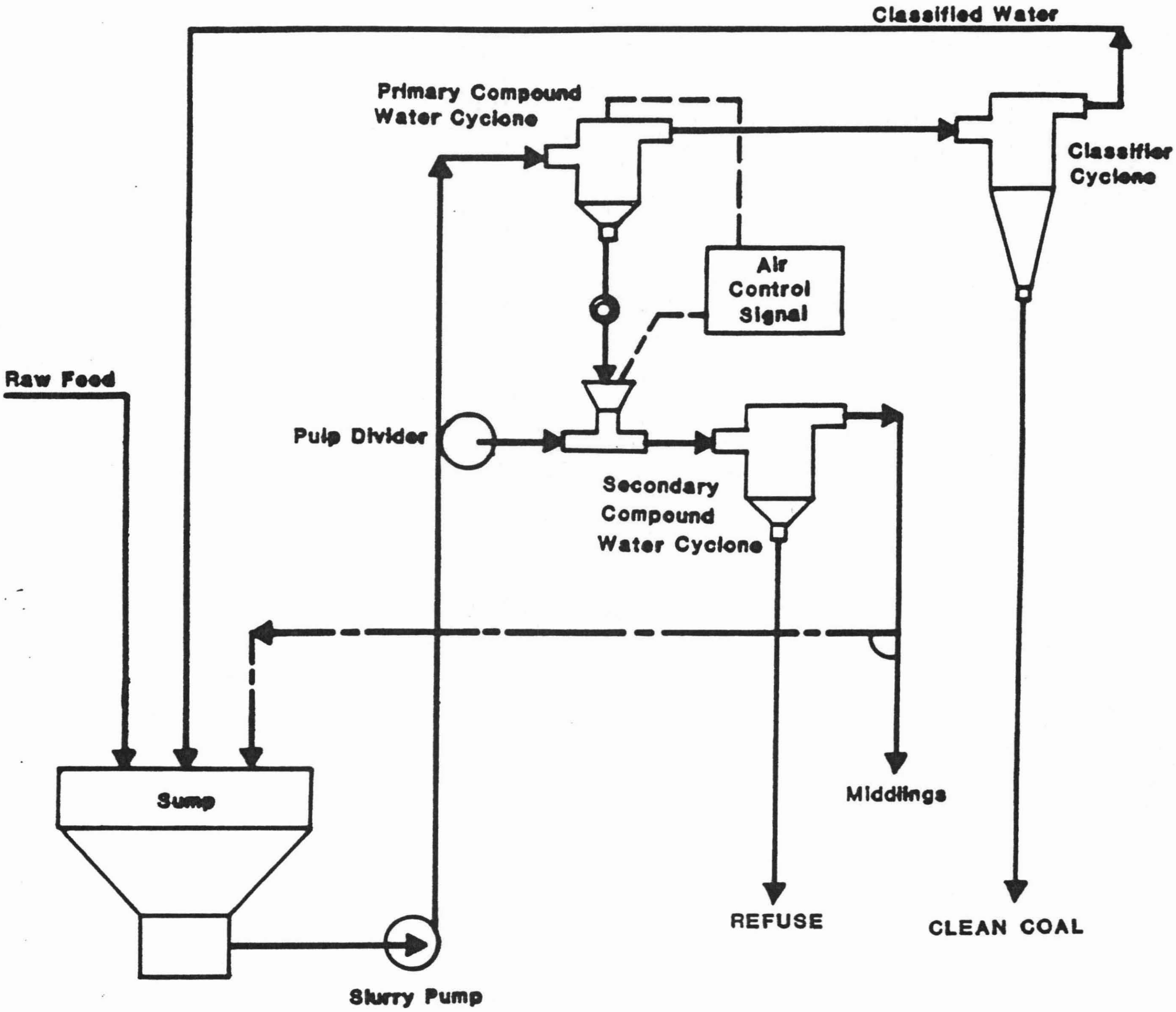
Fall 1983 - Spring 1984

LABORATORY STUDIES-FALL 1983 - SPRING 1984

In October, 1983, another laboratory test was completed on two samples of minus 10 mesh bank run placer material. This test work was performed to assist a local placer miner and to gather additional data on the CWC's performance characteristics. Each sample, weighing between 200 and 250 pounds, was concentrated using a single stage 4 inch compound water cyclone circuit. The cyclone's tailings and concentrates were upgraded on a Wilfley table. The enriched products were leached and assayed. A summary of these tests results as they were sent to the miner are included in the Appendix.

The cyclone unit was also used in demonstration for the Coal Preparation course offered in the Fall semester by the University of Alaska, Fairbanks. In this case the CWC pilot plant was used in its traditional role as a fine coal cleaning system in the configuration shown in Figure 5. Samples of the three products (clean coal, middlings, and refuse) were collected simultaneously and analyzed for ash content.

The Fall of 1983 also saw a mineral preparation graduate student begin research to investigate the effectiveness of the CWC to recover gold of various sizes and shape factors. The student, Mr. Daniel E. Walsh, is employed full time by MIRL as a mineral preparation technician. Consequently, time to devote to his thesis subject has often been difficult to find and was concentrated into late Spring and Summer of 1984. Regardless, considerable progress has been made. A revised copy of his thesis proposal along with relevant correspondence



Two-Stage Compound Water Cyclone Concentration With Automatic Control (Cyclone Engineering Sales Ltd., Canada) regarding his thesis topic are included in the Appendix. A brief summary of proposed further study is given below.

Mr. Walsh plans to send vials of free placer gold of various sizes and shape factors to the University of Washington's nuclear reactor for neutron activation. The chosen activation times will give each gold particle an initial activation of between 10^4 and 10^5 desintegrations per second. The radioisotope of interest Au^{198} is both a beta and gamma emitter but only the gamma energies will be used by Mr. Walsh in his work.

The irradiated gold will be introduced into a single stage closed circuit system for 4 inch CWC concentration. Each of the CWC products, underflow and overflow, will be monitored by a NaI scintilation crystal to detect the passage of the irradiated gold. Using appropriate electronics the pulses of radiation emitted by the passing gold flakes will be recorded on a dual pen chart recorder. This record of the gold reporting to the cyclone's tails and concentrate can then be used to calculate the recovery of gold of known sizes and shapes. In addition to studying the size-shape influence of gold on its recovery by CWC Mr. Walsh will also investigate the effect of adjustable cyclone parameters on gold recovery. Beginning mid July, 1984, Mr. Walsh will devote 100% of his working hours to his thesis work and thereafter rapid accumulation of data is expected.

FIELD TEST

Summer 1984

FIELD TEST WORK-SUMMER 1984

In response to a request from Mr. Bill Lanning, Manager of Northwest Exploration Company (NEC), a CWC field test was planned and executed in May, 1984. Preliminary visits to the mine site showed that the sluicing operation, because of its variable feed rate, could not yield definitive data on CWC performance. Nevertheless, it was felt that the 4" CWC pilot plant could be an effective tool for sampling the sluice box discharge in order to estimate sluice gold losses. The determination of sluice gold losses was the emphasis of Mr. Lanning's request.

Two test runs were completed by passing a portion of the sluice tailings flow over a 1/8" wedgewire panel located above a 60 gallon sump. The -1/8" slurry was then pumped under 7 psig pressure @ 50 gpm to two 4" CWC's operated in parallel. The concentrate (CWC underflow) was collected continuously throughout these tests while the tailings (CWC overflow) were sampled for 5 seconds every two minutes (1/24 of the total time).

These products, CWC underflow and overflow, were then transported to MIRL's laboratory for further processing, which included an additional stage of concentration by CWC and froth flotation. From the flotation concentrate, free gold was hand picked for microscopic examination.

The report prepared for NEC is included in the Appendix of this report. Despite the operational problems in both field and laboratory environments some interesting points are apparent when these test results are compared to previous lab and field work with the CWC. Lower field recovery of gold in the NEC tests are likely due not only to surge feeding but also to the higher overall average pulp density of the CWC feed. The high concentration ratio (~20:1) of laboratory reconcentration of field samples no doubt contributed to the low (~50%) recovery of fine free gold by the CWC. It is hoped and expected that the future thesis work to be performed by Mr. Walsh will more clearly illuminate the various influences of operational variables on gold recovery by the compound water cyclone.

CONCLUSION

The objective of the project was to test the efficiency of concentrating the fine gold fraction of placer material with the CWC. Test results indicate that the CWC can concentrate placer material efficently and can also act as an effective device for the sampling of sluice box tailings. The necessary additional laboratory test work indicated by the previous CWC research conducted by MIRL is currently underway by a mineral preparation graduate student. It is anticipated that the results of these laboratory studies will aid the planning of future field testing of the CWC pilot plant and lend a predictive capability to the investigators test design.

APPENDIX

APPLICATION OF COMPOUND WATER CYCLONES FOR FINE GOLD RECOVERY

Submitted to
Alaska Miners Association
1983 Convention

October 1983

Submitted by

P. Dharma Rao
David R. Maneval
Daniel E. Walsh

Mineral Industry Research Laboratory
University of Alaska, Fairbanks
Fairbanks, Alaska

This paper deals with the application of the compound water cyclone (CWC) for fine gold recovery. In particular, these authors were interested in studying the effectiveness of the CWC to recover gold lost by conventional sluice box recovery systems and also gold from such deposits as the Yakataga Beach Sands, whose size distribution and flatness greatly reduces its recovery by large scale gravity concentration methods. A brief summary of the separation mechanism of a sluice box may be helpful at this point.

Particles of gold and black sand enter a sluice box along with barren sand and gravel as a turbulent suspension and become trapped between the riffles by virtue of their high specific gravities, while the remaining lower specific gravity sand and gravel are discharged at the end of the sluice box. High turbulence keeps heavy minerals fluidized in the slots of the riffle thereby maintaining a specific gravity gradation. The heavy minerals also keep moving out of the riffles to an immediately following riffle, maintaining a slow moving "bed". Eventually, this process could result in the filling of the inter-riffle slots with gold, by the displacement of other heavy minerals, but would result in considerable loss of gold.(10) Sluice losses of gold can also occur with fine gold, generally finer than 150 microns (100 mesh), as well as with flaky gold; gold particles with low shape factors. Particles as coarse as 850 microns (20 mesh) with shape factors of 0.1 or less can find their way into the tailings as reported by Cook and Rao.(2) In addition to the intensity of turbulence other factors that contribute to gold losses are (10):

1. Clay entering slots as balls picks up gold from slots, and the gold thus entraped in clay is rejected with tailings.
2. Large concentrations of clay tend to increase the viscosity of water moving in and out of slots thus preventing entrapment of fine and flaky gold.

3. The clogging of the sluice box bed because of clays or freezing conditions.

Historically the main use of hydrocyclones in mineral processing has been as classifiers. These have proved extremely efficient at fine separation sizes. They are used increasingly in closed circuit grinding operations but they have found many other uses, such as desliming and thickening.

Recent years have seen the development of the compound water cyclone specifically for concentrating purposes. Its physical design is such that classification effects are suppressed and the influence of particle specific gravity is maximized. They were developed largely as a result of work in the coal industry (9), where cyclones operating with a water medium are now in wide use for upgrading fine coal. Their have also been studies into the use of cyclones for the beneficiation of cassiterite (11, 12) and iron ores, and a recent Russian paper (13) describes the concentration of gold from milled conglomerate ores by use of a short cone hydrocyclone. A recent thesis by a graduate student, Ravi Aluru, describes successful concentration of scheelite using compound water cyclones.

In a compound water cyclone, heavy minerals are separated by virtue of their density within a centrifugal force field whose strength is 30 to 50 times that of gravity. Clay does not pose a serious problem when using CWC's for recovery of fine gold because of the high centrifugal and shear forces that exist within the cyclone. Work reported by Visman and Andersen (10) has shown that compound water cyclones can recover in excess of 95% of the gold contained in the minus 6 mesh fraction of a placer material.

A project funded by the U.S. Bureau of Mines, was carried out by the Mineral Industry Research Laboratory (MIRL), University of Alaska, Fairbanks, to investigate the effectiveness of compound water cyclones for the recovery of fine free gold. Fine gold here is defined to mean not only that gold finer than 40 mesh but also free gold whose low shape factor decreases sluice box recovery of even the coarser size fractions. In the remainder of this paper, past and present research on the CWC conducted by MIRL is reported.

Preliminary investigations were conducted using a 2.75-inch CWC constructed of pyrex glass to test free gold recovery from placer gravels sampled at three mines located in interior Alaska. The results of this work were published in MIRL report no. 55. Free gold recoveries ranged from 84% to 99% using two stages of CWC concentration to attain overall concentration ratios of approximately 25:1. Testing also revealed the CWC performed well for concentrating heavy minerals of density greater than 3.3 and coarser than 270 mesh.

Encouraged by these initial findings it was decided to assemble a pilot scale compound water cyclone recovery test system with which to conduct both laboratory and field studies. Two 4-inch CWCs, one 4-inch classifying cyclone, a 2-inch slurry pump, and associated hardware were purchased and the assembly of the automatic two stage pilot plant was completed in July, 1982. The test system was designed for easy disassembly and transport.

Laboratory testing of the CWC pilot plant included single stage concentration of various feed materials. Figure 1 shows the laboratory flowsheet used in CWC processing a gold bearing beach sand from Yakataga. The entire concentrate was collected. CWC tailings were sampled for 5 seconds every 30 seconds. Gold from both the concentrate and tailings was further concentrated by froth flotation. The froth products were assayed for gold. Portions of the froth products were used to isolate gold particles for determination of their Corey shape factors. The concentrate assayed 0.94 ppm gold while the tailings assayed 0.17 ppm gold giving a recovery of 27%. The concentration ratio was 16:1.

Examination of shape factors of gold from the tailings and concentrates shows no significant difference (Figure 2). Low recoveries point to the need to operate the cyclone so as achieve lower concentration ratios. Recovery of gold with such low shape factors requires concentration ratios much lower than 8:1; normally considered good practice in mineral beneficiation systems, The fact that the CWC did recover gold with shape factors as low as .05 is very encouraging.

A synthetic sample was prepared by mixing 65 x 200 mesh placer gold with the tailings from the Yakataga CWC laboratory test, Measured shape factors for the gold used ranged from 0.25 to 0.89 (Figure 3). Figure 4 shows the flowsheet used in processing the sample. Concentrate and tailings were assayed for gold. The concentration ratio for the single stage system was 31:1. Concentrates assayed 28 ppm Au while the tailings assayed 0.6 ppm Au. Again use of lower concentration ratio should improve recovery.

The Yakataga beach sand test with a concentration ratio of 16:1 yielded a gold recovery of 27%. The synthetic sample gave a higher gold recovery (61%) at a concentration ratio of 31:1, which is attributable to the more favorable shape factor. Recoveries desired and the shape factor of the gold will dictate practicable concentration ratios per stage.

