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SETTLING TUBES FOR SIZE ANALYSIS OF FINE AND COARSE FRACTIONS OF OCEANIC SEDIMENTS

by

J. Thiede, T. Chriss,
M. Clauson and S.A. Swift

Reference 76-8
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Instrumentation for rapid, high precision size analysis of silt and sand size particles has been acquired and/or developed by the marine geology group of the School of Oceanography of Oregon State University. A Cahn automatic electrobalance with particle sedimentation accessories is used for size analysis of the silt fraction of pelagic sediment; a large diameter settling tube developed at Oregon State University is used for analysis of the sand size fraction. The data generated with these systems are recorded by a strip chart recorder as well as by a high speed paper tape punch. Computer programs to deal with large volumes of data and to calculate various size parameters for each sample have been developed for this instrumentation and are documented in this report. Instrumentation has also been developed to permit specific size fractions to be separated from the bulk sediment to allow compositional studies of the different size modes. All documentation necessary to understand this instrumentation system is presented in this report, and thus is available to all students interested in textural classifications of pelagic sediments.

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Summary

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Acknowledgments

The acquisition, development, and construction of the system of settling tubes has been funded through contracts from the Office of Naval Research to Drs. T. H. van Andel and G. Ross Heath until 1974 and to Drs. van Andel and J. Thiede since 1974. We gratefully acknowledge this support. We drew considerably upon previous experience of Mr. J. P. Dauphin and R. Oser with the Cahn balance. We would also like to extend our gratitude to the ONR program director responsible for the submarine geology and geophysics programs of Code 480 (Dr. A. Malahoff).

1. Introduction

Size analysis of silt and sand size particles is a controversial problem which has occupied researchers for many years (for an excellent review of most methods, see Müller, 1967). Since the component sizes of many marine sediments range over a fairly wide spectrum of size classes, different institutions have used different methods to study their granulometry. Most frequently, size distributions of the material > 0.063 mm have been determined using sieving methods while size distributions of the fine grained material have been investigated by measuring the rate of accumulation of particles settling through a fluid medium. It is disadvantageous that two different methods applied in separate steps have to be combined to obtain a size distribution of the total sediment. Since both methods measure different variables (settling velocity for the fine grained components, median axis of the coarse components) these size distributions are not compatible in many instances.

Size distributions of oceanic sediment samples are routinely determined as part of the research programs carried out by the various members of the marine geology group of the OSU School of Oceanography. To avoid the above disadvantage, a system of settling tubes for size determinations of pelagic sediments has been developed. It consists of a Cahn automatic electrobalance with particle sedimentation accessories (Cahn Instruments, Paramount, California) for determination of the size distributions of silt sized material and a large diameter settling tube which has been developed by Mr. Milo Clauson at Oregon State University for the analysis of the sand size fractions of sediments.

Both systems measure the settling velocities of particles. If desired, the range of measurement for the large diameter settling tube can be extended down to 40μm while the silt analysis system can analyze particles < 63μm in diameter. Thus, the total system permits the overlap of coarse and fine distributions, which allows proper matching of the individual grain size curves.

Various procedures and attachments to the settling tubes, as discussed in this report, allow the separation and subsampling of size classes for compositional studies of various size fractions. The generation of large volumes of data have forced us to develop computer programs to handle these data, to calculate various size parameters as outlined below, and to plot size distributions. The development of this instrumentation package and the accompanying procedures is now largely complete. We have collected all pertinent information about these instruments, all instructions on how to use the instrumentation, details of the computer programs developed for data reduction, as well as ideas on how to avoid mistakes when applying these methods. We feel that this instrument package is going to be widely used within this group as well as at other institutions, and therefore we want to share our successes and failures with future students of textural properties of pelagic sediments. This report is not consistent throughout in the detail used in describing and discussing the various components of the whole package because descriptions of some instruments have been detailed elsewhere. The Cahn balance is delivered with a comprehensive manual describing many of its essential features which need not be repeated here (Cahn Instrument Company, 1975). The large settling tube has been developed in-house, therefore, it requires more complete documentation. The development is the most recent stage in the evolution of a system that began in 1958 with the design and construction at Scripps Institution of Oceanography of a settling tube to measure automatically the size distribution of particles coarser than 0.06 mm (by T.H. van Andel and J.D. Snodgrass). In 1966, van Andel and R.M. Beer, with ONR support, added a fine fraction component based on the Cahn sedimentation balance. The system was transferred to Oregon State University in 1968 and used, with minor modifications, for various investigations including the ONR-supported study of Panama Basin deep-sea sedimentation. The current instrumentation is different from the previous ones because it is more refined and has a higher resolution than before, it is completely automated and it has the added capability of subsampling the size fractions.

The responsibilities for producing this manual have been distributed among the following colleagues of J. Thiede who is at present one of the Principal Investigators under the contract from ONR to the School of Oceanography of Oregon State University: Mr. S.A. Swift (size analysis of silt sized material, section 6.1), Mr. M. Clauson (instrumentation for size analysis and separation of size classes of coarse sediment component, section 7.1), and Mr. T. Chriss (data reduction and presentation for the large settling diameter tube, section 7.2).

2. Analysis of fine grained (mainly silt sized) sediment components of oceanic sediments

2.1. Size analysis of silt sized components through settling

The settling velocity of particles is a function of size, shape, fluid viscosity, and the density difference between the particle and the fluid. The principle of sedimentation analysis is that particles with higher settling velocities will settle through a given length of column faster than those with slower velocities. Sand and coarse silt particles are commonly introduced at the top of a column, separate according to their relative settling velocities, and produce an analog record of cumulative weight versus time on a sensing and recording system. (See elsewhere in this report). Fine silts and clays are introduced as a homogeneous suspension, particles settle out according to their settling velocity and their original height in the column, and a record of the accumulated weight vs. time is produced.

The results of sedimentation analysis are directly related to the settling velocity distribution of particles in the sample . The results may be interpreted also in terms of the sizes of spherical particles, of uniform density, which would settle at some theoretically or empirically determined velocity in distilled water at a standard temperature. Sedimentation diameter, here, refers to the diameter of the quartz sphere with the same settling velocity as the sample particle from nature. Size units used may be length units or the dimensionless phi unit, where Phi= $-\log_2\left(\frac{\text{diameter (mm)}}{1.0\text{mm}}\right)$. The major drawbacks to the technique is that it is not direct and that absolute particle dimensions are very rarely obtainable. For certain purposes other techniques which yield dimensional or volume results are preferable, but sedimentation is generally the more efficient method for large numbers of disaggregated sediment samples (see Poole (1957) and Swift et al. (1972) for reviews of methodology for coarse and fine material, respectively).

Characterization of the grain size distribution of a sample would, ideally, give the distribution of sizes of the original particles either just before, just at, or sometime after deposition. Such an analysis would provide information about the original material, about the depositional process, or about the extent of post-depositional changes. It would also serve to characterize the sediment for lateral correlation and for studies of changes in stratigraphy. Unfortunately, much of the information in marine deposits is probably lost due to post-depositional processes (bioturbation, chemical and physical diagenesis, and winnowing or total erosion by bottom currents), to alteration during sampling and analysis, and to random variability inherent in the depositional regime. This loss of information and the limitations of the settling tube system with respect to reproducibility and accuracy should be considered in any interpretations of size data determined by this system.

There are essentially three conceptual steps in automated sedimentation analysis which in practice may overlap: 1) pre-treatment of sample, 2) introduction of sample into settling column, separation by settling, recording of analog output, and 3) analysis of output and interpretation. Details of the hardware involved for analysis of fine silt to clay material are fully described in Oser (1972a, 1972b), Dauphin (1972), and Cahn Instrument Co. (1975). Procedural steps are described here because they may vary with the investigator, because they have not been published elsewhere, and because they are more closely related to the theory, limitations, and goals of the technique.

2.1.1. Procedures for sample preparation

2.1.1.1. General procedures

Ideally, pre-treatment should return the sample to its original size distribution. Because the results of sedimentation analysis are interpreted in terms of a hydraulic parameter, original size distribution in this case refers to the distribution of all the material which fell below the critical shear stress at the surface of the bed or was trapped during the interval of time represented by the sample. Very often this size distribution is no longer obtainable, especially with silts and clays deposited in aqueous environments. Syn- and post-depositional processes are active in most depositional environments other than restricted basins, which break down, build up, or otherwise alter the particles individually or *en masse*. Sampling and handling may further alter unconsolidated or water-indurated material. Thus, the degree to which the measured size distribution approaches the original pre-depositional distribution, which reflects the continued influences of source material, transport processes, and hydraulic conditions at the time of deposition, is uncertain. For some materials and some purposes this uncertainty is less than others. This is the case for workers who may be interested only in the sand-sized carbonate fraction or the silt-sized quartz fraction of a deep-sea mud. Pre-treatment then consists of treatments intended to remove air and free material from cavities, to remove post-depositional cement, and to otherwise return the particles to their pre-depositional hydraulic equivalents.

When some doubt arises as to the extent of alteration of material, pre-treatment procedures should be developed to reduce the effects of post-depositional processes as much as possible and to insure that valuable information in the size fractions significant to the study remains unchanged. The object of such procedures is to reduce the sample to hydraulically distinct components without altering those components in any way. A hydraulic or environmental interpretation can not be applied to the results of these analyses. The analysis serves to further define compositional features of the sediment and should only be used to these ends. These philosophical ideas should serve as guidelines in designing a proper pre-treatment program for one's samples.

Pre-treatment may consist of one or more of the following: dispersal of the fine-grained material; removal of post-depositional products; isolation of a grain-size fraction or a compositional fraction to be studied; and determination of the weight proportion of the analyzed fraction with respect to the sample as a whole.

Dispersal serves to disaggregate floccules. Techniques of sample dispersal are: rinsing with distilled water to remove soluble salts; tumbling sample in water; working sample through a fine-mesh sieve; removal of organic binders; immersion in an ultrasonic bath; and rinsing with peptizing agents (see Royse (1970) pp. 25-27).

Post-depositional products such as carbonate, silica, iron oxides, and hydrocarbons may form by chemical alteration, diagenesis, or substitution. To the extent that treatment does not alter the size of compositional components of the sample important to the study, removal may be accomplished by various chemical means (Royse (1970) p. 9).

If a particular size fraction is to be studied, separation by repeated shaking, settling through a measured height of water, and siphoning at time intervals indicated by theoretical relations (see section 6.1.1.2 below) are preferable to sieving. Whereas the settling method removes material according to its least cross-sectional area. Size boundaries derived by sieving may include or exclude material with higher or lower settling velocities than that desired, producing a poor separation or a misleading size distribution.

Particular compositional fractions, such as all the non-carbonate, all the silica-free, or only the inorganic material, are commonly studied. Removal methods include HF treatment for silica, HCl for carbonate, and H_2O_2 or sodium hypochlorite (Anderson, 1963) for organics. Care must be taken with the H_2O_2 treatment to insure that the reaction is not so violent as to break the shells of fragile marine microfossils. Also, solutions of H_2O_2 and distilled water should be buffered to near neutrality to prevent dissolution of carbonate tests.

Measurement of the proportion of sediment which is to be analyzed is done by drying and weighing the total sample and reweighing after material has been removed, or by drying and weighing before and after each pre-treatment step. The size distribution of fine silts and clays may be differentially altered by the drying process. If there is suspicion that this is occuring, an alternate procedure can be used. The sample suspension is diluted to a known volume, a small aliquot of known volume is removed by pipette, the aliquot is dried, weighed, and a value for the total mass of the sample calculated. The remainder of the sample may then be used in the sedimentation analysis. During this procedure, large errors may be introduced.

2.1.1.2. Sample preparation for grain size analysis on the Cahn balance

Disperse sample.

1. Remove 3-5 gm. of sediment and place in an 8 oz. jar.
2. Fill one half full with filtered distilled water (FDW) and add approximately one milliter of 0.033M Calgon solution.
3. Gently break up large cohesive lumps with a spatula.
4. Allow to stand 1-3 days, swirling occasionally.

Remove organic matter.

1. Transfer sample to quart screwtop jars washing well with distilled water.
2. Move samples into a well ventilated lab hood.
3. Add a small amount (25 ml) of basic H_2O_2 and note the degree of bubbling.

***Be careful not to lose small particles when large bubbles burst.

4. Add up to 200 ml of basic H_2O_2 if the evolution of CO_2 is non-violent.
5. Leave 1-3 days in hood with loose lids or with watch glass covers. Stir occasionally by swirling the jar gently.

***Hot plates and stirring rods are not necessary and only increase the chance of selectively loosing fine material.

6. If left for more than one day make periodic checks on the pH of the solution with pH paper. Solution should be basic. Add more basic H_2O_2 if acidic.
7. Test for complete oxidization of organics by addition of more basic H_2O_2. Repeat 3 through 6 if CO_2 evolution occurs.
8. When oxidization is complete (or if sediment has been oxidized for 3 days) rinse the sample 3 times by repeated candle filterings and refillings with FDW. (Usually only 1 day is necessary with 7'' long candle filters.)

***Be careful not to let filters dry out and not to lose significant amounts of fine sediment due to adhesion on candle filters.

Sieve at 63μ.

1. With liquid reduced by candle filtering in step 8, wash sediment through a 63μ sieve into a 1500 ml beaker.
2. Break up any remaining clay aggregates by gentle working with a camel hair brush and a gentle FDW spray from a squeeze bottle.
3. Backwash the > 63μ fraction into a 250 ml beaker using FDW.

4. Allow > 63µ fraction to settle out (5-10 min.). Decant off supernatant and transfer solids to a dry, weighed Teflon dish.
5. Dry the > 63µ material in a 60°C oven overnight (1-2 days), cool in a dessicator the next day, weigh, and record weight > 63µ. Transfer the dry sample to a labled vial.
6. Wash the < 63µ fraction from 1500 ml beaker back into its quart jar with FDW. (If quart jar is too small store excess in an 8 oz. jar and candle filter both volumes until the quart jar is sufficient.
7. The whole sieving procedure should take about 3 hrs. for 10 samples.

Decant at 4µ (8ϕ).

1. Label all jars with a vertical strip of tape marked off in overlapping 8 cm. intervals.
2. Fill jars up to one of the upper marks with FDW. Add one milliliter of 0.033M Calgon. Shake or swirl to produce a homogeneous suspension.
3. At the appropriate time (as calculated from the Stokes' equation) decant off 8 cm. of liquid into a clean quart jar and rinse the hose briefly by sucking FDW through.
4. Wash < 4µ fraction into clean labeled gallon jugs.
5. Repeat until a clear supernatant is obtained. Use no less than 4 decantings; 7 is usually sufficient. Total time for separation will depend on the number of decantings, on settling time, and on the dedication of the worker. Record the number of decantations.
6. Add 50-100 ml of 0.5 M $MgCl_2$ solution to gallon jugs containing the < 4µ fraction. Let stand overnight.
7. Siphon down until the volume of liquid is small enough to be washed with sediment into an 8 oz. jar.
8. Allow < 4µ fraction to settle overnight.
9. Siphon off supernatant and transfer to a weighed, dry Teflon evaporating dish. Dry at 60°C (may take 2 days), cool in dessicator, weigh and record weight <4µ. Transfer dry sediment to a labeled vial.

Estimate weight of the 4-63µ fraction.

1. Wash 4-63µ fraction into a 500 ml Erlenmeyer flask and dilute to 250 ml.
2. Swirl to produce a homogeneous suspension.
3. Pipette out 50 ml of suspension into a dry, weighed Teflon evaporating dish.
4. Dry at 60°C overnight, cool in dessicator, weigh, and calculate weight of 4-63µ fraction (multiply by 5). Transfer sample from

evaporating dish into a labeled vial.

5. Store remaining 4-63µ fraction in an 8 oz. jar and add 1 ml of 0.003M Calgon solution until ready to be run Cahn.

Warnings and Notes.

1. Do not store samples in water any longer than necessary. The longer that samples are exposed to carbonate dissolving water (either tap or FDW) the greater the possibility that significant size alteration of the sample will occur.
2. Do not crush, grind, or ultrasonic sediment samples. Some abrasion causing physical deterioration of the sample will occur during the normal lab routines given above (eg. candle filterings, sieving), but intentional alteration of the size distribution should be avoided.
3. Be careful not to spill any of the sample while stirring, sieving, oxidizing organics, or transferring suspensions between containers. There is some selective removal of fines during candle filtering and decanting. Careful work can minimize the loss.

Preparation of reagents.

H_2O_2 (pH basic)

1. Work with gloves in a well ventilated hood.
2. Dilute stock 35% H_2O_2 to about half strength with FDW.
3. Add concentrated NH_4OH and adjust to pH 7.0/7.5 with NH_4OH from a 50 ml beaker.

$MgCl_2$(0.5 M)

1. Weigh out 0.5 moles (about 101 gm) of reagent grade $MgCl_2$-$6H_2O$ and add to 1000 ml of FDW in an Erlenmeyer flask.
2. Cover with Parafilm and shake until dissolved.

***This solution is not intended to be used in quantitative analysis, so the strength of the solution need not be exactly known. $MgCl_2$-$6H_2O$ is wet and sticky. Do not bother with decimal places in weighing it out.

Calgon solution (0.033M).

1. Weigh out 20.4 gm of sodium Hexametaphosphate $(NaPO_3)_6$ in 1 l. of FDW.
2. Calgon is $(NaPO_3)$ with many impurities. If clay mineralogy is to be performed, reagent grade $(NaPO_3)_6$ should be used.

2.1.2. Calibration and use of the Cahn balance.

For material <30μ a tube (25cm) shorter than is normally used for sand-sized materials is necessary. A pan suspended from the arm of an electrobalance is used as a sensing device. The speed of the analysis is improved and problems of adhesion of clays and fine silts on introduction are avoided by starting from a homogeneous dispersion of particles (Krumbein and Pettijohn, 1938, pp. 91-92).

These instructions are intended to provide a brief description and stepwise procedure for running the Cahn Balance after it has been set-up. These do not fully take the place of the Instruction Manual provided by the Cahn Instrument Company. All the Cahn Manual should be examined and the sections 1.2-1.8, 7, 5.7.3-5.7.5 studied. The instructions and instrument settings listed below are used for a suspended sample weight of 0.080 to 0.500 gms.

Pre-operation set-up.

1. Use stirrup B on balance arm and set tabs on the MASS DIAL RANGE (MDR) and the RECORDER RANGE (RR) to B. Set dial on MDR to 500; set FACTOR on 1; and set FILTER on 3.
2. Switch power on in all Cahn units 24 hours before running. Switch on Speedomax Recorder several hours before calibration.
3. Fill pump in Lauda Constant Temperature Bath and Circulator to 1 inch from the top with distilled water. Insert hoses into water bath and turn on CIRCULATOR and COMPRESSOR. After water levels in pump and water bath have stabilized, add distilled water to water bath until water level is about 3/4 inch from top. Let pump and compressor run until water in sedimentation column is at 20.0°C (30-60 min. before calibration). Put test tube containing 50ml of slurry into pump well, so that it also comes to temperature.
4. Check paper in recorder and change roll if necessary. Clean pen and fill ink reservoir. When not in use leave pen in up position so ink is not drained from reservoir.
5. After cleaning glassware, pan, etc., fill small closed cylinder to $\frac{1}{2}$ inch below red line (25cm column) with de-gassed distilled water. Set this container in the larger water bath container and fill bath to about 2 inches from top. Insert pan and sedimentation column into the inner cylinder. Either add or remove water from inner container until level is exactly on red line. Align hangdown assembly beneath weighing mechanism and connect hangdown assembly to hook, making sure the nylon lines and the collection pan are hanging free. Place wind shield halves around the exposed strings.
6. Have ready: pipettes, beaker with rinse water, an empty beaker, forceps, and a long spatula.

Calibration

1. When RR is in the Z position there is zero output to the recorder. Switch RR to this position whenever changing the weight hanging on electrobalance beam arm.
2. Leave Automatic Range Expander (ARE) on DISABLED until a sample is to be run. Calibrate using FAST chart recorder speed.
3. Find zero on recorder by unplugging cable connection leading from ARE and shorting out the recorder with alligator clips across the double prongs in the cable plug. This will produce the recorder reading to which the rest of the electronics will be zeroed. Plug cable back into ARE.
4. Zero ARE by unplugging, from the Control Unit, the cable leading to range expander input, and inserting resistor wired onto banana plugs. Make adjustments to NULL screw in front of ARE with screwdriver and flashlight.
5. Suspend hangdown assembly from stirrup B as for a run and lay a 250 mg weight on the pan below stirrup B. Turn MASS dial to .500 and RR to 100 mg. If weights on stirrup C have not been changed since last run, simply adjust SET 5 until pen reads zero on recorder.
6. If it is necessary to readjust weights on stirrup C, first read sections 1.5.6 to 1.5.11 in Instruction Manual. With a 250 mg weight on Stirrup B, MASS dial on .500 and RR on 100 mg, add weights to stirrup C carefully until recorder reads on scale or below scale. If below scale, remove weights. Continue until recorder pen can be zeroed using SET 5 knob.
7. Switch RR to Z, remove 250 mg weight from stirrup B, and turn the MASS dial to .000. Flip RR to 10 mg and adjust SET 0/10 until pen is zeroed. Return RR to Z.
8. Place 250 mg on the left balance pan, set MASS dial to .300, and switch RR to 100 mg. Find chart paper marking 100 units above recorder zero, and adjust CALIBRATE RECORDER knob until pen stays on this line. Switch RR to Z, remove 250 mg weight from stirrup B, and turn MASS dial to 0.
9. Flip RR to 5 mg and readjust SET 10, if necessary, until pen stays on recorder zero. If any adjustment is necessary repeat 5, 7, 8, and 9 until little or no adjustment is required. The system will then be calibrated.