In June, 1983, the pilot plant was transported to and operated at a placer gold mine located in the Circle Mining District. The feed to the CWC pilot plant was a split from the operations sluice box tailings. Splits from both the main channel and one side channel of the sluice box were processed in single and double stage concentration circuits at a rate of 0.8 tons dry solids per hour. Because of the generally low pilot plant feed grades only one test yielded definitive results.

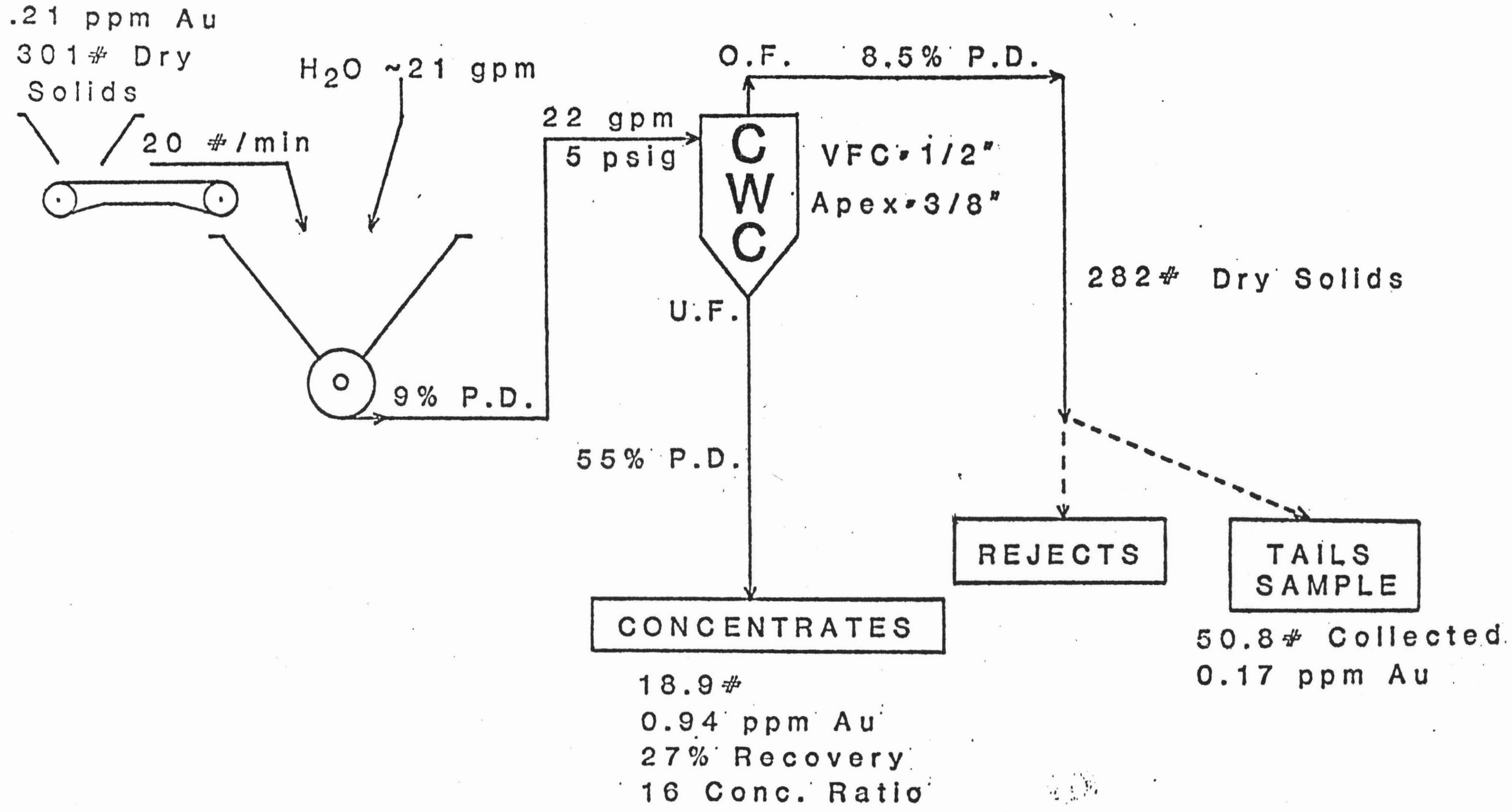
Figures 5 and 6 show the procedure used for testing and evaluating the field work. A wedge wire screen with 1/8" opening was mounted at the sluice box's mid channel discharge. Only the under current from the punch plate was sampled (Figure 7). Sampling was restricted to 10 inches of the 30 inch wide mid channel. The minus 1/8" material was further screened on a cross flow screen with 1 mm openings which had an effective screening size of 20 mesh. The -20 mesh material was collected in a 50 gallon sump and pumped to two 4" compound water cyclones in parallel. Total underflow was collected and the overflow was sampled for one minute every fifteen minutes of operation. The concentrate and tailing samples were further concentrated in the laboratory using a Richert Mark VII spiral. Both the spiral concentrate and tailings were assayed to arrive at a more accurate estimate for the grade of the CWC products.

The Richert spiral concentrate was upgraded by froth flotation to facilitate hand picking of gold particles for microscopic measurement of their shape factors. Figure 8 shows shape factors for various sizes from 20 mesh through 400 mesh. The average shape factor for 20 x 30 mesh particles was 0.11 which explains their loss by the sluice box. As particle size becomes finer, even particles of higher shape factor report to sluice box tailings. The compound water cyclones achieved a concentration ratio of 13:1, upgrading a feed containing 0.004 oz./T to 0.03 oz./ton. The froth flotation concentrate had a grade of 44.2 oz./T. There was 92% gold recovery by the cyclone system. The spirals operated at a 19:1 concentration ratio with 91% gold recovery.

Figure 9 shows a simplified flowsheet for two stage concentration using compound water cyclones followed by froth flotation. It is possible to expect 90-95 percent recovery per stage with CWC's at a combined concentration ratio of 50:1. Froth flotation could provide a high grade product of 40-50 oz./T. Froth flotation may not recover coarser gold particles with high Corey shape factors, therefore it may be necessary to treat the flotation tailings on tables or spirals to recover gold which is not floatable.

Conclusions:

1. Concentrating cyclones can be used for recovering gold lost in sluice box operations.
2. Recovery is interrelated to shape factor and concentration ratio. Low concentration ratios are recommended for gold particles with low shape factors; less than 0.1.
3. Gold recoveries of 90 - 95 percent can be achieved per CWC stage.
4. A final high grade concentrate can be achieved by froth flotation of cyclone concentrates.
5. The economics of using CWC's in the placer mining industry have not been assessed and would depend on the amount of gold lost in the sluice box tailings and the operating costs at the site.
6. Additional field tests are needed to more fully evaluate various operating parameters of the CWC on gold recovery.



O.F. = Overflow

U.F. = Underflow

P.D. = Pulp Density

VFC = Vortex Finder Clearance

C.W.C. SINGLE STAGE TEST OF -14M YAKATAGA BEACH SANDS

FIG. 1

FIG. 2

CHARACTERISTICS OF GOLD PARTICLES FROM C.W.C. UNDERFLOW AND OVERFLOW

(YAKATAGA BEACH SANDS)

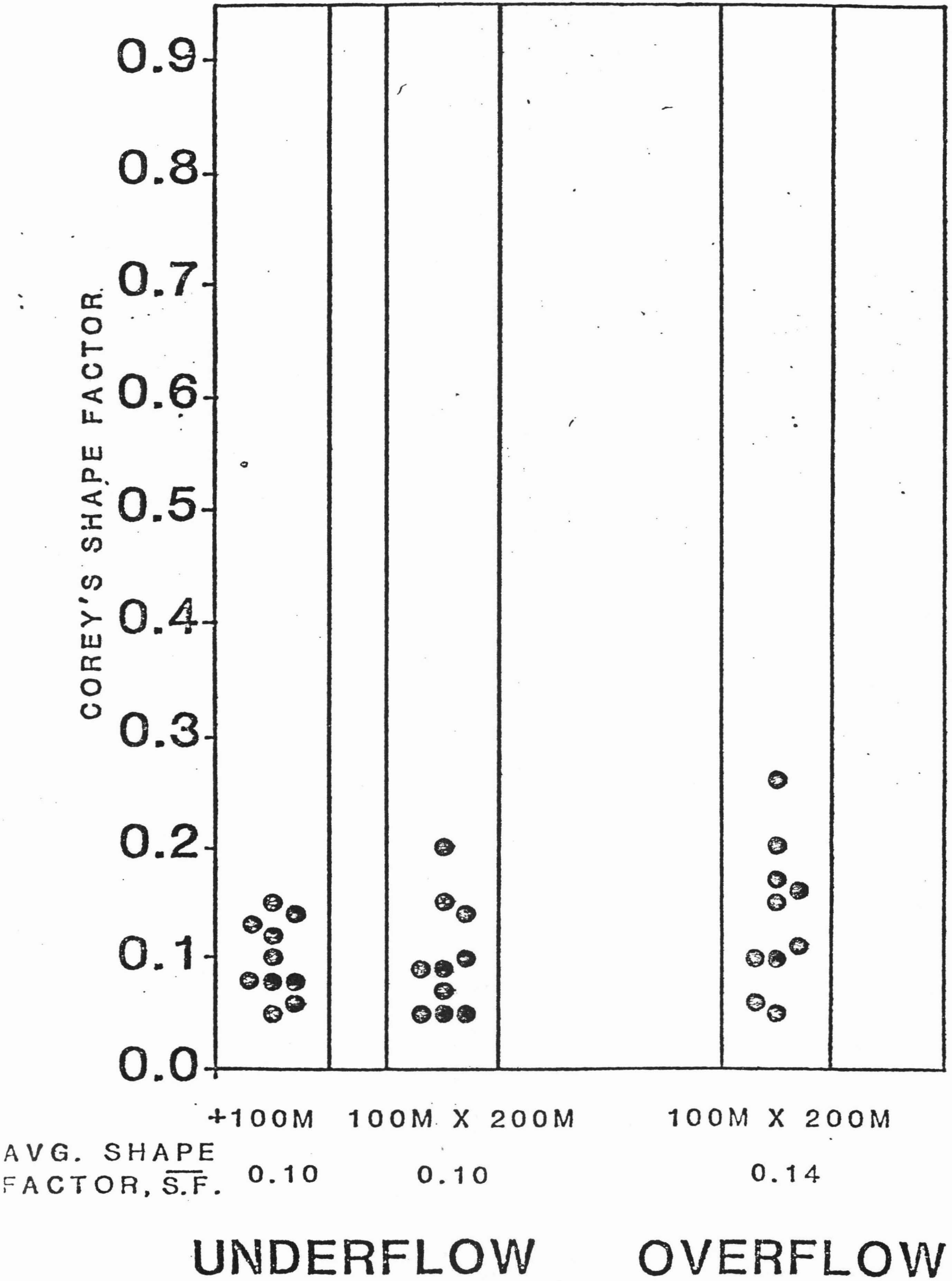
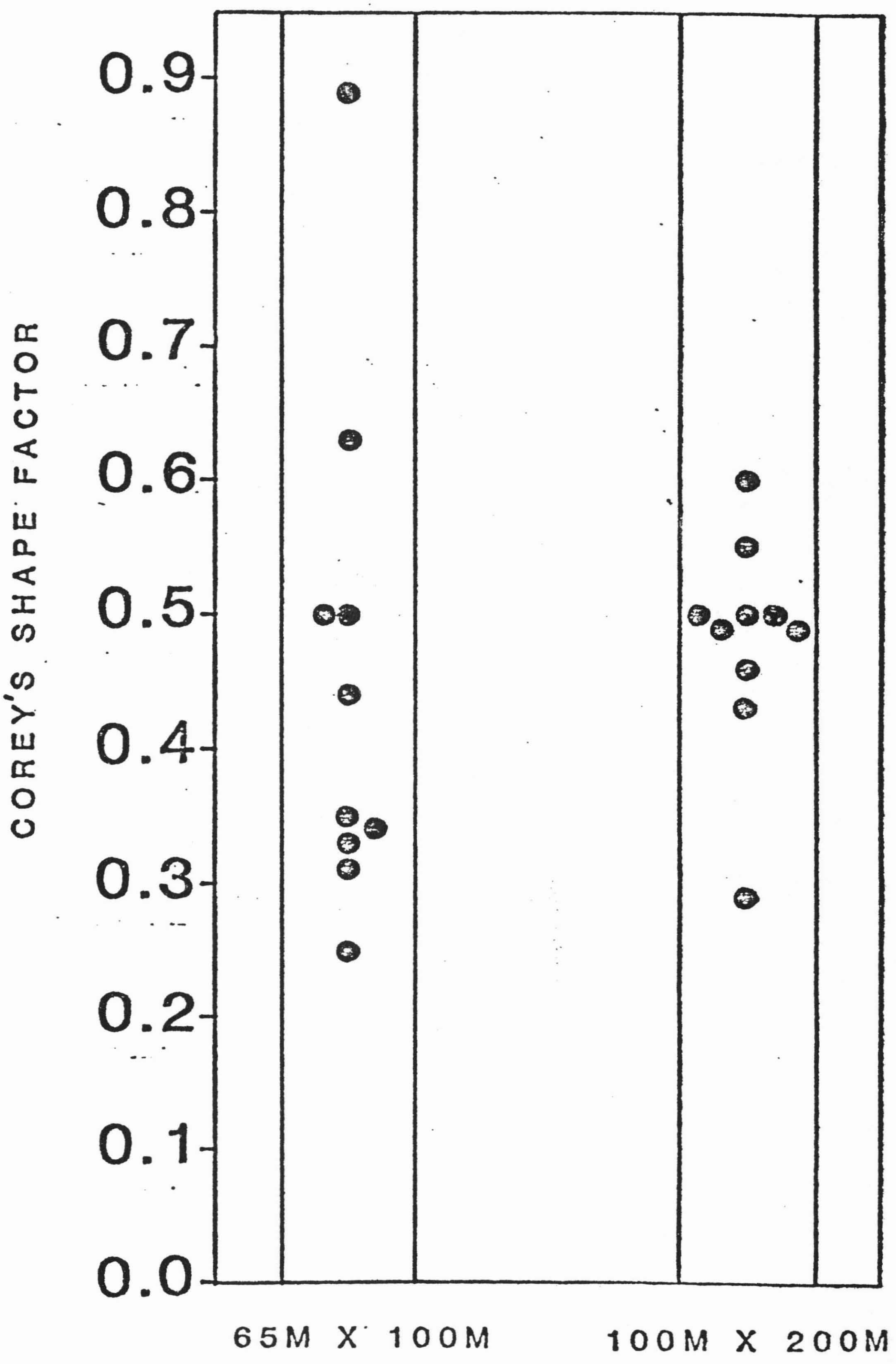