Operation

1. With RR on Z, unhook hangdown assembly from weighing mechanism and slide glassware outward so slurry can be added.

2. Using pipettes, remove an amount of water from the sedimentation column equal in volume to the combined volume of the sample slurry and the rinse water.
3. Hang stirrer on the edge of the water bath; shake the test tube containing the 50 ml of sample slurry until the sediment is thoroughly dispersed.
4. While holding the bridle so that the pan is pulled snugly against the bottom of the settling tube, pour the slurry into the settling tube. Pour rinse water into the test tube, swirl to suspend any particles adhering to the sides, and add to the settling tube. Stir until thoroughly mixed.
5. Immediately after removal of stirrer from column, quickly slide glassware under balance, connect hangdown assembly to hook, and free nylon lines if they are touching. Be careful not to lose any sediment out of the sedimentation column in the process of mixing and hanging the pan.
6. Flip RR to 10 mg, engage ARE, and replace wind shield halves.
7. The beginning of the run is the moment when the stirring stops and the sample material begins to settle. Mark the strip chart "Time = 0" at this point.
8. After the pen has crossed the full scale of the recorder eight times (or less) increase the MASS dial until the pen pegs on the low end of the recorder. Quickly decrease MASS dial just enough to bring the pen back on scale. If a sample with an immersed weight large with respect to the recorder range (RR) is run, then this procedure may have to be repeated 2 or 3 times during a run.
9. Switch the chart speed to slow sometime in the period of 34 to 101 minutes after initiation of run.

2.1.3. Data reduction of strip chart records

2.1.3.1. General procedures.

The analog output of sedimentation analysis on the CAHN electrobalance is a strip chart plot of accumulated weight vs. time (Oser, 1972a) The transformation of the plotted output into a frequency distribution of settling velocity or size is done by mathematically simple transformations. Unfortunately, these transformations are based on assumptions about the material in the sample and about the dynamics of the settling tube method (see Blatt et al., 1972, pp. 52-55; Krumbein and Pettijohn, 1938, pp. 95-119).

The assumptions made when the sample is settled out of a homogeneous dispersion differ from those made when samples are introduced and timing initiated at the top of the settling tube.

As soon as the sample is dispersed and the electrobalance engaged, particles will begin to settle throughout the entire water column. At any time the material accumulating on the pan is a combination of fractions of the sample with high settling velocities which have completely settled out and fractions with lower settling velocities for which there are portions still in suspension. This necessitates the use of Oden's Formula (Krumbein and Pettijohn, 1938, pp. 112-117) in order to determine the size distribution:

$$W = P - \left(\frac{t\ dP}{dt}\right)$$

where W= weight of the totally settled fractions

P= weight of the pan at some time t

$\frac{dP}{dt}$= slope of the weight - accumulation vs. time curve.

This formula assumes that the conditions of Stokes' Law hold true. In particular, the fluid should be of infinite extent and there should be no particle-particle interactions. Wall effects and entrainment of small particles within the turbulence of faster settling particles undoubtedly occurs, but no empirical assessment of the deviance from Stokes' Law in a fine grained sedimentation system has been made. Stokes' Law is generally assumed valid as the transforming function between settling velocity and sedimentation diameter. An attempt to reduce the error associated with the assumptions is made by running only dilute suspensions--.50 - .84 gm/l. The errors will probably be greater in the fine end of the size distribution.

The composition, density, and shape of particles in the silt and clay fraction varies and is usually unknown in geologic work. But particle sizes calculated by Stokes' Law from settling velocities are determined by assuming a quartz density (2.65 gm/cm^3) and a spherical shape. The size distribution therefore, is that of the standard sedimentation diameter of Gibbs _et al._ (1971). Thus, a complete size distribution for one sample over the limits of sedimentation systems (2000μ - 1μ) may be formed. Though the units of the size axis remain the same across the boundary between large and small settling tube data (in contrast to past distributions incorporating the results of sieving with settling methods), the uncertainty of the points does increase markedly at the size where Stokes' Law is used to transform settling velocity to size.

2.1.3.2. Digitizing

Recommended set-up and materials:

Light table with ample room to either side
Plastic base sheets inscribed with digitizing intervals
    (phi or time lines)
Table of settling times (Table 1)
Data recording sheets
Ship's curves
See-through plastic rulers one of which is marked off in
    0.1'' increments
Several sharp #3 or harder pencils
Masking tape
Strip chart records
Patience

Task:

Accumulated weight values (short axis of strip chart) relative to an arbitrary scale are picked off analog record at intervals on the time axis which correspond to 0.1 phi increments. These intervals were calculated using settling times of quartz spheres from Stokes' formula and using the chart speeds of the recorder.

Procedure

1. Tape fast chart speed base sheet to light table with scale increasing from right to left. Note the equivalence of these terms Horizontal axis = long axis = time or phi axis
   Vertical axis = short axis = weight axis.

2. Unroll strip chart and use masking tape to mount the strip chart over the base sheet.

   2.1 The point on the time axis of the strip chart corresponding to the initiation of the settling of grains (withdrawal of stirrer) should be placed over the vertical line (marked Time = 0) on the base sheet.

Table 1. CAHN System Settling Times for ρ=2.65 and 25 cm column at 20.0°C.

Based on Cahn equation:

$$K = \frac{(0.3) h\ r\ 10^{8}}{(d_{s} - d_{l})\ g} = \frac{(0.3)\ (25)\ (0.01005) 10^{8}}{(2.65 - 0.99823) 980} = 4656.415$$

Then: $t_{(min)} = \frac{K}{d_{(cm)}^{2}} = \frac{4656.415}{d_{(cm)}^{2}}$

ϕ	µm	Time (minutes)	ϕ	µm	Time (minutes)
4.0	62.500	1.19	6.6	10.309	43.81
.1	58.314	1.37	.7	9.618	50.34
.2	54.409	1.57	.8	8.974	57.82
.3	50.766	1.81	.9	8.373	66.42
.4	47.366	2.08	7.0	7.812	76.30
.5	44.194	2.38	.1	7.289	87.64
.6	41.235	2.74	.2	6.801	100.67
.7	38.473	3.15	.3	6.346	115.62
.8	35.897	3.61	.4	5.921	132.82
.9	33.493	4.15	.5	5.524	152.59
5.0	31.250	4.77	.6	5.154	175.29
.1	29.157	5.48	.7	4.809	201.35
.2	27.205	6.29	.8	4.487	231.28
.3	25.383	7.23	.9	4.187	265.61
.4	23.683	8.30	8.0	3.906	305.20
.5	22.097	9.54	.1	3.645	350.48
.6	20.617	10.95	.2	3.401	402.56
.7	19.251	12.58	.3	3.173	462.50
.8	17.948	14.46	.4	2.960	531.43
.9	16.746	16.60	.5	2.762	610.36
6.0	15.625	19.07	.6	2.577	701.16
.1	14.579	21.91	.7	2.405	805.05
.2	13.602	25.17	.8	2.244	924.63
.3	12.691	28.91	.9	2.093	1062.87
.4	11.842	33.20	9.0	1.953	1220.87
.5	11.049	38.14			

2.2 Vertical scale lines on strip chart should be aligned parallel with vertical markings on base sheet.

3. With a ruler and sharp pencil scribe a straight line onto the strip chart directly over each vertical line on the base sheet. Continue out to the last line before the change in chart speeds.

4. Select portion(s) of a ship's curve(s) which will best fit smoothly each segment of the analog record between scale changes and scribe in pencil on the strip chart record a smooth line which best represents the curvature of that record.

4.1 Noise in the record (unusual peaks and troughs) should be smoothed out. This includes noise associated with pan and string vibrations at the start of a run, short period noise due to disturbances (door slamming, elevators, or air currents) while the CAHN is running, long period noise due to heating and cooling cycles during the night, and any noise associated with scale changes, adjustments to the automatic range expander, and changes in recorder chart speed.

4.2 Near-vertical curves at scale changes and large amounts of noise at the start of a run present problems. Scribed curves should extend the smoothed record back to 4 phi on the base sheet. Scribed curves on either side of a scale change should be extended far enough that they intersect an already existing vertical line or so that a vertical line intersecting the two can be drawn.

5. Choose a convenient weight scale for the short axis of the strip chart record and place zero at any horizontal line which intersects the scribed line to the right of the 4.0 phi line.

6. Pick off weight values at each intersection of the pencil line scribed on the weight accumulation curve with a vertical phi line on the base sheet. Record the value opposite the corresponding phi number in the data sheet.

7. Where there is a scale change or a change due to an adjustment in the MASS dial, the weight scale must be recalibrated to the chart markings. An example of a scale change is given in Figure 1.

7.1 A line (a) perpendicular to the time axis is selected (could be a line on the base sheet or on the strip chart) or constructed so that it intersects the extensions of the pencil curves (b_1, b_2) scribed on the strip chart record to either side of the scale change.

7.2 It is assumed that the weight at the intersection of b_1 and a (read off the old weight scale) is the same as at the intersection of b_2 and a. A new scale is started from this point (using the same ratio of unit chart height to unit weight on the pan).

7.3 The same routine is used for changes in the strip chart record due to adjustments in MASS dial.

8. When there is a change from fast to slow chart speed it is necessary to replace the plastic base sheet with the sheet marked for slow chart speeds and to proceed with digitizing as in steps 2.0 - 7.3. In changing the base sheets, the location of the time axis of the strip chart with respect to the new phi scale must be calculated using the settling time tables (i.e., the horizontal scale must be re-zeroed.

8.1 Locate as precisely as possible the point where the change in chart speeds was made. Draw a vertical line, hereafter referred to as the Scale Line, through the point.

8.2 If the line lies within 1 mm of a 0.1 phi line on the fast chart speed base sheet, switch base sheets, lay the line constructed in 8.1 over the corresponding 0.1 phi line on the slow chart speed base sheet, and continue digitizing.