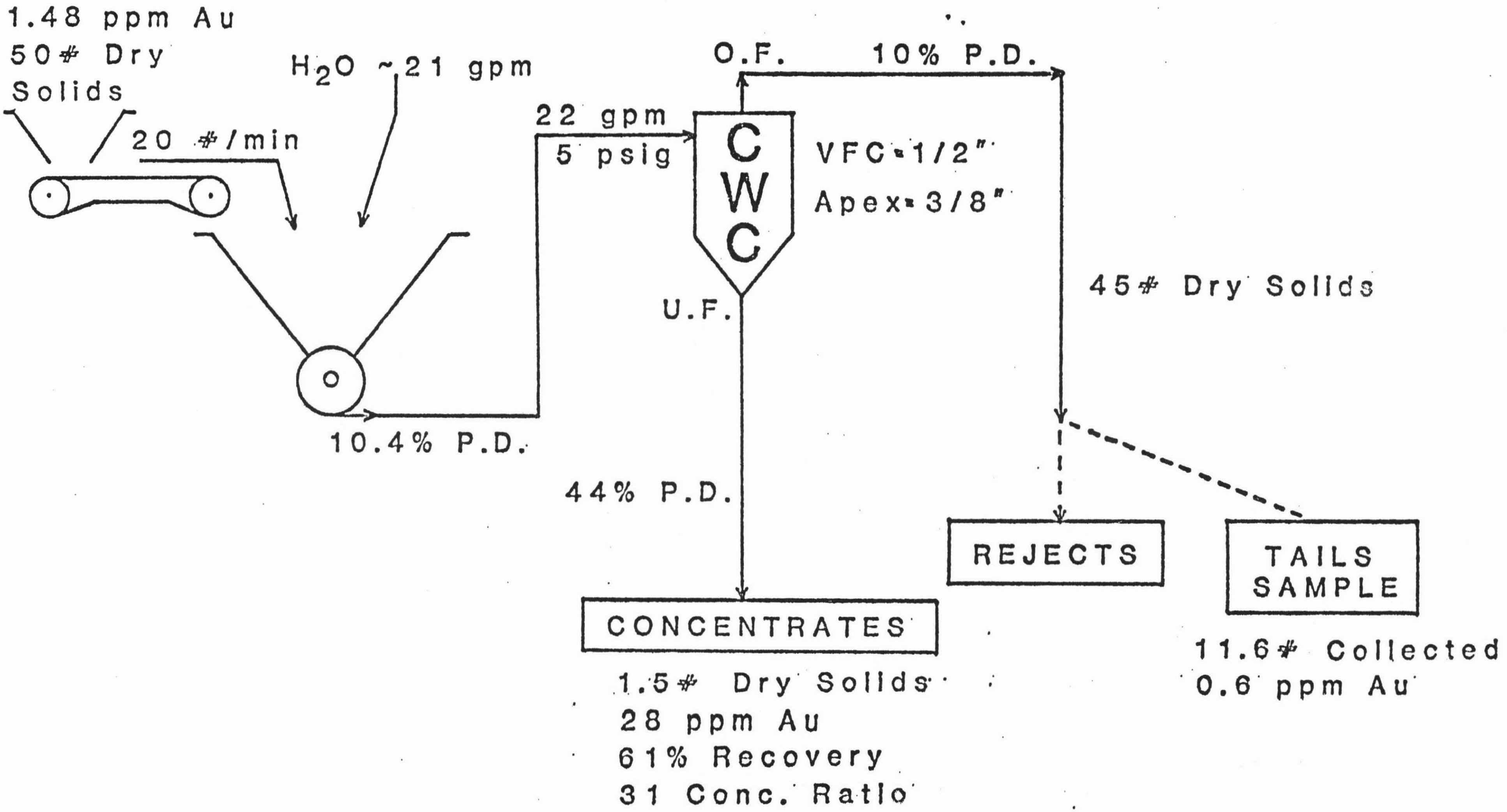
FIG.3

CHARACTERISTICS OF GOLD PARTICLES
FROM C.W.C. SYNTHETIC FEED



AVG. SHAPE FACTOR, $\overline{S.F.}$	0.45	0.48

C.W.C. TEST USING SYNTHESIZED FEED



O.F.=Overflow

U.F.=Underflow

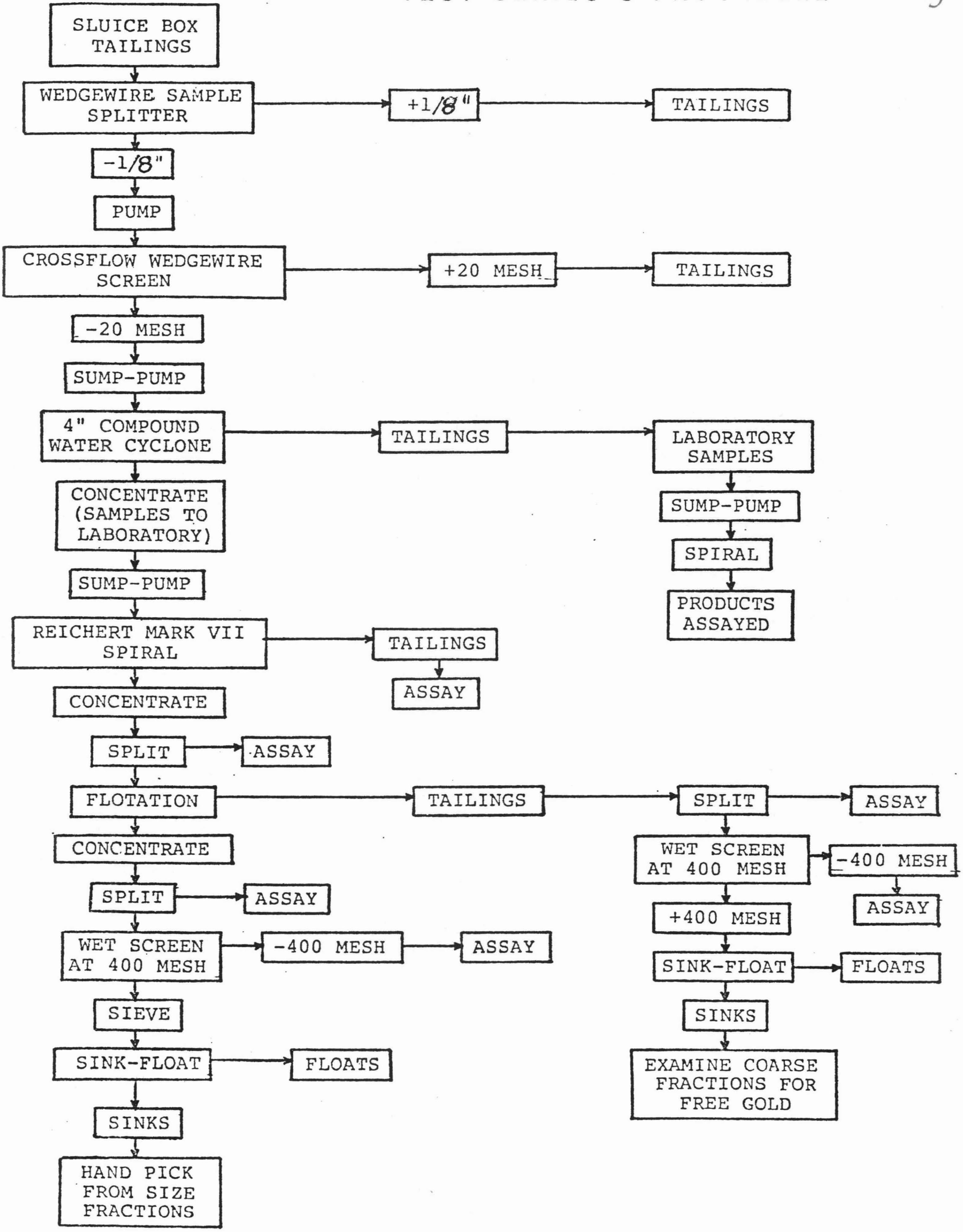
P.D.=Pulp Density

VFC=Vortex Finder Clearance

FIG. 4

FIG
5

TEST SERIES C PROCEDURE



GHD ENTERPRISES CWC FIELD TEST–TEST SERIES C

CWC Feed Grade = 0.004 oz/ton

CWC Concentration Ratio = 13:1
CWC Recovery Au = 92%
CWC U.F. Grade = 0.03 oz/ton

Spiral Concentration Ratio = 19:1
Spiral Recovery Au = 91%
Spiral Concentrate Grade = 0.6 oz/ton

Flotation Concentration Ratio = 145:1
Flotation Recovery Au = 93%
Flotation Froth Product Grade = 44.2 oz/ton

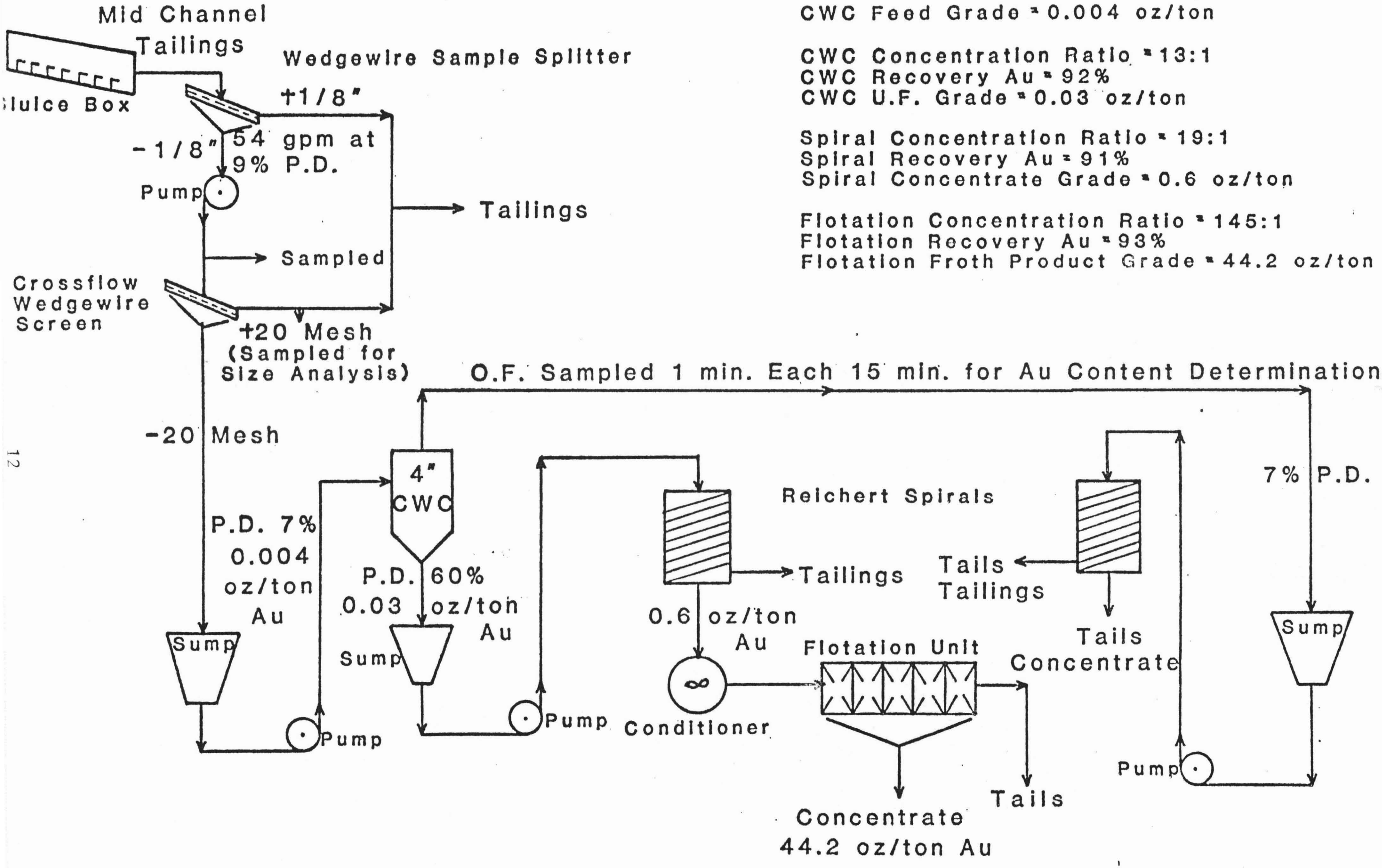


FIG. 6

Mid Channel Sluice Box

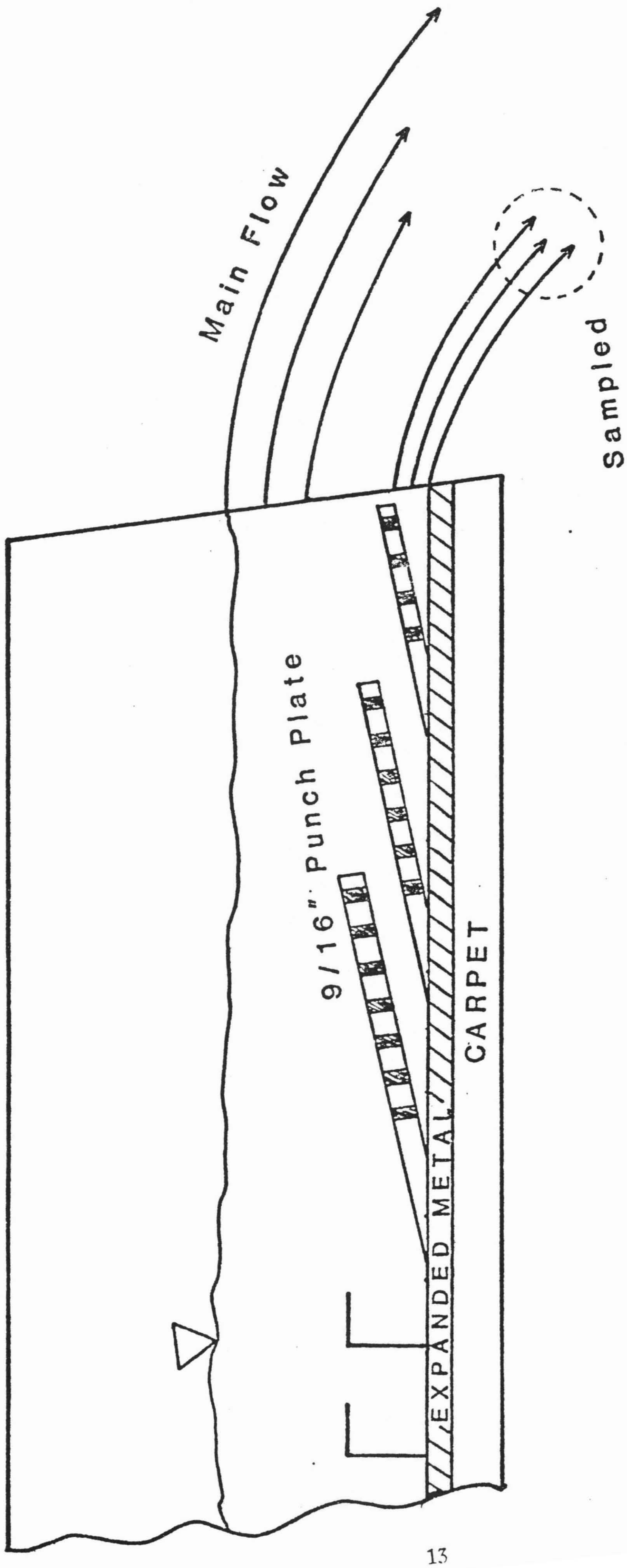


FIG. 8

TEST SERIES C – C.W.C. UNDERFLOW

GOLD MEASUREMENTS.