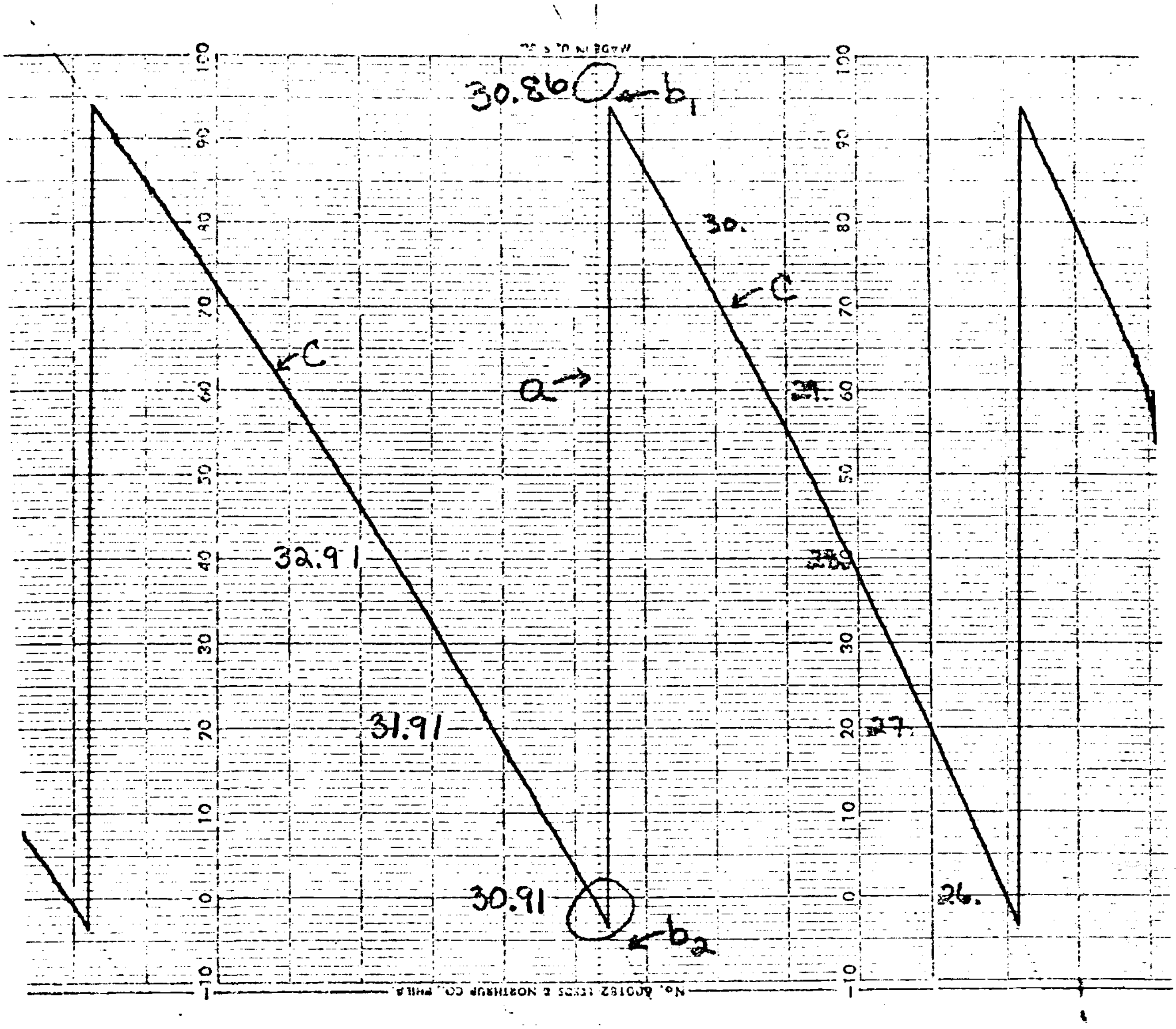


Figure 1. An example of a scale change in a CAHN strip record. Horizontal axis is time from T=0 increasing towards the left. Record is digitized from right to left. Vertical axis is accumulated weight. Line a is a vertical line constructed perpendicular to horizontal chart markings. Lines b_1 and b_2 are pencil lines fitted to the analog record (line c) by the use of ship's curves.

8.3 Usually the Scale Line is further than one mm away from a 0.1 phi line. Look up in the data tables the settling time, T_1, elapsed between the two 0.1 phi values bracketing the Scale Line. Measure the horizontal distance between the Scale Line and the last vertical 0.1 phi line to the right. Convert this distance to time, T_2 (30" = 60 min.) Subtract T_2 from T_1. Convert the remainder from time to distance at slow chart speed (3" = 60 min.).

8.4 On the strip chart, measure off this distance to the left of the Scale Line and construct another vertical line. This vertical line corresponds to the 0.1 phi value at which the next digitizing point should be taken. Line up this vertical line over its appropriate 0.1 phi value line on the slow chart speed base sheet and continue digitizing as in steps 2.0 - 7.3.

9. The matrix of 51 values of accumulated weight vs. 0.1 phi value should be keypunched for storage and for computer processing using the program SIZEBAL (see below). A description of the format for punching is contained in the next section. Using this format eight cards will be required for each sample.

Problems:

1. At present the base sheets are marked from 4.0 phi to 7.2 phi (fast chart speed) and from 6.4 to 9.0 phi (slow chart speed). Occasionally the switch in chart speeds during a run is made at a point outside the overlapping phi interval, that is, outside the interval of 33.2 to 100.7 min. after Time=0 (6.4-7.2 phi). If the switch is made too soon then the position of each vertical 0.1 phi line after the Scale Line must be calcualted and marked on the strip chart by hand up to 6.4 phi. First, the procedure for chart speed changes given above (Step 8) is used to find the first 0.1 phi line after the speed change. Then, look up the difference in settling time between the two 0.1 phi values, convert this to distance (using 3" =60 min.) and construct a vertical line at a point this distance to the left of your last 0.1 phi line. If the chart speed is changed too late, the same procedure must be done from the 7.2 phi line up to the chart speed switch after which digitizing may proceed as in Step 8 above.

2. If too large a sample is introduced into the CAHN settling column, if the sample contains a large amount of coarse silt, or if too sensitive a full scale range (selected by the Recorder Range dials on the control unit) is chosen, then rapid scale changes in the recorder may occur at the start of a run. The near vertical analog record produced by the pen is difficult to digitize because curves drawn through the pen tracings to either side of the scale change do not overlap. Consideration should be given to rerunning a smaller subsample or to rerunning at a higher value of Recorder Range. If this is impractical, digitizing across the scale changes can be made somehwat easier by extending the vertical width of the chart paper. Fix a blank sheet of paper just beneath the chart record, extend the pen tracings on to this sheet using the ship's curves until they overlap and proceed as in step 7 above.

2.1.3.3 Explanation and listing of computer programs

Data from both the CAHN settling tube (CAHN) and the large settling tube (LST) can be analyzed through program SIZEBAL. SIZEBAL will accept multiple data sets from either terminal or batch jobs, will calculate cumulative and frequency distributions, will calculate descriptive statistics, and will output the results on lineprint and as plotted curves. An up-to-date version of SIZEBAL in Fortran and binary images is stored on cards. The subroutines in SIZEBAL which analyze CAHN data use a modified version of Oden's Formula (see Krumbein and Pettijohn, 1938, p. 110-119) to calculate the cumulative curve. The user has several options to choose from in selecting a differentiating algorithm to transform cumulative to frequency data.

The CAHN reduction routines will force several types of error to new values:

1) If the cumulative raw data is not strictly ascending, an error message is sent to the line printer. Checks for reversal of slope are also made before and after differentiation to a frequency curve. Any aberrant points will be set equal to the value of the previous data point.

2) If the derivative of the cumulative curve is negative, the derivative will be set equal to zero.

The last point on the fine end of the cumulative distribution is forced to terminate in a straight line with the preceding two points.

The subroutine LST (large settling tube, see below) does not check the raw data for strict accension, therefore, be careful to check your data during digitization. No forcing of the ends of the frequency distribution occurs as in the CAHN subroutines, but the derivatives will be set equal to zero if they are negative.

Options available in running SIZEBAL

1. Differentiating routines are loaded separately from SIZEBAL. Four options are available to the user:

- Routine *SMOOTH contains a cubic spline interpolation algorithm. Use of *SMOOTH allows additional smoothing of the distributions. Increasing the value of input variable SS will increase the smoothness of the curves.

- Routine *CSLOPE estimates the differential at each point by calculating the slope between the preceding and the following point. At the ends of the distribution the slope is calculated using the first two and the last two data points.

- Routine*LSLOPE is similar to *CSLOPE but the slopes at the first and last points are set equal to zero.

- The user may prepare her/his own algorthm to obtain derivatives by doing the following:

  Write a subroutine named SMOOTH containing the algorithm to generate derivatives. The calling string should be: CALL SMOOTH (N, X, DY, SS, A, B, C, D) where:

  N is the number of data points in arrays X and Y
  X is the array of phi values at the digitized points
  Y is the array of accumulated weights at each point in X
  DY, SS, A, C, and D are dummy variables
  B is the array of derivatives at each point in X.

  This subroutine must be compiled and the binary loader deck saved under a file name (e.g., *NEWSMOOTH).

  This is done by the following commands on the teletype:

```
#FORTRAN, I= <PRONAME> , X   (CR)
                   <PRONAME> contains the Fortran version of
                   the subroutine.
NO ERROR FOR SMOOTH  the teletype should respond with this
#SAVE, 56=*NEWSMOOTH    (CR)
```

See additional comments under deck makeup regarding use of this algorithm.

2. Any number of data sets may be run within the user's time limits. The number of data sets must be input as a value of NJOBS on Control Card A.

3. The values of smoothing parameters and punch option in CAHN processing may be specified only once for all data sets in a batch or may be read in for each data set. Use variable KONTROL on Control Card A to indicate which method you will be using.

4. Either Cahn or large settling tube data digitized off strip chart records can be run through the program. Use variable ITYPE on Control Card A to specify which kind of data is being analyzed.

5. Descriptive statistics from the cumulative curve (according to Inman, 1952, and Folk and Ward, 1957) and from the frequency curve (moments statistics from Friedman, 1961) may be requested using variable ISTATS on Control Card A.

6. Routines for 3-point smoothing of the CAHN cumulative curve and/or 5-point smoothing of the CAHN frequency curve can be selected if desired using variables WT1 and WT2 on Control Card One. The same variables are used to control the use of routines which can do a 3-point smoothing of the raw data from the LST and/or a 3-point smoothing of the LST frequency distribution. It should be noted that 3-point smoothing of the cumulative curve has the effect of also smoothing the frequency curve from which it is derived.

7. The frequency percent data may be output on punched cards. For CAHN data use variable WT3 on Control Card One to select for this option. For LST data equip LUN 44 to PUN.

8. Plots of the cumulative curve and the frequency curve overlying each other may be requested using variable IPLOT on Control Card One.

9. The high and low phi values of the distribution and the increment between digitizing points may be changed for each data set using variables LOPHI, HIPHI, and DELPHI on Control Card Three. The program assumes that the increment between the data points within a data set is constant. Default values are 4 to 9 phi at 0.1 phi increments (51 data points) for CAHN data and 2 to 4 phi at 0.05 phi increments (41 data points) for LST data.