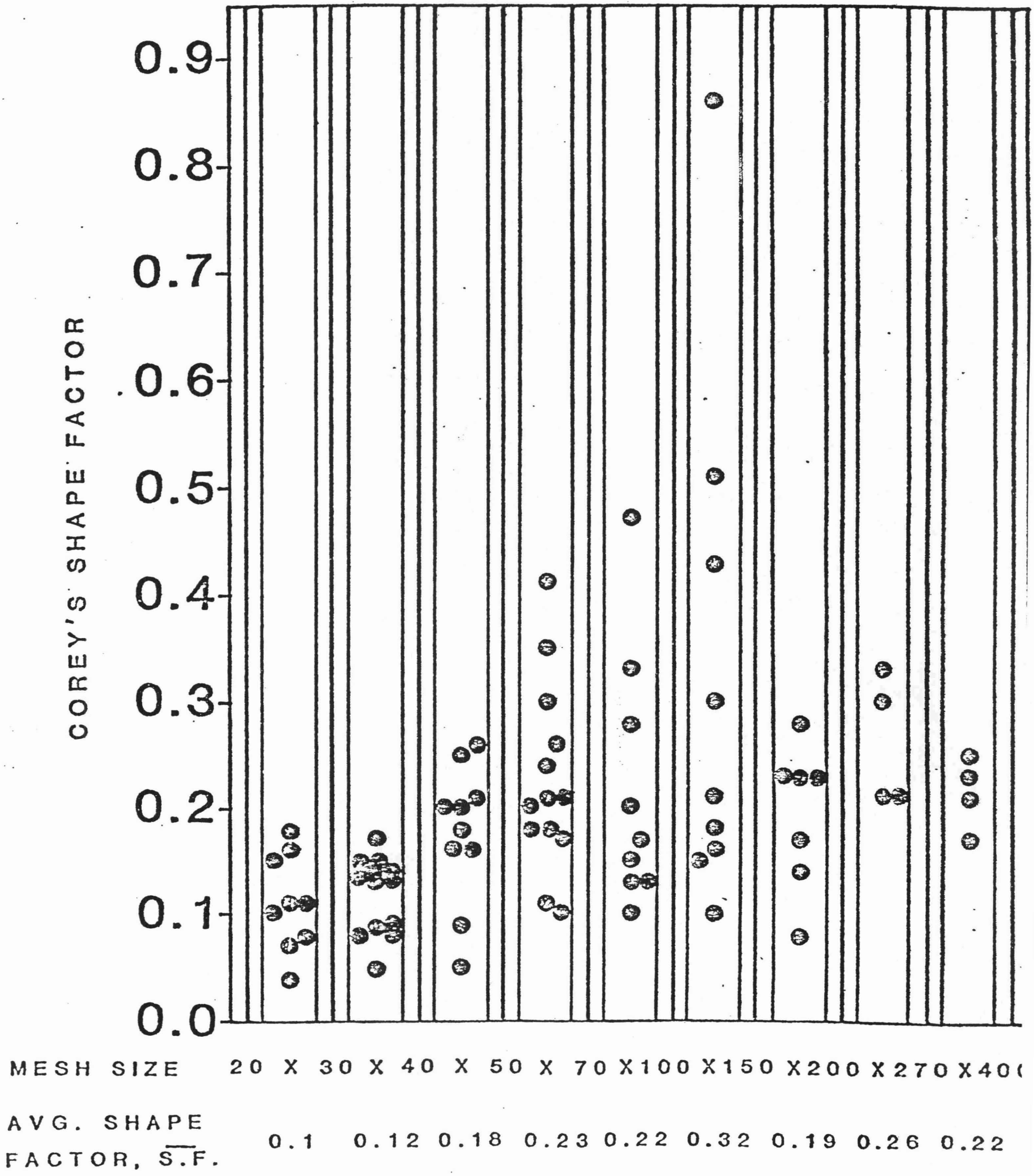
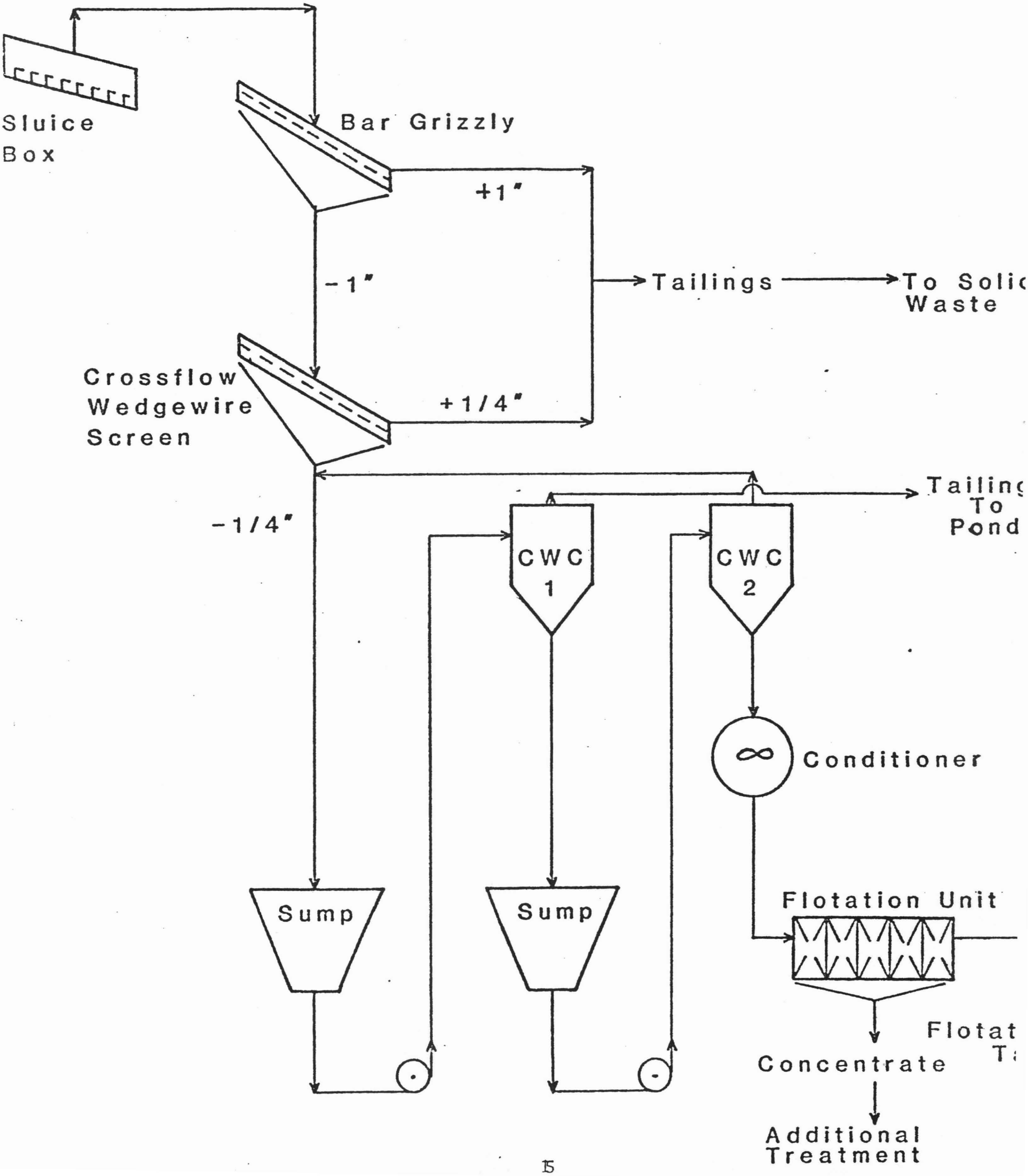


FIG. 9

POSSIBLE PRODUCTION FLOWSHEET



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PROPOSAL AND CORRESPONDENCE RELATED TO MASTER THESIS

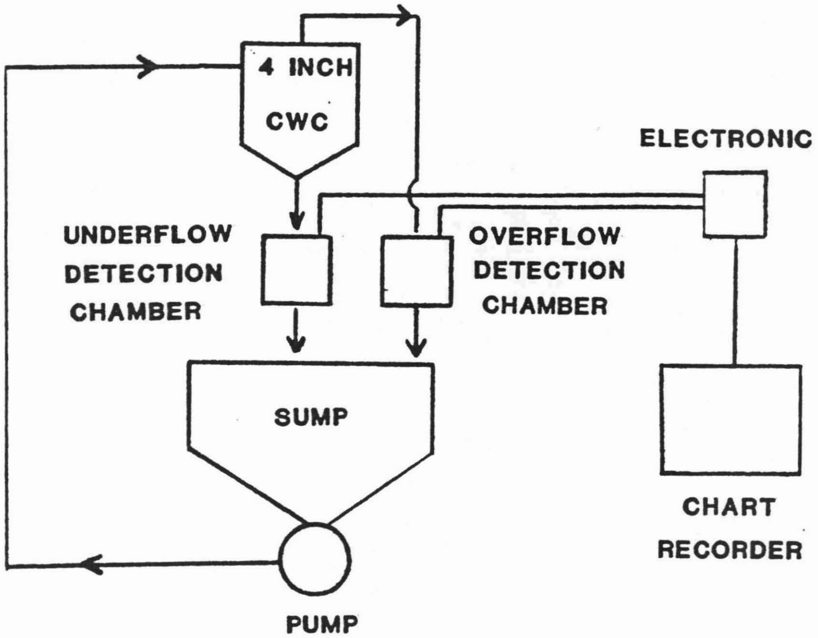
STUDY OF THE COMPOUND WATER CYCLONE

OUTLINE FOR PROPOSED MINERAL PREPARATION MASTERS THESIS

TITLE: The Influence of the Size and Shape Factor of Fine Gold on its Recovery by Compound Water Cyclones.

TEST CIRCUIT:

Irradiated placer gold particles (Au^{198}) of known size and shape factor would be introduced into circuit and a percentage recovery for them will be recorded.



OBJECTIVES: Determine the statistical probability of a gold particle's recovery via CWC given size and shape factor of the gold. This is to be investigated as a function of all or a choice of the parameters listed below:

(1) Top size of Feed, (2) Vortex Finder Clearance, (3) Apex Spigot Diameter, (4) Feed Pressure (Feed Rate), (5) Feed Pulp Density, and (6) Effect of -400 Slimes Wt.% in Feed Material.

RESULTS: Data gathered would be used to:

(1) Construct Gold-Size-S.F. vs. Recovery Curves for CWC's.
(2) Estimate CWC recovery of placer gold from placer materials (R.O.M. feed or sluice box tails) given the nature of the CWC feed (i.e. size consist, density consist, gold size - S.F. distribution). Possibly construct a computer model for CWC recovery based on the above mentioned variables.
(3) Predict the possibility of increasing the CWC recovery of fine gold by modifying the feed's size consist and/or density consist. Modification might be accomplished by addition of a readily recoverable reusable material such as magnetite.

North Carolina State University
School of Engineering

November 16, 1983

Department of Nuclear Engineering
Box 5636 Zip 27650

Mr. Daniel E. Walsh
University of Alaska, Fairbanks
Mineral Industry Research Laboratory
Fairbanks, AK 99701

Dear Mr. Walsh:

This is in answer to your letter of November 1, 1983 requesting my opinion on your proposed M.S. thesis work. This work seems very reasonable to me. First of all I believe you would have to arrange your system so as to not recycle the product during any one test. The gold tracer could be introduced as an impulse injection somewhere between the sump and CWC unit.

In answer to your request No. 2 there should be minimal or no radioactive contamination problems. The radioisotope of gold that you would use is Au-198 which has a half life of about 2.7 days. You could probably arrange to use amounts of this radioisotope that could be safely and legally discharged to the environment. Or you could arrange to hold the gold for a period of about 10 half lives (27 days) which would ensure that it has decayed to 1/1000 of its original activity. It could then be reused in your research program.

In answer to your request No. 3, I can refer you to the first nine chapters of our book:

> R. P. Gardner and R. L. Ely, Jr., RADIOISOTOPE MEASUREMENT APPLICATIONS IN ENGINEERING, Reinhold Publishing Corporation, New York, 1967.

I believe Kriegger Publishing Company is now handling the sale of this book. The address is P. O. Box 542, Huntingdon, New York, 11743.

Do you have a nuclear reactor or other neutron source available to you for producing the Au-198 radioisotope tracer in your gold samples? If not there will be some expense associated with having your samples irradiated in a nuclear reactor and flown to you.

While you can in principle learn all that you need to know by reading, it would be much easier for you if you could attend a short course on radioisotope techniques. We offer such a course here at the University in the summer, and I enclose a brochure that describes it.

Let me know if you have additional questions. Good luck!

Yours truly,

Robin P. Gardner

Robin P. Gardner
Professor

RPG:dcr
Enclosure

Mineral Industry Research
Laboratory

November 1, 1983

Dr. Robin Gardner
Dept. of Chemical and Nuclear
Engineering
N. Carolina State University
Raleigh, N.C. 27607

Dear Dr. Gardner,

I am a mining engineer employed by the Mineral Industry Research Laboratory at the University of Alaska, Fairbanks. Concurrently, I am enrolled as a graduate student in the school's M.S. program in mineral preparation engineering. For my thesis, I plan to study the recoverability of fine placer gold when using compound water cyclones as heavy mineral concentrators. I hope to use irradiated placer gold as a tracer in order to determine the influence of its size and shape factor on recovery.

Your name was recently given to me by D.W. Fuerstenau of U.C. Berkeley as one who has had considerable experience in using tracers to study unit mineral preparation processes. I have enclosed a brief outline of my proposed work and based on your past experience, I would like to ask if you feel this is possible and practical. Of particular concern to me is the system used to detect the very fine gold particles (ranging in size from 65m to 400m) in the overflow (23 gpm) and underflow (2 gpm) pulp streams of the Compound Water Cyclone.