10. The vertical scale of the plotted frequency curve is in weight percent of the size fraction analyzed per digitizing unit. The magnitude of these scale units is controlled in part by variable TOTLSILT.

If percentages based on the total sample are desired, set TOTLSILT equal to the percent silt in the bulk sediment. If percentages based on the silt fraction only are desired, set TOTLSILT equal to 100. The vertical axes of the cumulative curves are scaled from 0 to 100 percent.

II. The vertical scale of the frequency curve may be adjusted so that maximum height will occur at full plot scale (6 inches). Use variable ICHOOSE to select this option. Alternatively, the frequency percent at full scale may be specified using variables ICHOOSE and HISCALE.

Deck makeup for batch jobs: (For 0S-3 operating system at OSU)

Cover Card

$^{7}_{8}$JOB, XXXXXX, BBB, NAME

$^{7}_{8}$TIME=100

$^{7}_{8}$LABEL, 62/<NAME> must be present whether or not punched option is requested

$^{7}_{8}$EQUIP, 44=<FILE NAME> for output of LST data only. May also be equipped to punch (44=PUN). For Cahn data equip to NULL

$^{7}_{8}$LOAD, *SIZEBAL, *SMOOTH, L=*GLIB Note: the name of file containing an alternative differentiating routine may be substituted for *SMOOTH

RUN
    data deck

$^{7}_{8}$LOGOFF

Data deck makeup:
    Control Card A
    Control Card one
    Control Card two
    Control Card three
    Data cards

Control Card one, Control Card two, Control Card three and Data cards: must be repeated for each data set.

Card description:

Control Card A

Cols.	Numonic	Format	Explanation
2-3	NJOBS	I2	Number of data sets
5-6	KONTROL	I2	00 - if parameters SS1, SS2, WT1, WT2, WT3 are to be read once for job. 01 - if parameters are to be read for each data set.
8-9	ITYPE	I2	00 - if data from large settling tube 01 - if data from CAHN
11-12	ISTATS	I2	01 - if requesting statistics routine 02 - to suppress statistics
13-20	TITL(Z)	A8	Default is <Heath> Name under which plot is labeled and saved at Computer Center.

Control Card one

Cols.	Numonic	Description
1-7	ACCNO	sample identification number
11-20	SS1	value of first smoothing factor in the cubic spline fitting subroutine (Punch decimal).
21-30	SS2	value of second smoothing factor (Punch decimal)
31-40	WT1	Controls use of smoothing average. See below (Punch decimal)
41-50	WT2	Controls use of smoothing average. See below (Punch decimal)

Control card one continued:

Cols.	Numonic	Description
51-60	WT3	If WT3=0.0, then final CAHN frequency distribution will not be punched. Any other real number will produce a punch-deck. (Punch decimal).
71-72	IPLOT	If blank, cumulative and frequency curves are plotted. If any other integer, then plots are suppressed (No decimal).

For CAHN data reduction:

if WT1 = 0.0, then SIZEBAL will skip 3-point moving average on the cumulative distribution.

if WT2 = 1.0, then SIZEBAL will skip 5-point moving average on the frequency distribution

For large settling tube reduction:

if WT1 = 0.0, then SIZEBAL will skip the 3-point moving average on the crude cumulative weight data.

if WT2 = 0.0, then SIZEBAL will skip the 3-point moving average on the frequency distribution

If KONTROL = 0, then only values for ACCNO and IPLOT are required on Control Card one after the first data set.

Control Card two

Cols.	Numonic	Format	Description
1-40	TITL(4, 5, 6, 7, 8)	5A8	Descriptive label for each plot. May be left blank

Control Card three (may be blank, see instructions regarding default values above).

1-10	LOWPHI	F10.0	Smallest phi value digitized (Punch decimal).
11-20	HIPHI	F10.0	Largest phi value digitized (Punch decimal).
21-30	DELPHI	F10.0	Phi digitizing increment (Punch decimal).
31-40	TOTLSILT	F10.0	Total area below the frequency curve. Default value is 100. (Punch decimal).
41-42	ICHOOSE	I2	If ICHOOSE=00 or is blank vertical scale of frequency curve is adjusted so maximum frequency occurs at full scale (6 in.). If ICHOOSE is any other two digit integer, frequency at full scale is read from HISCALE.
43-52	HISCALE	F10.0	Percentage value at full scale of frequency plot. Default value is 20 when ICHOOSE is not equal to 00 and HISCALE is blank.

Data Cards

1-8	SIZEBAL	A8	Job label (not required)
9-71	CONWT	7(X, F8.4)	Cumulative sample weights
72-78	ACCNO	A7	Data set label (not required)
79-80		A2	Card number (not required)

Program Listings:

The program listings for SIZEBAL and its subroutine can be found on the following pages:

PROGRAM LISTINGS

```
OS3 FORTRAN  VERSION 3.13

      PROGRAM SIZERAL
C
C     ROUTINE TO PROCESS SEDIMENT SIZE DISTRIBUTIONS.
C     ORIGIONAL VERSION WRITTEN BY G.R. HEATH, GRADUATE SCHOOL
C     OF OCEANOGRAPHY, UNIVERSITY OF RHODE ISLAND.
C
      COMMON ACCNO,HOLS,TITL(10),INPUT,IOUTPUT,CONWT(800),DY(300),
     1 CUMWTP(300),FREQP(300),X(300),A(300),B(300),C(300),D(300),
     2 XY(100),LOPHI,HIPHI,DELPHI,NPOINTS
      REAL LOPHI
      INTEGER HARDWARE
      CALL UNEQUIP(10)
      CALL UNEQUIP(20)
      IWARE=HARDWARE(61)-2
      IF(IWARE) GO TO 1
      CALL EQUIP(11,600)
      CALL EQUIP(20,610)
      GO TO 2
    1 CALL EQUIP(20,8HLP      )
    2 CONTINUE
      CALL EQUIP(10,8HPLOT    )
      CALL DATE (TITL( 9))
      CALL ARMYTIME (TITL(10))
      TITL(1) = 8HSAVE FOR
      DO 3 I = 3, 8
    3 TITL(I) = 8H
      IOUTPUT = 20
      INPUT=11
      READ (INPUT,8) NJOBS,KONTROL,ITYPE,ISTATS,TITL(2)
    8 FORMAT(4(X,I2),A8)
      IF(TITL(2).EQ.8H        )TITL(2)=8H HEATH
      IF(IWARE)WRITE(20,4000)TITL(2)
 4000 FORMAT(≠ SAVE FOR ≠,A8,≠ ...OCEANOGRAPHY...≠)
C     NJOBS AND KONTROL ARE USED TO CONTROL THE VALUES OF SMOOTHING
C      PARAMETERS AND THE PUNCH OPTION IN MULTIPLE BATCH RUNS.
C     NJOBS= NUMBER OF BATCHES OF DATA.
C     KONTROL= 0 IF THE VALUES OF THE SMOOTHING PARAMETERS AND
C      PUNCH OPTION ARE TO BE READ IN ONLY ONCE.
C     KONTROL= 1 IF THE VALUES ARE TO BE READ IN WITH EACH
C      SUBSEQUENT BATCH OF DATA.
C     ITYPE = 1 IF DATA IS FROM CAHN, OTHERWISE IT IS FROM
C      THE LARGE SETTLING TUBE(LST)
C     ISTATS = 1 IF REQUESTING THE STATISTICAL
C      SUBROUTINE
C
      CALL PLOTINT(6.,-6.,10)
      CALL PLOTSYMB(0.,0.,.21,TITL,0.,80)
      CALL PLOT(-6.,6.,-3)
      CALL ROTATEXY
      CALL PLOTINT(0.0,-26.0,10)
      KEEP=NJOBS
    9 READ(INPUT,10)ACCNO,SS1,SS2,WT1,WT2,WT3,IPLOT
     1 ,(TITL(I),I=4,8)
   10 FORMAT(A7,3X,5F10.0,9X,I2,/,5A8)
      READ(INPUT,17)LOPHI,HIPHI,DELPHI,TOTLSILT,ICHOOSE,HISCALE
   17 FORMAT(4F10.0,I2,F10.0)
C
C     SS1= SMOOTHING FACTOR FOR SPLINE CURVE FIT TO CONWT VALUES
C     SS2= SMOOTHING FACTOR FOR SPLINE CURVE FIT TO CUMWTP VALUES
C     WT1 = 0.0 WILL SKIP 3-POINT SMOOTHING OF THE CUMULATIVE DISTRIBUTION.
C     WT2 = 1.0 WILL SKIP 5-POINT SMOOTHING OF FREQUENCY DISTRIBUTION.
C     WT3= 0.0 WILL SKIP PUNCHOUT OF FREQUENCY DATA.
C     FOR LST REDUCTION
C      WT1 = 0.0  WILL SKIP 3 POINT SMOOTHING ON THE INPUT DATA
C      WT2 = 0.0  WILL SKIP THE 3 POINT SMOOTHING OF THE
C       FREQUENCY DISTRIBUTION
C      WT3  IS NOT USED
C  WHEN IPLOT=0, NORMAL PLOTTING OF CUMULATIVE AND FREQ.DISTRIBUTIONS
C  IS DONE.  WHEN IPLOT HAS ANY VALUE OTHER THAN ZERO, PLOTTING IS
C  OMITTED
C
C      ROUTINE TO RETAIN SS1,SS2,WT2,WT3 VALUES FOR MULTIPLE BATCHES
C
      IF(DELPHI.NE.0.0)GO TO 15
      IF(ITYPE.EQ.0)GO TO 16
      LOPHI = 4.0
      HIPHI = 9.0
      DELPHI = 0.1
      GO TO 15
   16 LOPHI = 2.0
```

```
      HIPHI = 4.0
      DELPHI = 0.05
   15 NPOINTS = IFIX((HIPHI - LOPHI)/DELPHI + 1.01)
      IF (KEEP .EQ. 1) GO TO 12
      IF (KONTROL .EQ. 1) GO TO 12
      IF (NJOBS .EQ. KEEP) GO TO 11
      SS1=TSS1
      SS2=TSS2
      WT1=TWT1
      WT2=TWT2
      WT3=TWT3
      GO TO 12
   11 TSS1=SS1
      TSS2=SS2
      TWT1=WT1
      TWT2=WT2
      TWT3=WT3
C
C     LINE PRINTOUT OF CONTROL CARD VARIABLES
C
   12 WRITE(IOUTPUT,4001)(TITL(I),I=3,8)
      WRITE(   44    ,4001)(TITL(I),I=3,8)
 4001 FORMAT(1H1,6A8)
      WRITE(IOUTPUT,13) ACCNO,SS1,SS2,WT1,WT2,WT3,NJOBS
      WRITE(    44   ,13) ACCNO,SS1,SS2,WT1,WT2,WT3,NJOBS
   13 FORMAT(1H0,≠ACCNO=≠,A7,2X,≠SS1=≠,F8.4,2X,≠SS2=≠,F8.4,2X,
     1≠WT1=≠,F8.4,2X,≠WT2=≠,F8.4,2X,≠WT3=≠,F8.4,2X,≠NJOBS=≠,I2)
      WRITE(IOUTPUT,4002)LOPHI,HIPHI,DELPHI,TOTLSILT,ICHOOSE,HISCALE
      WRITE(    44   ,4002)LOPHI,HIPHI,DELPHI,TOTLSILT,ICHOOSE,HISCALE
 4002 FORMAT(1H0, ≠LOW PHI =≠,F5.2,/,≠ HIGH PHI = ≠,F5.2,/
     1 ,≠ DELTA PHI = ≠,F5.3,//,≠ TOTLSILT = ≠,F6.2,/,≠ ICHOOSE = ≠
     2 ,I2,/,≠ HISCALE = ≠,F6.2)
C
C  .  CALL SUBROUTINES
      CALL RWTS(CONWT,INPUT,NPOINTS,IFLAG)
      IF(IFLAG.EQ.1) GO TO 9
      IF(ITYPE.EQ,1) GO TO 3003
      CALL LST(WT1,WT2,SS1,IPLOT)
      GO TO 3004
3003  CALL CAHN(SS1,WT1)
      CALL CALC(SS2,WT1,WT2,WT3,IPLOT,TOTLSILT,ICHOOSE,HISCALE,ITYPE)
3004  CONTINUE
      IF(ISTATS.EQ.1) CALL STATS(ITYPE)
C
C     REDUCE NJOBS BY ONE AND CHECK FOR ANOTHER BATCH.
      NJOBS=NJOBS-1
      IF (NJOBS .LT.1) GO TO 14
      GO TO 9
   14 CONTINUE
      CALL PLOT(10.,26.0,-3)
      END
```

```
      SUBROUTINE RWIS(CONWT,INPUT,NPOINTS,IFLAG)
      DIMENSION CONWT(800)
      COMMON ACCNO
      IFLAG=0
      READ(INPUT,3002)(CONWT(I),I=1,NPOINTS)
 3002 FORMAT(8X,7(X,F8.4))
      DO 3011 I=2,NPOINTS
      IF(CONWT(I).LT.CONWT(I-1)) GO TO 3200
3011  CONTINUE
      RETURN
3200  WRITE(20,3201)ACCNO
3201  FORMAT(≠0   HEY YOU GOOFED▼  ACCNO ≠,A8,≠ IS NOT IN ORDER.≠)
      IFLAG=1
      RETURN
      END
```

```
      SUBROUTINE CAHN(SS1,WT1)
      COMMON ACCNO,HOLS,TITL(10),INPUT,IOUTPUT,CONWT(800),DY(300),
     1 CUMWTP(300),FREQP(300),X(300),A(300),B(300),C(300),D(300),
     2 XX(100),LOPHI,HIPHI,DELPHI,NPOINTS
      REAL LOPHI
      DIMENSION CF(75)
      II=NPOINTS
      III = II - 1
      IV = II - 2
C
C     USES ACCUMULATED WEIGHT VALUES NORMALIZED TO ZERO (CONWT)
C     AND THE TRANSFORMED SETTLING TIME VALUES (XX) TO
C     CALCULATE CUMULATIVE WEIGHT PERCENT (CUMWTP) USING ODEN≠S FORMULA.
      P = LOPHI + DELPHI
      R=CONWT(1)
      CONWT(1) = 0.
      DY(1) = 1.
      X(1) = LOPHI
      XX(1) = 1.
      DO 615 K=2,II
      CONWT(K)=CONWT(K)-R
      DY(K) = 1.
      X(K)=P
      XX(K) = 4.**(P-4.)
  615 P=P+DELPHI
      SS=SS1
      CALL SMOOTH(II,XX,CONWT,DY,SS,A,B,C,D)
      DO 625 K=1,II
  625 CUMWTP(K) = CONWT(K) - (XX(K)-1.)*(B(K))
C
C     FORCES CUMWTP CURVE TO BE NON-DECREASING AND FORCES THE
C     LAST DATA POINT TO A STRAIGHT LINE WITH PRECEEDING TWO POINTS.
      DO 627 K=2,IV
      IF(CUMWTP(K).GT.CUMWTP(III))CUMWTP(K) = CUMWTP(III)
      IF(CUMWTP(K).LT.CUMWTP(1))CUMWTP(K) = CUMWTP(1)
      CMM = CUMWTP(K) - CUMWTP(K-1)
  627 IF(CMM.LT.0.0)CUMWTP(K) = CUMWTP(K-1)
      CUMWTP(II) = 2*CUMWTP(III) - CUMWTP(IV)
C
C     DOES A 3-POINT SMOOTH OF CUMWTP CURVE IF DESIRED.
      IF(WT1.EQ.0.) GO TO 633
      DO 631 K=2,III
  631 CF(K) = (CUMWTP(K-1)+2.*CUMWTP(K)+CUMWTP(K+1))/4.
      DO 632 K=2,III
  632 CUMWTP(K) = CF(K)
  633 RETURN
      END
```

```
      SUBROUTINE CALC(SS2,WT1,WT2.WT3,IPLOT.TOTLSILT,
     1 ICHOOSE,HISCALE,ITYPE)
      COMMON ACCNO,HOLS,TITL(10),INPUT,IOUTPUT,CONWT(800),DY(300),
     1 CUMWTP(300),FREQP(300),X(300),A(300),B(300),C(300),D(300),
     2 XY(100),LOPHI,HIPHI,DELPHI,NPOINTS
      REAL LOPHI, MATLUSED
      DIMENSION FC(75)
      ENCODE (8,2001,HOLS) SS2
 2001 FORMAT(≠ S=≠,F5.1)
      NN = NPOINTS
      NI = NN - 1
      NIT = NN - 2
      TS=0.1*TOTLSILT
      IF(TS.EQ.0.) TS = 10.
      FF = 0.
C
C     CALCULATES FREQUENCY DISTRIBUTION AS THE DERIVITIVE
C     OF THE CUMULATIVE CURVE.
      S=SS2
      CALL SMOOTH (NN,X,CUMWTP,DY,S,A,B,C,D)
      DO 2024 I=1,NN
      FREQP(I) = B(I)
      IF(FREQP(I).LT.0.) FREQP(I)=0.
 2024 CONTINUE
C
C     SMOOTHES FREQUENCY DISTRIBUTION WITH 5-POINT WEIGHTED
C     AVERAGE IF DESIRED.
      IF(WT2.EQ.1.) GO TO 2025
      FC(NI) = (FREQP(NII) + 2.*FREQP(NI))/3.
      FC(2)  = (2.*FREQP(2) + FREQP(3))/3.
      FF = FC(2) + FC(NI)
      DO 2027 K=3,NII