Would you please take time to comment upon:

1) possible detection systems,

2) Radioactive contamination problems I might encounter,

3) particular articles and/or research reports I might not readily find in a literature search which could be of use to me.

Thanking you in anticipation of your response and for your time.

Sincerely,

Daniel E. Walsh

DEW:cw

Enc.

Mineral Industry Research
Laboratory

December 15, 1983

Dr. Robin Gardner
Dept. of Chemical and Nuclear
Engineering
N. Carolina State University
Raleigh, N.C. 27607

Dear Dr. Gardner,

Thank you for your reply to my letter of 11/01/83 and for your suggestions and advice.

I will be leaving for a months vacation beginning December 16, 1983. During this period I hope to do considerable reading on the subject of radioisotope measurement. Once I return and begin development of my laboratory layout and procedure I will no doubt be contacting you.

Thank you.

Sincerely,

Daniel E. Walsh

Daniel E. Walsh

DEW:cw

University of Washington
College of Engineering
Nuclear Engineering Laboratories
Mail Stop FD-10
Seattle, Wa 98195
April 16, 1983

Mr. Dan Walsh
Mineral Industry Research Laboratory
University of Alaska
Fairbanks, Alaska 99701

Dear Mr. Walsh:

In reference to our telephone conversation of April 12th concerning the irradiation of Au particles to produce Au-198 for your experiments.

The University of Washington Radiation Safety Division will need a copy of the University of Alaska license. That can be sent to me and I will forward it.

The shipment of the irradiated material should be routine. The University of Washington Radiation Safety would supervise the packageing of your samples. The shipments will probably be handled by Airborne.

The normal charge for the reactor for performing irradiations is \$ 30.00 per startup and \$ 50.00 per hour for reactor time with a minimum of 0.5 hour. Therefore the minimum charge would be \$ 55.00. Also, I would assume the University of Alaska would cover the shipping costs.

4×10^4 [illegible]

I did a calculation and a 10 microgram sample of Au irradiated for 1 hour would produce about 1.1 microcuries of Au-198. The actual activity would probably be greater due to activitation by fast neutrons. The larger samples would require less total exposure for the activities you mentioned,ie, up to 1×10^5 dis/sec per sample.

We would want to schedule the irradiations a week ahead of time. This will allows us time to integrate other operations and the shipping of your samples.

If I can be for further assistance please let me know. We are looking forward to being able to assist you with your research.

Sincerely yours,

Pat Miller

William P. Miller, Associate Director
Telephone No. (206) 543-4170

Mineral Industry Research
Laboratory

April 27, 1984

William P. Miller, Assoc. Director
University of Washington
College of Engineering
Nuclear Engineering Laboratories
Mail Stop FD-10
Seattle, WA 98195

Dear Mr. Miller:

Thank you for your informative letter of April 16, 1984. I have enclosed a copy of University of Alaska's licensing information. Our radiation officer, Mr. Dan Holleman, believed this would fulfill your requirements. Should you desire any additional documentation I will supply it upon request.

I have also enclosed two small vials of the type in which I plan to send our gold samples. Are these adequate? How many of these vials could be irradiated in what you consider one sample space in your reactor? Would it be acceptable to individually wrap the various sizes and shapes of gold in aluminum foil or plastic wrap prior to putting them in these vials?

The reactor rates you quoted appear within our budget for our larger samples. However, some calculations I performed for our smaller gold particles indicate a reactor detention time of approximately 24 hrs. (Our smallest particles would weigh ~0.8 ug and would require activities of ~10^5 - 10^6 dps/particle). If your $50.00/hr rate will apply, I will need to irradiate all of these low particle mass gold samples at one time. We would of course begin our test work with the coarser gold. Perhaps these early tests will indicate the possibility of using lower activities to achieve acceptable results.

Assuming activities of ~10^5 dps/particle could you please comment upon what quantity of gold particles we could expect to ship through your UW Radiation Safety Department before we would encounter excessive shielding requirements? University of Alaska will make arrangements to cover the shipping costs. Would you expect payment in advance of sample activation or would you bill us? The scheduling you suggest (one week prior to activation) is most agreeable to us.

Our testing proceedure has taken shape and we have ordered our radiation detection systems. We would anticipate sending our first samples to you sometime in July. Once again, I wish to thank you for your prompt and helpful correspondence. I realize this letter asks for answers to many questions. I hope you will not find it to demanding of your time.

Sincerest thanks,

Daniel E. Walsh

Daniel E. Walsh

DEW:cw

Encl.

Mineral Industry Research
Laboratory

May 14, 1984

William P. Miller
University of Washington
College of Engineering
Nuclear Engineering Laboratories
Mail Stop FD-10
Seattle, WA 98195

Dear Mr. Miller:

Thank you for your recent reply of May 7, 1984, and for all of the helpful information it contained.

I will make arrangements to acquire a supply of 2/5 dram polyethylene vials, and will plan to enclose individual samples in these vials rather than wrapping samples in foil and/or plastic. Since you can include such a large number of these 2/5 dram vials in your reactor sample space this will be most convenient for us.

Your answers to my other questions were very clear and I now have a firm idea of how our irradiation program will proceed. As I mentioned in my last letter, we will likely be sending our first gold samples to you in July. Once again, thanks for your very capable help in this matter.

Sincerely,

Daniel E Walsh

Daniel E. Walsh

DEW:cw

University of Washington
College of Engineering
Nuclear Engineering Laboratories
Mail Stop FD-10
Seattle, Wa 98195
May 7, 1984

Mr. Daniel E. Walsh
Mineral Industry Research Laboratory
University of Alaska
Fairbanks, Alaska 99701

Dear Mr. Walsh:

Thank your for your letter of April 27, 1984. I will attempt to answer the questions that you asked in your letter.

The copy of the license you sent is all that we need to ship the material to your facility.

The 2 dram vial you sent is the same type we use for doing our irradiations, except that in most cases we use a 2/5 dram vial. We usually heat seal the tops which prevents any accidentaly opening. I can send you some of the 2/5 dram vials for sample containers if you do not have any. From past experience these polyethylene vials does not contain material that activitates in significant quantities. The other vial with the removable top may be suitable, however I would prefer to use the polyethylene vials that we have used successfully in the past.

We place the smaller vials in a larger bottle before we put them in the reactor. The size of that bottle is approximately 2 inch diameter by 6 inches tall. We can place 50 to 60 of the 2/5 dram vials in these bottles or 10 of the 2 dram vials.

Using either Al foil or platic wrap may add to the activity that would be produced during irradiation. Any added activity would increase our exposure during packaging and the dose from the package during shipment. Hence I would prefer to see only the 2 dram or 2/5 dram polyethylene vials used to contain or separate the samples for the irradiation. The vials used during the irradiation would then be placed in another container prior to packaging for shipment, most likely a plastic bag.

Regarding the activity for shipping without significant shielding. A package with a Radioactive Yellow II label, the dose rate can be up to 1 mrem/hr at 1 meter from the package. In that case we would be able to ship approximately 5 millicuries of Au-198. However, it is probably better to use a small lead pig and reduce the dose rate from the package. This would reduce the dose rate and not significantly add to the shipping cost if the total sample volume were relatively small.

If each particle was appoximately 3 microcuries then there would be approximately 1600 particles for 5 millicuries. With the use of a small lead pig the quantity could be increased.

Also, we usually do not perform long irradiations,ie, for 24 hours. Normally we would not expect to irradiate a set of samples in excess of 4 hours.

I did a calculation based only upon thermal neutron cross-section and for 0.8 micrgams of Au, a three hour irradiation at 1.2×10^{12} would give an activity of approximately 10^{4} dps. Decay would reduce the activity by the time the sample arrived at your laboratory.

We would bill you at the end of the month for the irradiations done during the month.

Sincerely yours,

Pat Miller

William P. Miller

Mineral Industry Research
Laboratory

May 4, 1984

Airborne
4025 W. 50th
Suite 1
Anchorage, Alaska 99503

Dear Sirs:

I am a mining engineer employed by the Mineral Industry Research Laboratory at the University of Alaska, Fairbanks. Currently we are engaged in a research project sponsored by the U.S. Bureau of Mines to study the recoverability of fine placer gold using compound water cyclones. Our research team is considering the use of irradiated placer gold as a tracer in order to better determine the influence of its size and shape on recovery.

In this context, I wish to inquire as to the availability, cost, and speed of Airborne's service between Seattle, Washington and Fairbanks, Alaska. Our gold samples (less than one gram in weight) would be irradiated at the University of Washington reactor in Seattle and packaged by their Radiation Safety Department. Would this package need to be delivered to your office in Seattle or do you provide pick-up service? Also, how would delivery be made at Fairbanks?

Thanking you in anticipation of your prompt reply.

Sincerely,

Daniel E. Walsh

Daniel E. Walsh

DEW:cw

AiRBORNE®

May 11, 1984

Mr. Daniel E. Walsh
Univeristy of Alaska, Fairbanks
Mineral Industry Research Laboratory
Fairbanks, Ak. 99701

Re: Airborne Services

Dear Mr. Walsh:

Thank you for your inquiry regarding Airborne's service between Seattle and Fairbanks. Our service to Fairbanks from anywhere in the lower 48, including of course Seattle, is a standard 2nd morning delivery, i.e. if we picked up your sample on Monday, it would be delivered before noon on Wednesday.

Radioactive shipments are classified as restricted articles, as you know, and will have to move on all cargo air craft. Airborne has the expertise in these kinds of shipments and will provide the critical control you will require..

The cost would be $9.00 pick-up, $23.00 freight (our 1-5# rate) and $9.53 delivery.

Please call me if you have any further questions, 452-1868. I will be in Fairbanks next week and would be happy to meet with you.

Once again thank you for your inquiry.

Sincerely,

Betty Overvold

Betty Overvold
Sales Representative

BO:mem

35.00 / start up
50.00 / hr reactor t.
41.53 / Freight

AIRBORNE FREIGHT CORPORATION

4025 West 50th
Suite 1 Anchorage, Alaska 99503

Phone (907) 243-4313

Radioisotope - Au^{198}

Half - Life - 2.7 days

Mode of Decay: Beta - 0.97 Mev

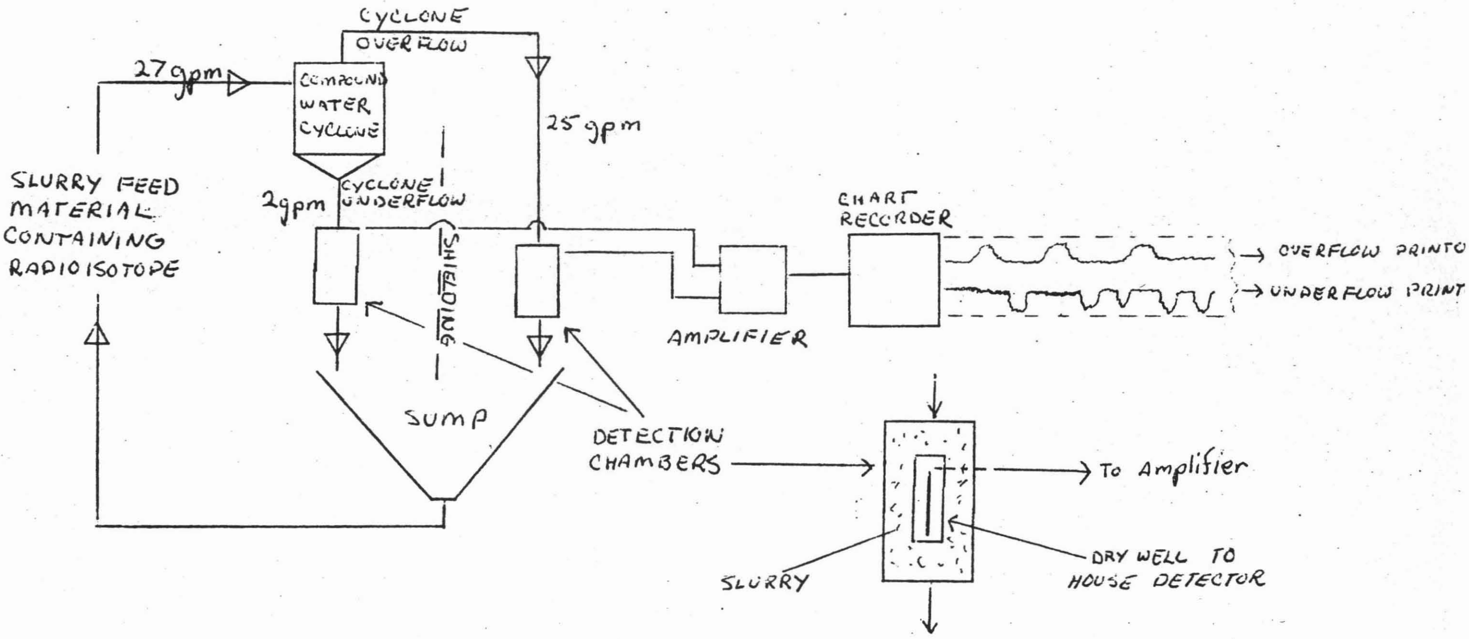
Gamma - 0.41 Mev

Experimental Activity Range: $10^2 - 10^3$ disintegrations/particle · second

Radioisotope particle size range: 10^3 - 10 microns

Radioisotope particle mass range: 35mg - 10^{-2} μg

Transported quantities: 0.5 grams @ $10^2 - 10^3$ microcuries



Slurry Characteristics

Pulp Density: 5% - 15% solids by weight

Maximum Particle Size: 3/16 inch

Velocity Through Detection Chamber: Maximum- 6 inches/second
Minimum- ½ inches/second

Mineral Industry Research
Laboratory

MEMORANDUM May 22, 1984

TO: Barbara Jackson, Purchasing Agent

FROM: Dan Walsh, MIRL

RE: Requisition FS 152602; Choice of Supplier.

I have reviewed the copies of the bids which you sent to me. After a careful inspection of the bidders' specifications and dollar quotations I feel we will be getting the most for our money by going with the Canberra bid of $6,487.00. Canberra's equipment allows us more flexability in our experimental design. Though the Technical Associates bid is considerably lower, their equipment would be less adaptable to our needs. The Tennelec equipment is nearly identical to that quoted by Canberra but slightly more expensive.

Should you need more details concerning my choice of suppliers, please contact me. Thank you for your expeditious handling of this requisition.

Dan Walsh

Dan Walsh
MIRL
6746

Mineral Industry Research
Laboratory

MEMORANDUM June 11, 1984

TO: Barbara Jackson, Purchasing Agent

FROM: Daniel E. Walsh, MIRL

SUBJECT: Requisition 152602; Justification for Bid Selection.

Having reviewed the submitted bid information for the supply of gamma radiation detection equipment, MIRL has determined that those products quoted by Canberra are the most acceptable for our research program. This decision is based upon the following:

(1) The TA scintillation probe has a cable connector along its side. The Canberra probe has only an end connector, allowing it to be housed in a smaller diameter dry-well detector chamber, and therefore our entire flow detection system may be made smaller. We have already purcahsed many of the supplies for fabrication of our detection chambers based on the dimensions of a smooth sided probe such as Camberra and other manufacturers offer.

(2) The ratemeter which TA quotes has only linear output capability. Canberra's quoted ratemeter has also logorithmic output available. Canberra's model also offers a greater selection of time constants, when the ratemeter is operated in the linear mode, and a greater count rate range.

(3) No spectroscopy amplifier is quoted by TA nor are any specifications given for the same. This is a critical component of our system.

We hope that Canberra will be contacted immediately so that this order may be processed without delay.

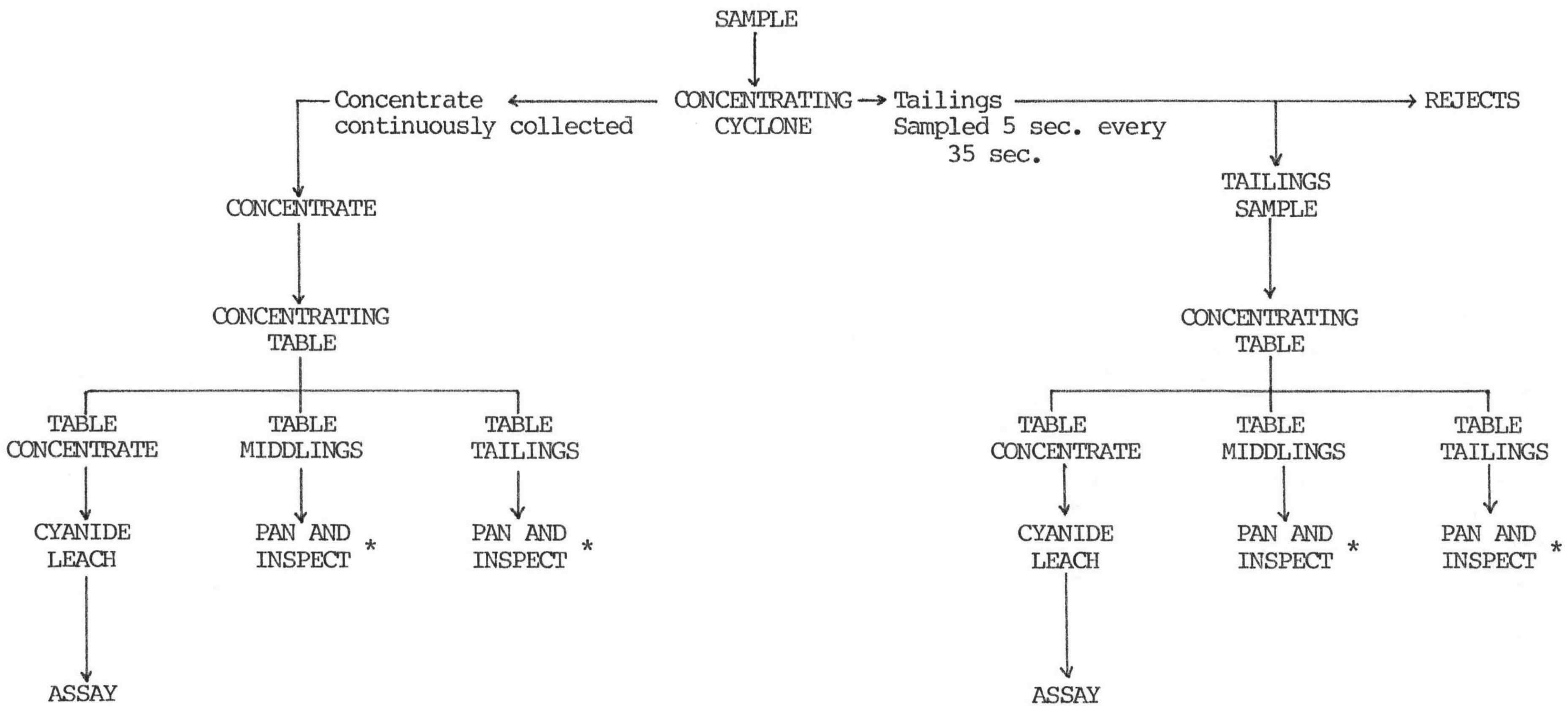
Thank you.

Daniel E. Walsh
MIRL
6746

LABORATORY TEST DATA

Fall 1983

FLOWSHEET USED FOR PROCESSING R. LOHR SAMPLES I & II



*Pans of these products were panned and the pan concentrate was inspected for free gold. No free gold was visable to the eye. For this reason, these products were not assayed, as it was felt that any traces of gold found in them would not add significantly to the overall grade of the samples, and that such gold would also be unrecoverable with conventional placer recovery practice.

ASSAY INFORMATION

Cyanide Leach Time - 72 hrs.

Cyanide Leach Solution - 0.4% Sodium Cyanide; Ph at +10 with lime.

LEACHED TABLE CONCENTRATE DATA

Sample	Sample Wt.	Leach Solution Gold Concentration	Weight Total Gold (mg)
L#1 CWC Tails	1430.3 g	3.25 ppm	6.5
L#1 CWC Conc.	199.1 g	3.90 ppm	9.8
L#2 CWC Tails	973.4 g	2.30 ppm	13.0
L#2 CWC Conc.	281.0 g	6.84 ppm	17.1

OVERALL SAMPLE GRADE DATA

Sample	Total Wt. (g)	Gold Content (mg)	Grade (oz./ton)
L#1 CWC Tails	119,952	39.4	0.01
L#1 CWC Conc.	2,581	9.8	0.11
LOHR #1	122,533 g (270 lbs.)	49.2	0.01
L#2 CWC Tails	89,176	78.8	0.03
L#2 CWC Conc.	2,851	17.1	0.18
LOHR #2	92,027 g (203 lbs.)	95.9	0.03

CYCLONE PERFORMANCE DATA

Sample	Weight		Conc. Ratio	Gold Wt.		Gold Recovery
	Tails	Conc.		Tails	Conc.	
LOHR #1	119,952g	2581g	47:1	39.4 mg	9.8 mg	20%
LOHR #2	89,176g	2851g	32:1	78.8 mg	17.1 mg	18%

Poor recovery of gold in the CWC concentrate can most probably be attributed to the extremely large concentration ratios achieved. Normal mineral processing practice considers single stage concentration ratios of 5:1 to 10:1 to be the upper limits for good recovery. We had expected to realize a concentration ratio of ~15:1 in our testing of your material with our selected settings of the cyclone's parameters. The higher concentration ratios realized could be due to a number of factors, a few of which I set out below:

1. High percentage of fines in the feed,
2. Low percentage of coarse material in the feed,
3. Low percentage of heavy minerals in the feed,
4. Variable feed rate.

FIELD TEST

Summer 1984

REPORT

TO

NORTHWEST EXPLORATION COMPANY

Determination of Gold Loss from Fish Creek Sluicing Operation

By

Daniel E. Walsh
Dr. P. D. Rao
Dr. David R. Maneval

Mineral Industry Research Laboratory
University of Alaska-Fairbanks
Fairbanks, Alaska

SUMMARY

A project was conducted for Northwest Exploration Company by the Mineral Industry Research Laboratory of the University of Alaska, Fairbanks, to investigate the free gold being lost from their sluicing operation. The placer mine is located on Fish Creek in the Fairbanks mining district, Alaska.

Two preliminary visits to the site showed that the operation would be adaptable to sampling via a portable 4" compound water cyclone pilot plant with which MIRL has performed similar test work. During the second of these visits a head sample of ~400 lbs was taken from the mine pit for screen analysis. Subsequent screening showed the run of mine material to be 53% + 1/8 inch.

Two test runs were completed by passing a portion of the sluice tailings flow over a 1/8" wedge wire panel located above a 60 gallon sump. The -1/8" slurry was then pump under 7 psi pressure @ 50 gpm to two 4" CWC's operated in parallel. The concentrate (CWC underflow) was collected continuously throughout these tests while the tailings (CWC overflow) were sampled for 5 seconds every two minutes (1/24 of the total time).

These products, CWC underflow and overflow, were then transported to MIRL's laboratory for further processing, which included an additional stage of concentration by CWC and froth flotation. From the flotation concentrate, free gold was hand picked for microscopic examination.

In this report, the results of the two on-site test runs with their subsequent laboratory processing are given. Free gold loss from the operation's sluice box appears to be on the order of 23¢/yd. This value is based on a gold price of $400/oz troy and a run of mine material bulk density of 3000 lbs./yd^3.

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INTRODUCTION

A request for assistance was received from Northwest Exploration Company of Fairbanks, Alaska, in May, 1984, regarding the determination of free gold being lost by their sluice box recovery system. They also desired information on how to improve their gold recovery by modification of their sluicing operation.

The recovery system as tested consisted of a 50 ft. long, three channel sluice box. The side channels, each 18 inches wide, processed the punch plate (9/16 inch diameter holes) oversize, while the middle channel of 40 inch width, processed the material passing through the punch plate. The riffles in both side and middle channels were of 2 inch angle iron, hungarian type design and were underlain by astroturf. The box grade was 12.5% and the water flow through the sluice was approximately 3000 gpm.

A 19 yard dump truck delivered the run of mine material to the sluice's wash box, where it was washed over the punch plate and into the channels by both a manifold and monitor. The material contained very little clay and washed easily. Laboratory screening also bore out the fact of easy washability. The punch plate was located between the slick plate of the wash box and the start of the sluice channels. A deflector wedge shunted the water and material not passing through the punch plate to the side channels. Large rocks of $\leq$ 12 inches were washed down the side channels. Rock blockages were cleared manually with a rock rake, bar, etc.

Prior to the actual sluice tails processing a 20 gallon drum of run of mine material was collected from the mine's pit. This sample was taken to MIRL and wet screened over a 1/8" screen. The products were dried and weighed. This test showed that excluding the larger (+6 inch) pit rock, the material was 47% - 1/8 inch.

Also prior to the field tests, Mr. Bill Lanning supplied MIRL with a concentrate obtained from two pannings of pit material from near the pumping station sump. This concentrate was screened and the free gold was hand picked from each size fraction, weighed, and the number of colors counted. These results are shown in Table 1.

With the preliminary investigation and inspection completed, the actual sluice tails processing was planned for and completed in one day. Two tests were run. In each, a fraction (~50 gpm) of the sluice box tailings were processed through one stage of compound water cyclone concentration.

FIELD TESTING PROCEDURE

The general flowsheet for field processing of the sluice box tailings is shown in Figure A. The concentrates from the two 4 inch CWC's were collected continuously during a test while the CWC tailings were sampled for 5 seconds every 2 minutes. It had been anticipated that the CWC pilot plant would yield a concentration ratio of approximately 10:1 with the vortex finder clearance and apex diameter chosen. This proved to be a false premise. Concentration ratios of approximatly 2:1 were realized causing the test runs to be shorter (13

TABLE NO. 1

Pan Color Classification by Sieve Mesh (ASTM)

Mesh			# of Colors	Wt. Au (mg)	Wt %	Cum. Wt.% Retained
Passed		Retained				
1/8"	x	30	1	2.56	48	
30	x	40	0	--	--	48
40	x	50	1	0.15	3	48
50	x	70	4	0.37	7	51
70	x	100	27	1.60	29	58
100	x	140	17	0.51	10	87
140	x	0	20	0.18	3	97
				5.37	100	

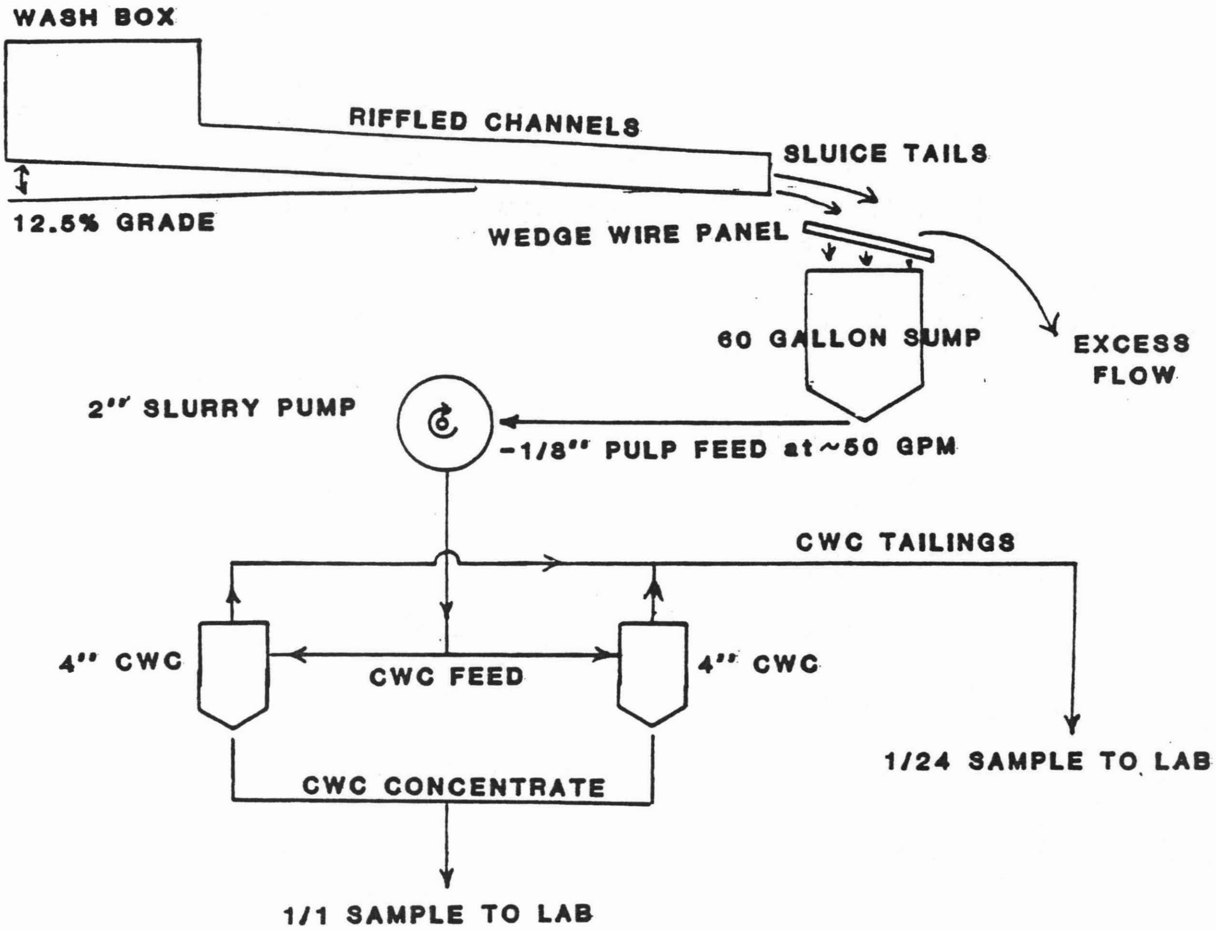


FIGURE A

FIELD TEST FLOWSHEET

minutes and 20 minutes) than the one hour length originally planned in order to acquire a concentrate sample weighing ~500 lbs.