      FC(K)=(FREQP(K-2)+2.*FREQP(K-1)+3.*FREQP(K)+
     1       2.*FREQP(K+1)+FREQP(K+2))/9.
 2027 FF = FF + FC(K)
      DO 2028 K=2,NI
 2028 FREQP(K) = FC(K)/(FF*.001)
      CONTINUE
C
C     NORMALIZES FREQUENCY DISTRIBUTION TO 100 PERCENT
 2025 SUM=(0.05*FREQP(1))+(0.05*FREQP(NN))
      DO 2030 I=2.NI
 2030 SUM=SUM+0.1*FREQP(I)
      DO 2032 I=1,NN
 2032 FREQP(I)=TS*FREQP(I)/SUM
C
C     NORMALIZES CUMULATIVE DATA TO 100 PERCENT
      MATLUSED = CUMWTP(NN) * .1
      CUMWTP(1)    = 0.
      CUMWTP(NN)   = 100.
      DO 630 K=2,NI
      CUMWTP(K) = CUMWTP(K)/(MATLUSED*.1)
C
C     FORCES EACH POINT ON CUMULATIVE CURVE TO BE GREATER THAN
C     OR EQUAL TO THE PRECEEDING POINT.
      IF(CUMWTP(K).GT.100.) CUMWTP(K)=100.
      IF(CUMWTP(K).LT.0.)    CUMWTP(K) =    0.
      CM = CUMWTP(K) - CUMWTP(K-1)
  630 IF(CM.LT.0.) CUMWTP(K) = CUMWTP(K-1)
C
C     PUNCHES OUT SMOOTHED FREQUENCY DISTRIBUTION IF DESIRED.
      IF(WT3.EQ.0.)GO TO 2020
      DO 2020 K=1,5
      JJ = K
      II=10*JJ - 9
      III = 10*JJ
      J = 10*K - 9
      WRITE(62,2021) (FREQP(I),I=II,III),ACCNO,K
 2020 CONTINUE
 2021 FORMAT (10F7.2,X,A7,I2)
C
C     OUTPUTS CURVES TO LINEPRINT AND PLOTTER.
      WRITE(IOUTPUT,1000)
 1000 FORMAT(1H1,18X,≠CUMWTP≠,5X,≠FREQUENCY≠,/,10X,≠PHI≠,5X,
     1 ≠DATA≠,5X,≠DISTRIBUTION≠)
      WRITE(IOUTPUT,1001)(X(K),CUMWTP(K),FREQP(K),K=1,NN)
 1001 FORMAT(10X,F3.1,5X,F5.1,6X,F7.2)
      ITYPE = 1
      IF (IPLOT .NE. 0) GO TO1002
      CALL GSPLOT(ITYPE,ICHOOSE,HISCALE)
 1002 RETURN
      END
```

```
      SUBROUTINE GSPLOT(ITYPE,ICH,HISC)
      COMMON ACCNO,HOLS,TITL(10),INPUT,IOUTPUT,COMWT(900),DY(300),
     1 CUMWTP(300),FREQP(300),X(300),A(300),B(300),C(300),D(300),
     2 XX(100),LOPHI,HIPHI,DELPHI,NPOINTS
      REAL LOPHI
      INTEGER COUNT
      DATA (COUNT=0)
C   X IS ARRAY OF X VALUES TO PLOT CUMWTP AND FREQP AGAINST
C   CUMWTP IS ARRAY OF Y VALUES
C   FREQP IS ARRAY OF Y VALUES
C   N IS THE DIMENSION OF X,CUMWTP, AND FREQP
      INTEGER  PENUP, PENDOWN, END
      COUNT = COUNT + 1
      PENDOWN = 2
      PENUP = 3
      END = -3
      N = NPOINTS
      ADJUST = LOPHI
      RLENGTH = (HIPHI-LOPHI)/0.5
      IF (ITYPE .EQ.1) ADJUST=4.0
      SCALER= 2.0
      IF (ICH.EQ.0.) GO TO 5
      AMAX=HISC
      IF (AMAX.EQ.0.) AMAX =20.
      GO TO 10
    5 AMAX=0.
      DO 10 I = 1,N
      IF (FREQP(I) .GT. AMAX) AMAX = FREQP(I)
10    CONTINUE
      REMEBER = RLENGTH
      IF(RR.GT,REMEBER)REMEBER = RR
      LENGTH = IFIX(RLENGTH)
      KCOUNT = MODF(COUNT,3)
      IF(KCOUNT.EQ.1)SHIFT = 0.0
      IF(KCOUNT.EQ.2)SHIFT = 9.0
      IF(KCOUNT.EQ.0)SHIFT = 18.0
      FSCALE = 6. / AMAX
      YFIRST = (AMAX - FLOAT (IFIX (AMAX))) * FSCALE
      YNEXT = ( 6. - YFIRST ) / FLOAT ( IFIX (AMAX))
      AMAX = FLOAT ( IFIX (AMAX))
      ENCODE (8,100,RTYSCALE) AMAX
  100 FORMAT (F8.2)
      CSCALE = 6. / CUMWTP(N)
      ENCODE(5,1000,RLOPHI)LOPHI
      ENCODE(5,1000,HHIPHI)HIPHI
      ENCODE(8,2000,DDELPHI)DELPHI
 1000 FORMAT(F5.2)
 2000 FORMAT(≠DEL=≠,F4.2)
      CALL PLOTSYMB(-.4,-.5+SHIFT,.21,RLOPHI,0.,8)
      CALL PLOTSYMB(RLENGTH/2.,-.5+SHIFT,.21,DDELPHT,0.,8)
      CALL PLOTSYMB(RLENGTH-.4,-.5+SHIFT,.21,HHIPHI,0.,8)
      CALL PLOTSYMB (0.,-1.0+SHIFT,.21,ACCNO,0.,16)
      CALL PLOTSYMB(4.,-1.0+SHIFT,.21,TITL(4),0.,40)
      CALL PLOT (0.,SHIFT,PENUP)
      DO 15 I = 1,5
      YINCRE = I + SHIFT
      CALL PLOT (0.,YINCRE,PENDOWN)
      CALL PLOT (-.05,YINCRE,PENDOWN)
      CALL PLOT (.05,YINCRE,PENDOWN)
   15 CALL PLOT (0.,YINCRE,PENDOWN)
      CALL PLOT (0.,6.0+SHIFT,PENDOWN)
      CALL PLOT (RLENGTH,6.0+SHIFT,PENDOWN)
      Y = 6. - YFIRST + SHIFT
      CALL PLOT (RLENGTH,Y,PENDOWN)
      CALL PLOT (RLENGTH-.05,Y,PENDOWN)
      CALL PLOT (RLENGTH+.05,Y,PENDOWN)
      CALL PLOTSYMB (RLENGTH,Y,.21,RTYSCALE,0.,8)
      CALL PLOT (RLENGTH+.05,Y,PENUP)
      CALL PLOT (RLENGTH,Y,PENDOWN)
      J = AMAX - 1
      DO 16 I = 1,J
      YNOW = Y - YNEXT * I
      CALL PLOT (RLENGTH,YNOW,PENDOWN)
      CALL PLOT (RLENGTH-.05,YNOW,PENDOWN)
      CALL PLOT (RLENGTH+.05,YNOW,PENDOWN)
   16 CALL PLOT (RLENGTH,YNOW,PENDOWN)
      CALL PLOT (RLENGTH,0.+SHIFT,PENDOWN)
      CALL PLOT(FLOAT(LENGTH),.0+SHIFT,PENDOWN)
      CALL PLOT(FLOAT(LENGTH),0.05+SHIFT,PENDOWN)
      CALL PLOT(FLOAT(LENGTH),-.05+SHIFT,PENDOWN)
```

```
          CALL PLOT(FLOAT(LENGTH),0.0+SHIFT,PENDOWN)
          DO 17 I = 1,LENGTH
          XINCRE = LENGTH - I
          CALL PLOT (XINCRE,0.+SHIFT,PENDOWN)
          CALL PLOT (XINCRE,-.05+SHIFT,PENDOWN)
          CALL PLOT (XINCRE,.05+SHIFT,PENDOWN)
       17 CALL PLOT (XINCRE,0.+SHIFT,PENDOWN)
          CALL PLOT (0.,0.+SHIFT,PENDOWN)
          CALL PLOT (SCALER*(X(1)-ADJUST),CUMWTP(1)*CSCALE+SHIFT,PENUP)
          DO 20 I=2,N
 20       CALL PLOT(SCALER*(X(I)-ADJUST),CUMWTP(I)*CSCALE+SHIFT,PENDOWN)
          CALL PLOT(SCALER*(X(N-1)-ADJUST),FREQP(N-1)*FSCALE+SHIFT,PENUP)
          DO 30 I=3,N
          J = N - I + 1
 30       CALL PLOT (SCALER*(X(J)-ADJUST),FREQP(J)*FSCALE+SHIFT,PENDOWN)
          IF(KCOUNT.NE.0)GO TO 40
          CALL PLOT(0.0,0.0,END)
          CALL PLOTINT(REMEBER+5.0,0.0,10)
          RR = 0.0
          RETURN
       40 RR = REMEBER
          RETURN
          END
```

```
      SUBROUTINE STATS(ITYPE)
      COMMON ACCNO,HOLS,TITL(10),INPUT,IOUTPUT,CONWT(300),DY(300),
     2 CUMWTP(300),FREQP(300),X(300),A(300),B(300),C(300),D(300),
     3 XY(100),LOPHI,HIPHI,DELPHI,NPOINTS
      REAL LOPHI
      REAL MEANI,MEDI,KURTI,KURTF,MEANF
C
C   THIS SUBROUTINE CALCULATES INMAN, MOMENT AND FOLKS WARD STATISTICS
C
C   CAHN OR LST DATA  ITYPE=1 FOR CAHN
      PHISTART = LOPHI
      P = DELPHI
      N = NPOINTS
      FF = 0.0
      DO 2030 JJ = 1, N
 2030 FF = FF + FREQP(JJ)
      DO 2040 I=1,N
      R=5.-CUMWTP(I)
      IF(R.LT.0.) GO TO 2042
      H=R
 2040  M=I
 2042  P5=P*H/(H-R)+X(M)
       DO 2045 I=M,N
       R=16.-CUMWTP(I)
       IF(R.LT.0) GO TO 2047
       H=R
 2045  MM=I
 2047  P16=P*H/(H-R)+X(MM)
        DO 2050 I=MM,N
        R=25.-CUMWTP(I)
        IF(R.LT.0.) GO TO 2052
        H=R
 2050    M=I
 2052   P25=P*H/(H-R)+X(M)
        DO 2055 I=M,N
        R=50.-CUMWTP(I)
        IF(R.LT.0.) GO TO 2057
        H=R
 2055   MM=I
 2057   P50=P*H/(H-R)+X(MM)
        DO 2060 I=MM,N
        R=75.-CUMWTP(I)
        IF(R.LT.0.) GO TO 2062
        H=R
 2060   M=I
 2062   P75=P*H/(H-R)+X(M)
        DO 2065 I=M,N
        R=84.-CUMWTP(I)
        IF(R.LT.0.) GO TO 2067
         H=R
 2065   MM=I
 2067   P84=P*H/(H-R)+X(MM)
        DO 2070 I=MM,N
        R=95.-CUMWTP(I)
        IF(R.LT.0.) GO TO 2072
        H=R
 2070   M=I
 2072   P95=P*H/(H-R)+X(M)
C
C
C      INMAN STATISTICS
        MEANI=0.5*(P16+P84)
        MEDI=P50
        DEVI=0.5*(P84-P16)
        SKEWI=(MEANI-MEDI)/DEVI
        SK2I=(0.5*(P5+P95)-MEDI)/MEDI
        KURTI=(0.5*(P95-P5)-DEVI)/DEVI
C     FOLK AND WARD STATISTICS
        QDEV=0.5*(P75-P25)
        MEANF=(P16+P50+P84)/3.
        SORTF=(P84-P16)/4.+(P95-P5)/6.6
        SKEWF=(P16+P84-2.*P50)/(2.*(P84-P16))+(P5+P95-2.*P50)/(2.*
       2      (P95-P5))
        KURTF=(P95-P5)/(2.44*(P75-P25))
C
C     MOMENT STATISTICS
C
         XM1=XM2=XM3=XM4=0.0
         IF (PHISTART.LT.0.0) GO TO 20
         Q=PHISTART
```

```
          DO 10 I=1,N
          XM1=XM1+Q*FREQP(I)/FF
       10 Q=Q+P
          XMEAN=XM1
          GO TO 30
       20 Q=PHISTART+ABS(PHISTART)
          DO 25 I=1,N
          XM1=XM1+Q*FREQP(I)/FF
       25 Q=Q+P