Upon initial start up of the pilot plant, some problems were experienced with the screen-sump arrangement which sampled the sluice tailings flow. Too large an amount of solids were passing through the wedge wire screen. With the classifiying action of the 60 gallon sump, the pulp density of the system soon built up to exceed the pump's capacity. It was necessary to shut the system down, clean the plugged sump and lines and fabricate a plate to restrict the wedge wire screen's effective working surface. Thereafter the pilot plant functioned satisfactorally. Pertinent test parameters for the two runs are given in Table 2 and 3.

At this point, same discussion must be given to the representativeness of our sluice tails sampling. Ideally it would have been preferable to sample one channel's entire flow. Unfortunately the pilot plant's capacity is only 50 gpm and each side channel's water flow was in the region of 1100 gpm. We were, therefore, sampling a fraction of the total flow. The wedge wire screen and sump was positioned beneath the discharge of one of the side channels in a manner to split off a fraction of the tailings stream as shown in Figure B. It is obvious then, that our sample tells us nothing about center channel gold losses. Further, from Figure B it can be seen that much of the flow never encountered the screen surface. It could be argued that this upper portion of the stream which did not contact the screen may have been carrying a disproportionate amount of the flow's, fine, flakey gold, which consequently would

TABLE NO. 2

Field Test No. 1 Pilot Plant Data

Flow Rate to CWCs - ~50 gpm

Feed Pressure - 7 psig

Vortex Finder Clearance - 1-1/4 inches

Apex Diameter - 1 inch

Feed Pulp Density (Calculated) - 17% by weight

Total test time - 13 minutes

Total CWC Concentrate Wt. - 610 lbs.

CWC Tailings Sample Wt. - 19 lbs.

Total CWC Tailings Wt. (Calculated) - 454 lbs.

Concentration Ratio - 1.7 : 1

TABLE NO. 3

Field Test No. 2 Pilot Plant Data

Flow Rate to CWCs - ~50 gpm

Feed Pressure - 7 psig

Vortex Finder Clearance - 3/4 inch

Apex Diameter - 1 inch

Feed Pulp Density (Calculated) - 12% by Weight

Total Test Time - 20 minutes

Total CWC Concentrate Wt. - 496 lbs.

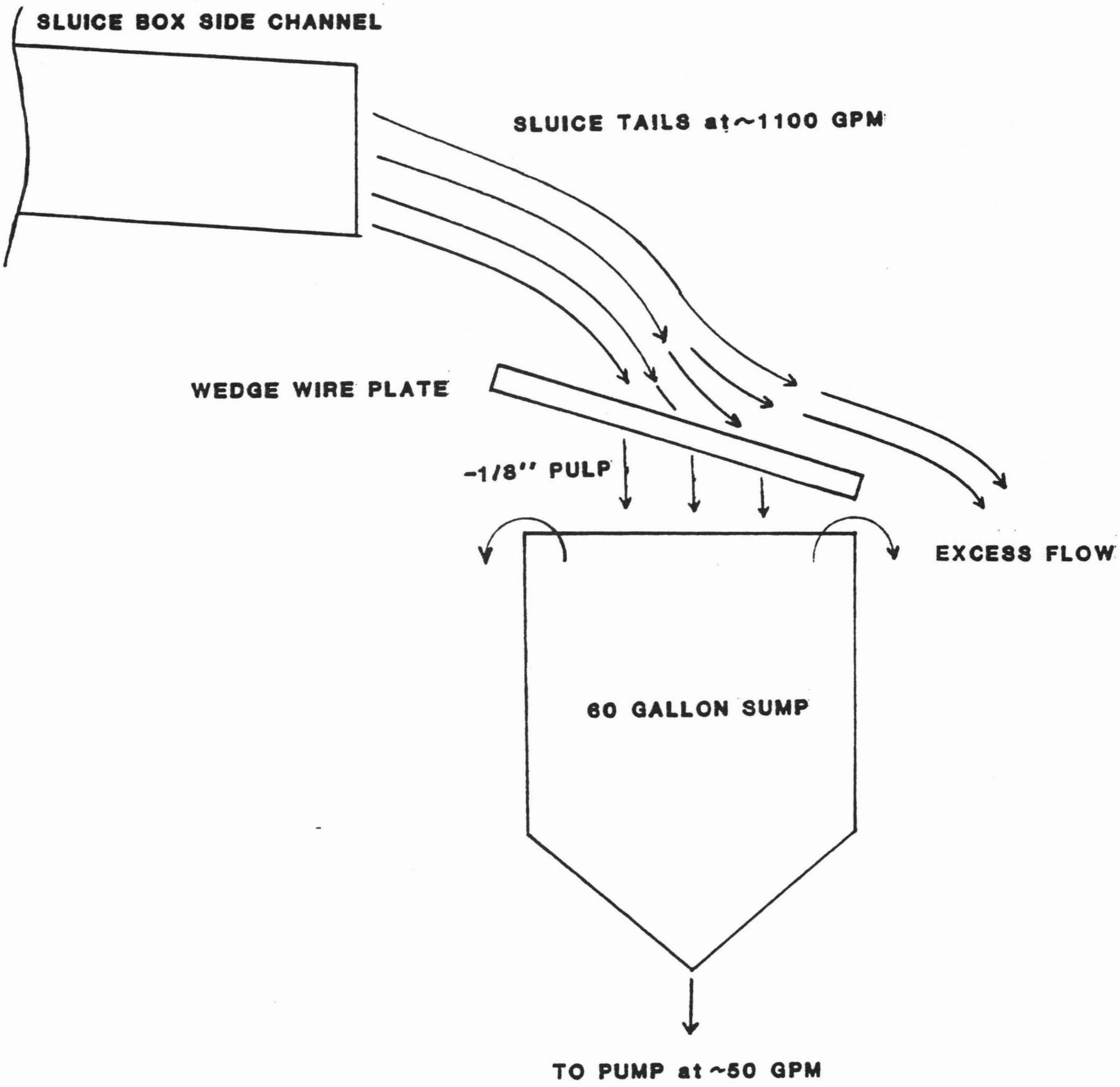
CWC Tailings Sample Wt. - 23 lbs.

Total CWC Tailings Wt. (Calculated) - 552 lbs.

Concentration Ratio - 2.1 : 1

FIGURE B

SLUICE TAILS SAMPLING



never have been sampled. It might also be said that the turbulence of the sluice flow acted to randomize the -1/8" material with which we were concerned, thereby insuring representation by the sample.

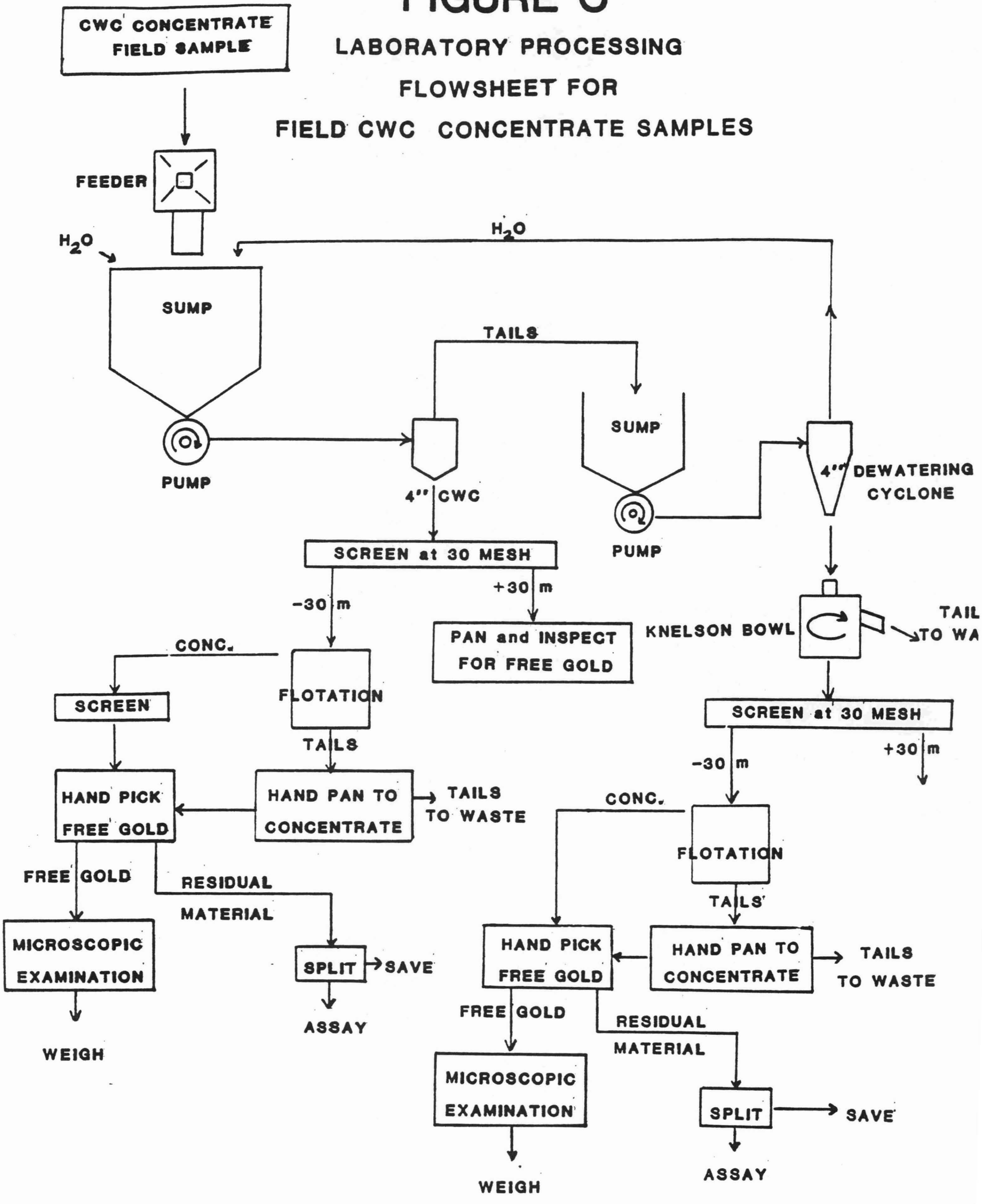
It would be difficult to state definatively the degree of representation by our sampling procedure. Therefore, no conclusion is drawn concerning it here. Rather, the nature of the sampling procedure has been discussed to alert the reader to the possible influence of sampling error on the results of this test work.

LABORATORY TESTING PROCEDURE

The CWC concentrate and tailings samples were transported from the mine site to MIRL's laboratory where they were decanted and weighed. The cyclone concentrates from field tests 1 and 2 were processed as shown in the flowsheet, Figure C. The additional stage of compound water cyclone concentration was performed to reduce the sample bulk prior to froth flotation. Passing the laboratory CWC tails through a dewatering cyclone, then to a 6 inch Knelson centrifugal concentrator was intended to act as a check on CWC gold losses. During laboratory processing of field test #2 sample, we experienced electrical problems which caused us to purge our Knelson bowl concentrate at 2 different occasions. This caused the loss of much of the gold that had been concentrated up to the point of the system purge. We therefore have no accurate value of the Knelson bowl gold content for field test #2 sample. Both the cyclone concentrate and the Knelson bowl concentrate from field test #1 were wet screened over a 30 mesh screen. The -30 mesh fractions were then sent to froth

FIGURE C

LABORATORY PROCESSING FLOWSHEET FOR FIELD CWC CONCENTRATE SAMPLES



flotation. The screen oversize was panned and the pan concentrates were inspected for free gold.

Froth flotation was conducted using either a Wemco laboratory scale flotation machine for the Knelson bowl concentrate (~1500g) or a Denver Sub A No. 7 pilot plant flotation cell (modified for batch operation) for the larger CWC concentrate material. Aeroxanthate 350 (0.2#/ton), Aerofloat 208 (0.2 #/ton) and Aerofloat 15 (0.4 #/ton) were the reagents used in the quantities indicated. The flotation concentrates were wet screened over a 400 mesh sieve, dried and examined for free gold, which was hand picked under a binocular microscope. Flotation tailings were panned, and the pan concentrates inspected for free gold which might not have responded to the flotation process. These pan concentrates were saved for assay.

The field tests' CWC tailings samples were processed as shown in Figure D. The samples were wet screened at 30 mesh. Froth flotation was conducted using the larger Denver cell at the reagent concentrations stated above. The screen oversize was panned and inspected for free gold, none was found. The flotation concentrate was wet screened over 400 mesh, dried, and weighed. The flotation tailings were panned down to a heavy mineral concentrate and dried. This pan concentrate was combined with the flotation concentrate and the mixed material split using a small Jones riffle. A fractional split was set aside for assay.

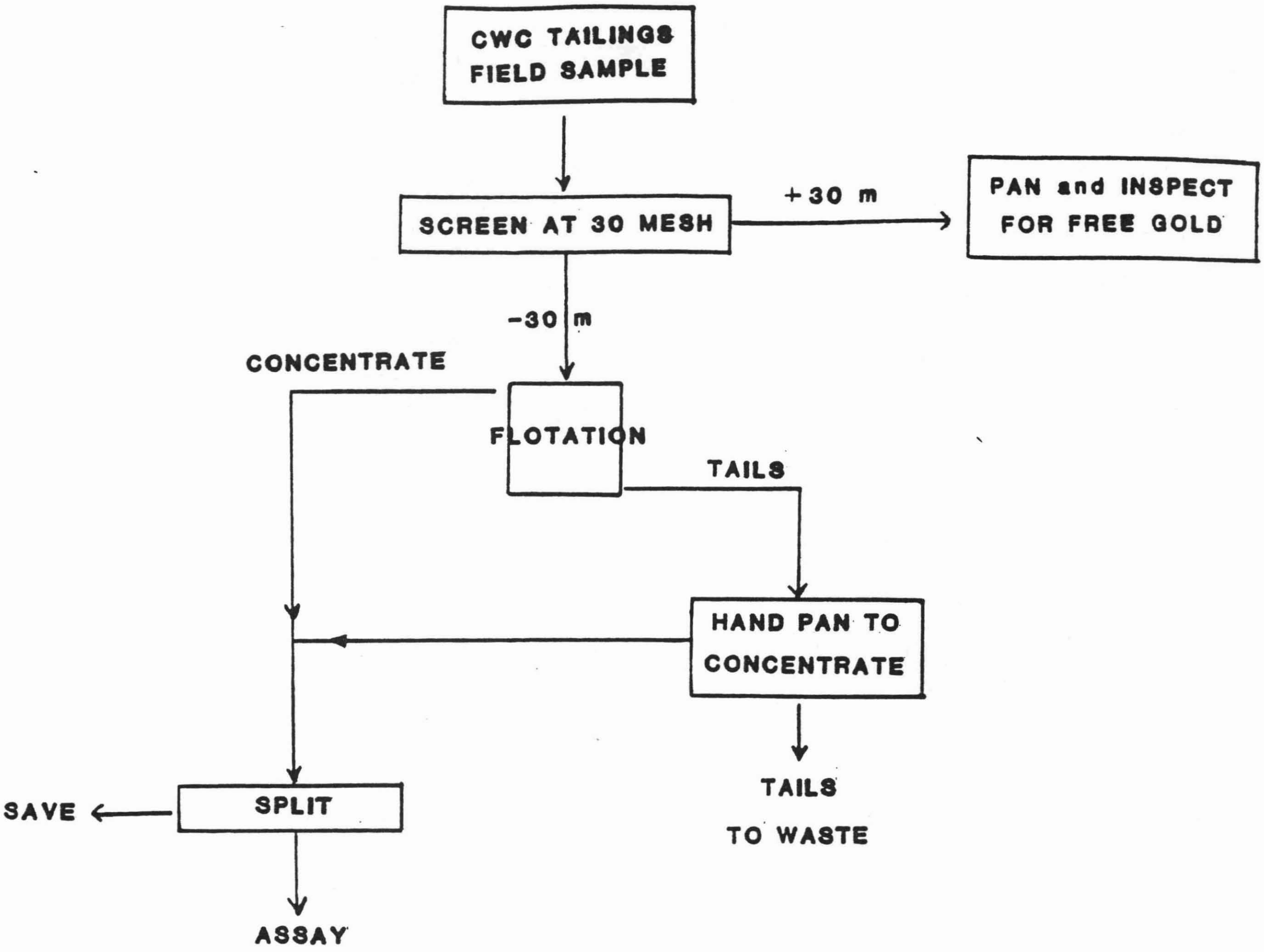


FIGURE D

LABORATORY PROCESSING FLOWSHEET FOR FIELD CWC TAILING SAMPLES

TABLE NO. 4

Gold Particles by Mesh Size Hand Picked from Flotation Products of Laboratory CWC and Knelson Bowl Concentrates; Field Test No. 1

CWC CONCENTRATE

Product/Mesh	No. of Gold Particles	Average Corey Shape Factor
Flotation Conc.		
40 x 50	4	.20
50 x 70	1	.15
70 x 100	10	.25
100 x 150	36	.40
150 x 200	25	.44
200 x 270	30	.28
270 x 400	24	.28
Flotation Tails		
30 x 0	11	.42

KNELSON BOWL CONCENTRATE

Product/Mesh	No. of Gold Particles	Average Corey Shape Factor
+30 mesh Pan Conc.		
20 x 30	1	.12
Flotation Conc.		
30 x 0	45	.25
Flotation Tails		
30 x 0	34	.30

INSPECTION OF RECOVERED FREE GOLD

As mentioned above, the flotation concentrates resulting from the further processing of the field test #1 CWC concentrate were examined under a microscope for free gold. This gold was hand picked by size fraction and shape factor measurements were made. The number of flakes from each size fraction is given in Table 4. It must be noted that not all of the free gold was hand picked from the flotation concentrate. The picked through material was assayed to determine residual gold content. The average Corey shape factor values for the free gold measured are also presented in Table 4. Corey shape factors determined for the individual gold particles measured are presented in tables A1 - A9 of the appendix.

SAMPLES' GOLD CONTENT DETERMINATION

The gold which was hand picked from the flotation concentrates was weighed as part of the final gold value determination. No fineness factor has been used to adjust these weighed values. The "picked through" flotation concentrate was assayed to determine residual gold. All assays were by aqua regia digestion - DIBK extraction with subsequent atomic absorption spectroscopy.

Pan concentrates of the flotation tailings were combined with the flotation concentrate products prior to splitting for assays. A portion of the through sieve, -400 mesh material, from the flotation concentrates of field test #1's CWC concentrate and tailings were assayed to determine if significant gold existed below this size limit. Tables 5 and 6 give the results of the gold assays for all

TABLE NO. 5

Assay Results for Laboratory Products of Field Test Sample No. 1

Sample Description	Sample Wt. (g)	Digested Wt. (g)	Dilution Factor	Solution ppm Gold	Digested Gold Wt. (mg)	Total Gold Wt. (mg)	Calculated Sluice Box Gold Loss (mg)
Flotation Conc. & Flotation Tails Pan Conc. from CWC Concentrate (Hand Picked Gold).	—	—	—	—	—	3.12	3.12
Flotation Conc. & Flotation Tails Pan Conc. from CWC Concentrate (After Removal of Hand Picked Gold).	45.92	21.71	250	2.87	0.72	1.52	1.52
Flotation Conc. from CWC Concentrate (-400 mesh material).	55.29	55.29	100	0.80	0.08	0.08	0.08
Flotation Conc. & Flotation Tails Pan Concentrate from Knelson Bowl Concentrate (Hand Picked Gold).	—	—	—	—	—	3.00	3.00
Flotation Conc. & Flotation Tails Pan Concentrate from Knelson Bowl Concentrate (After Removal of Hand Picked Gold).	5.86	5.86	125	6.8	0.85	0.85	0.85
Flotation Conc. & Flotation Tails Pan Concentrate from Field CWC Tails.	181.80	51.22	100	0.60	0.06	.21(x24)*	5.04
Flotation Concentrate from Field CWC Tails (-400 Mesh Material).	207.29	51.22	100	0.27	0.03	0.11(x24)*	2.64

Total Gold Loss Excluding -400 Mesh Gold: 13.53 mg

Total Gold Loss Including -400 Mesh Gold: 16.17 mg

*Field CWC Tailings Sampling Time Factor.

TABLE NO. 6

Assay Results for Laboratory Products of Field Test No. 2.

Sample Description	Sample Wt. (g)	Digested Wt. (g)	Dilution Factor	Solution ppm Gold	Digested Gold Wt. (mg)	Total Gold Wt. (mg)	Calculated Sluice Box Gold Loss (mg)
Flotation Concentrate & Flotation Tails Pan Concentrate from CWC Concentrate.	46.27	24.97	500	3.02	1.51	2.80	2.80
Flotation Concentrate & Flotation Tails Pan Concentrate from Field CWC Tails.	40.53	40.53	100	0.93	0.09	0.09(x24)	2.16

products assayed from both field tests. Due to the system failure mentioned earlier in this report, which accured during the laboratory processing of the field test #2 sample, most attention was subsequently given to the processing of the field test #1 sample. Assays for the latter were therefore more numerous as they were used to evaluate side channel gold loss.

SIDE CHANNEL GOLD LOSS CALCULATIONS

In the following calculations, the gold values of the -400 mesh (37 um) material have not been factored into the total gold loss figure. This is a cut off point arbitrarily chosen for this project but is well below the 100 mesh (149 um) gold particle size commonly accepted as the lower limit recoverable by conventional sluicing operations. The calculations also include no factor for the fineness of the natural gold alloy existing in the placer ore body. The final gold loss figure is calculated based on $400/troy oz. gold and a run of mine material bulk density of 3000 lbs/yd^3. Recall that the head screen analysis showed the pit material (neglecting + 6 inch boulders) to be 47% - 1/8 inch.

Total gold recovered from sluice tails by CWC concentrate - 8.49 mg.
Total gold recovered from sluice tails by CWC tailings - 5.04 mg.
Total gold lost by sampled sluice box tails stream - 13.53 mg.

$$\left.\begin{array}{l}\text{CWC concentrate wt. - 610 lbs.}\\ \text{CWC tailings wt. - 456 lbs.}\end{array}\right\}\ \text{1066 lbs.}$$

Grade of cyclone feed (Processed sluice tails) = $\frac{13.53\text{ mg Gold}}{1066\text{lbs}}$

$= \frac{0.0008\text{ troy oz.}}{\text{ton}}$

Value of cyclone feed =

$$\frac{0.0008\text{ troy oz.}}{\text{ton}} \times \frac{\$400}{\text{troy oz.}} \times \frac{1.5\text{ ton}}{\text{yd}^3} \times .47 = 23¢/\text{yd}^3$$

Sluice box side channel loss = $23¢/\text{yd}^3$

DISCUSSION

The field test work performed, indicates a sampled sluice tailings value of 23¢/yd^3. Due to the short duration of the test it would seem unwise to attempt to relate this sluice loss value to the head grade of the property and arrive at a gold recovery figure for the sluicing operation. The grade of the few yards of material sampled during the test period may have varied considerably from that determined by drilling the ground. Further, as discussed earlier in this report, the splitting of the sluice tailings stream by the wedge wire panel may have introduced a bias to the results. Also, the time elapsed since the date of the last clean-up would have an influence upon the amount of gold exiting the box with the tailings. For these reasons, no attempt is made here to state a sluice box recovery based on the findings of this testing program.

The information of greatest importance resulting from this study comes from the inspection of actual gold particles found in the tailings. The average shape factors for the 40 x 50, 50 x 70, and 70 x 100 mesh gold particles were 0.20, 0.15 and 0.25 respectively, which could explain their loss by the sluice box. As particle size becomes smaller than 100 mesh, even particles of higher shape factor report to the sluice box tailings. A look at the tables of the appendix shows a broad range of shape factors for the lost gold. This would indicate a rather indiscriminant gold loss mechanism operating within the box. Surging feed rates and/or riffle scouring when large rocks squeeze their way down the narrow side channels may contribute to this.

Of the improvements that could be made to the sluicing operation, the most obvious and probably the most beneficial, would be the addition of a grizzly, to scalp of the coarse rocks from the run of mine material. The selection of the optimum bar spacing would require analysis of the size and shape of the gold found in the head material and balancing this against the largest gravel one wished to work through the box without significant gold loss. Regardless, any removal of the coarse rock would most certainly improve gold recovery and at the same time decrease water requirements and thereby pumping costs. The larger rocks presently being forced through the narrow side channels no doubt induce scouring of the riffle. As the cross sectional flow area of these channels is restricted, a large increase in flow velocity around the obstructing rock results in the annihiliation of the riffles concentrating action and a redistribution of much of the gold which may have been trapped therein. A simple reallocation of channel function could help reduce the effect of this scouring. By processing the punch plate underflow in the narrower side channels and forcing the coarser material to the center channel where it would cause less disruption of the water flow, better gold recoveries could result.

MIRL wishes to thank Northwest Exploration Company for their cooperation and support. The assistance of their workers at the Fish Creek operation made the completion of this test work a much simpler and more enjoyable task.

APPENDIX

Table No. A1

Corey shape factors for selected gold particles hand picked from the flotation concentrate of the Knelson bowl concentrate, (30 x 0 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor *
285	247	35	.13
133	114	38	.31
304	209	43	.17
190	152	60	.35
361	266	58	.19
380	228	48	.16
285	150	64	.31
342	190	55	.22
190	114	50	.34
114	76	20	.21
209	152	42	.24
160	95	48	.39
209	190	52	.26
323	171	50	.21
217	141	45	.26
171	133	44	.29

*Corey Shape Factor = $\text{Thickness}/\sqrt{\text{Length x Width}}$

Table No. A2

Corey shape factors for selected gold particles hand picked from the flotation tailings of the Knelson bowl concentrate, (30 x 0 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
190	114	45	.31
95	209	42	.37
494	456	46	.10
152	152	21	.14
114	152	62	.32
114	140	44	.35
103	133	55	.47
114	152	25	.19
190	95	63	.47
190	87	30	.23
84	72	28	.36
179	217	50	.25
76	87	32	.39
103	179	40	.30
209	95	34	.24

Table No. A3

Corey shape factors for selected gold particles hand picked from the flotation concentrate of the CWC concentrate, (40 x 70 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
646	380	72	.15
532	475	138	.27
456	570	72	.14
684	456	70	.13
494	532	135	.26

<u>Table No. A4</u>

Corey shape factors for selected gold particles hand picked from the flotation concentrate of the CWC concentrate, (70 x 100 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
380	190	70	.26
380	152	62	.26
380	285	64	.19
323	247	62	.22
342	152	85	.37
380	133	68	.30
342	182	64	.26
315	171	65	.28
437	190	70	.24
532	266	64	.17

Table No. A5

Corey shape factors for selected gold particles hand picked from the flotation concentrate of the CWC concentrate, (100 x 150 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
152	266	60	.30
190	201	69	.45
133	152	67	.47
228	122	70	.42
236	133	98	.55
380	122	89	.41
167	236	73	.37
152	190	67	.39
323	133	58	.30
190	266	75	.32

Table No. A6

Corey shape factors for selected gold particles hand picked from the flotation concentrate of the CWC concentrate, (150 x 200 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
84	141	44	.41
133	99	90	.79
84	122	57	.57
114	171	34	.24
103	179	79	.58
144	84	62	.56
144	106	26	.21
114	114	47	.41
114	247	27	.16
95	247	77	.50

Table No. A7

Corey shape factors for selected gold particles hand picked from the flotation concentration of the CWC concentrate, (200 x 270 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
76	65	32	.46
95	68	29	.36
122	103	19	.17
277	68	34	.25
76	95	29	.34
91	266	18	.12
114	61	44	.53
68	122	16	.18
84	95	24	.27
68	106	14	.16

Table No. A8

Corey shape factors for selected gold particles hand picked from the flotation concentrate of the CWC concentrate, (270 x 400 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
95	61	24	.32
38	106	35	.55
95	61	12	.16
95	57	16	.22
57	76	19	.31
133	46	31	.40
65	57	14	.23
76	95	10	.11
76	76	20	.26
76	57	12	.26

Table No. A9

Corey shape factors for selected gold particles hand picked from the flotation tailings of the CWC concentrate, (30 x 0 mesh), Field test #1.

Particle Length (um)	Particle Width (um)	Particle Thickness (um)	Corey Shape Factor
156	182	92	.55
201	182	85	.44
84	95	33	.37
209	342	62	.23
144	209	51	.29
87	152	70	.61
266	190	57	.25
266	152	60	.30
95	114	65	.62
171	103	73	.55
60	95	67	.32