          XMEAN=XM1-ABS(PHISTART)
       30 Q=PHISTART
          DO 40 I=1,N
          QM=Q-XMEAN
          XM2=XM2+QM*QM*FREQP(I)
          XM3=XM3+(QM**3)*FREQP(I)
          XM4=XM4+(QM**4)*FREQP(I)
       40 Q=Q+P
          XSTDEV=SQRT(XM2/FF)
          XSKEW=XM3/(FF*XSTDEV**3)
          XKURT=XM4/(FF*XSTDEV**4)
          WRITE(IOUTPUT,2002)ACCNO
     2002 FORMAT(1H1,80X,≠ ACCESSION NUMBER  ≠,A7//)
          WRITE(IOUTPUT,2003)XMEAN,XSTDEV,XSKEW,XKURT
     2003 FORMAT(≠ MOMENT STATISTICS ....MEAN ≠,F6.3,4X,≠ STANDARD ≠
         2≠DEVIATION ≠,F6.3,≠      SKEWNESS ≠,F6.3,≠       KURTOSIS ≠,
         3 F6.3)
          WRITE(TOUTPUT,2004)MEDI,MEANI,DEVI,SKEWI,SK2I,KURTI

          WRITE(TOUTPUT,2005)QDEV
     2004 FORMAT(≠0 INMAN STATISTICS ..... MEDIAN ≠,F6.3,11X,≠MEAN ≠,
         2 F6.3,8X,≠ DEVIATION ≠,F6.3,/,24X,≠SKEWNESS ≠,F6.3,10X,
         3 ≠SECOND SKEWNESS ≠,F6.3,8X,≠ KURTOSIS≠,F6.3)
     2005 FORMAT(≠0 PHI QUARTILE DEVIATION ≠,F6.3,X)
          WRITE(IOUTPUT,2006)MEANF,SORTF,SKEWF,KURTF
     2006 FORMAT(≠0 FOLK AND WARD STATISTICS .... MEAN ≠,F6.3,12X,
         2 ≠ SORTING ≠,F6.3,/,26X,≠ SKEWNESS ≠,F6.3,11X,≠ KURTOSIS ≠,F6.3)
          RETURN
          END
```

```
      SUBROUTINE LST(WT1,WT2,SS1,IPLOT)
      COMMON ACCNO,HOLS,TITL(10),INPUT,IOUTPUT,CONWT(300),DY(300)
     1, CUMWTP(300),FREQP(300),X(300),A(300),B(300),C(300),D(300),
     2  XX(100),LOPHI,HIPHI,DELPHI,NPOINTS
      REAL LOPHI
      DIMENSION CF(100),FREQ(100),FK(100)
C
C     THIS SUBROUTINE TAKES NPOINTS DATA POINTS AT 0.05 PHI STEPS FROM
C     2.0 PHI TO 4.0 PHI, SPLINE FITS THE DATA AND YIELDS A
C     SMOOTHED DERIVATIVE , THEN PLOTS THE FUNCTION
C
C     GENERATE X VALUES FOR SMOOTH CALL 2 TO 4 PHI BY .05
C     GENERATE CONFIDENCE LIMITS ABOUT EACH DATA POINT, DY(I)
C
      R = CONWT(1)
      CONWT(1) = 0.0
      X(1)=LOPHI
      NN = NPOINTS - 1
      DY(1)=1.0
      ENCODE(9,2001,HOLS)SS1
 2001 FORMAT(≠ S=≠,F5.1)
      DO 710 K=2,NPOINTS
      CONWT(K) = CONWT(K) - R
      DY(K)=1.0
710   X(K)=X(K-1)+0.05
C     NORMALIZE ALL DATA TO CONWT(NPOINTS)
      DO 720 J=1,NPOINTS
      CUMWTP(J)=CONWT(J)/CONWT(NPOINTS)*100.
  720 CONWT(J) = CONWT(J) + R
C      3 POINT SMOOTHING IF DESIRED
      IF(WT1.EQ.0.) GO TO 730
      DO 721 K=2,NN
721   CF(K)=(CUMWTP(K-1)+2.*CUMWTP(K)+CUMWTP(K+1))/4.
      DO 722 K=2,NN
722   CUMWTP(K)=CF(K)
C     CALL SMOOTH FOR SPLINE FIT PARAMETERS
730   CALL SMOOTH(NPOINTS,X,CUMWTP,DY,SS1,A,B,C,D)
C     ERROR CHECK   B.LT.0.0
      DO 731 I=1,NPOINTS
      FREQ(I)=B(I)
731   IF(FREQ(I).LT.0.0)FREQ(I)=0.0
C      3 POINT SMOOTHING ON FREQUENCY DISTRIBUTION IF DESIRED
      IF(WT2.EQ.0.0) GO TO 734
      DO 732 I=2,NN
732   FK(I)=(FREQ(I-1)+2*FREQ(I)+FREQ(I+1))/4.0
      DO 733 I=2,NN
733   FREQP(I)=FK(I)
      FREQP(1)=FREQ(1)
      FREQP(NPOINTS)=FREQ(NPOINTS)
      GO TO 735
734   DO 736 I=1,NPOINTS
736   FREQP(I)=FREQ(I)
735   CONTINUE
      WRITE(IOUTPUT,780)
      WRITE(44      ,780)
780   FORMAT( 18X,≠CRUDE≠,5X,≠CUMULATIVE≠,5X,≠FREQUENCY≠,/,10X,≠PHI≠,5X,
     2 ≠DATA≠,6X,≠PERCENTAGE≠,4X,≠DISTRIBUTION≠)
       WRITE(IOUTPUT,781)(X(K),CONWT(K),CUMWTP(K),FREQP(K),K=1,
     1 NPOINTS)
       WRITE( 44      ,781)(X(K),CONWT(K),CUMWTP(K),FREQP(K),K=1,
     1 NPOINTS)
  781 FORMAT(8X,F5.2,5X,F5.1,6X,F7.2,6X,F7.2)
      ITYPE = 0
       IF (IPLOT .NE. 0) GO TO 900
      CALL GSPLOT(ITYPE)
900   RETURN
      END
```

```
      SUBROUTINE SMOOTH(N,X,Y,DY,S,A,B,C,D)
      DIMENSION X(250),Y(250),DY(250),A(250),B(250),C(250),D(250)
C
C     ROUTINE TO SMOOTH A SERIES OF DISCRETE POINTS AND INTERPOLATE
C     BETWEEN THEM BY MEANS OF A CUBIC SPLINE FUNCTION.   THE COMP-
C     ONENTS OF ARRAY X MUST BE STRICTLY INCREASING.    S IS A NON-
C     NEGATIVE PARAMETER WHICH CONTROLS THE EXTENT OF SMOOTHING.
C     DY IS AN ESTIMATE OF THE ERROR OF Y AT EACH POINT.
C
      DIMENSION  R(250),R1(250),R2(250),T(250),T1(250),U(250),
     *V(250),SR(250),SR1(250),SR2(250),ST(250),ST1(250),SU(250),
     *SV(250)
      EQUIVALENCE (R(1), SR(2)), (R1(1), SR1(2)), (R2(1), SR2(2))
      EQUIVALENCE (T(1), ST(2)), (T1(1), ST1(2)), (U(1), SU(2))
      EQUIVALENCE ( V( 1), SV(2) )
              LIMTT =250
              N1 = 1
      N2=N
      IF ( N2 .GT. LIMIT )  GO TO199
      M1 = N1 - 1
      M2 = N2 + 1
     0R( M1 ) = R( N1 ) = R1( N2 ) = R2( N2 ) = R2( M2 ) = U( M1 ) =
     1 U(N1)=U(N2)=U(M2)=P=0.
      M1 = N1 + 1
      M2 = N2 - 1
      H = X(M1 ) - X( N1 )
      F =(Y( M1) - Y( N1 )) /  H
      DO 10 I = M1, M2
      G = H
      H = X ( I + 1 ) - X( I )
      E = F
      F = (Y(I+1) - Y(I)) / H
      A(I) = F - E
      T(I) = 2. * (G + H) / 3.
      T1(I) = H / 3.
      R2(I) = DY (I - 1 ) / G
      R(I) = DY ( I + 1 ) / H
      R1( I ) = - DY (I) / G - DY (I) / H
   10 CONTINUE
      DO 20 I = M1, M2
      B(I) = R(I)* R(I) + R1(I)*R1(I) + R2(I)*R2(I)
      C(I) = R(I)*R1(I+1)+R1(I)*R2(I+1)
      D(I) = R(I)*R2(I+2)
   20 CONTINUE
      F2 = -S
C     NEXT ITERATION.
   21 DO 30 I = M1, M2
      R1(I-1) = F*R(I-1)
      R2(I-2) = G*R(I-2)
      R(I) =1./(P*B(I)+T(I) - F* R1(I-1) - G* R2 (I-2))
      U(I) = A(I) - R1(I-1)* U(I-1) - R2(I-2) * U(I-2)
      F = P* C(I) + T1(I)- H*R1(I-1)
      G = H
      H = D(I) * P
   30 CONTINUE
      K=M1 + M2
      DO 40 J=M1, M2
      I=K - J
      U(I) = R(I) * U(I) - R1(I)* U(I+1) - R2(I) * U(I+2)
   40 CONTINUE
      E = H = 0.
      DO 50 I = N1, M2
      G=H
      H = (U(I+1) - U(I)) /(X(I+1) - X(I))
      V(I) = (H - G) * DY(I)* DY(I)
      E = E + V(I) * (H-G)
   50 CONTINUE
      G = V( N2 ) = - H* DY(N2) * DY(N2)
      E =  E - G * H
      G =  F2
      F2 = E*P*P
C     IF F2 NOT LESS S OR F2 NOT GREATER G THEN GO TO FIN.
      IF( F2.GE.S.OR.F2.LE.G) GO TO 99
C      FIN EQUALS 99.
      F = 0.
      H = (V(M1) - V(N1)) / (X(M1) - X(N1))
      DO 60 I = M1, M2
      G = H
      H = (V(I+1) - V(I)) / (X(I+1) - X(I))
      G = H - G - R1(I-1)* R(I-1)- R2(I-2)* R(I-2)
```

```
      E = E + G*R(I)*G
      R(I) = G
   60 CONTINUE
      H = E - P*F
C     IF H NOT GREATER 0  THEN GO TO FIN.
      IF (H) 99, 99, 61
   61 CONTINUE
      P = P + (S - F2) / (( SQRT(S/E) + P) * H)
C     GO TO NEXT ITERATION.
      GO TO 21
C      NEXT ITERATION EQUALS 21
C      USE NEGATIVE BRANCH OF SQUARE ROOT, IF THE SEQUENCE
C      OF ABSCISSAE X(I) IS STRICTLY DECREASING.
C     FIN
   99 CONTINUE
      DO 70 I = N1, N2
      A(I) = Y(I) - P* V(I)
      C(I) = U(I)
   70 CONTINUE
      DO 80 I = N1, M2
      H = X(I + 1) - X(I)
      D(I) = (C(I+1) - C(I)) / (3. * H)
      B(I) = (A(I+1) - A(I)) / H - ( H* D(I) + C(I)) * H
   80 CONTINUE
      RETURN
  199 CONTINUE
C     ERROR EXIT.
      PRINT 1000, N2
 1000 FORMAT ( 50H ERROR EXIT FROM SMOOTH. DIMENSION LIMIT EXCEEDED. ,/
     1,                         7H  N  =  , I5    )
      STOP
      END
```

*CSLOPE

```
       SUBROUTINE SMOOTH (N,X,Y,DY,SS,A,B,C,D)
      DIMENSION X(200),Y(200),DY(200),A(200),B(200),
     1 C(200),D(200)
      B(1)=(Y(2)-Y(1))/(X(2)-X(1))
      NN=N-1
      B(N)=(Y(N)-Y(NN))/(X(N)-X(NN))
      DO 2 I=2,NN
    2 B(I)=(Y(I+1)-Y(I-1))/(X(I+1)-X(I-1))
      RETURN
      END
```

*LSLOPE

```
      SUBROUTINE SMOOTH(N,X,Y,DY,SS,A,B,C,D)
      DIMENSION X(200),Y(200),DY(200),A(200),B(200),C(200),D(200)
      B(1)=0.0
      B(N)=0.0
      DO 2 I=2,N
    2 B(I)=(Y(I+1)-Y(I-1))/(X(I+1)-X(I-1))
      RETURN
      END
```

2.1.4. Discussion of some test runs

The effects of pre-treatment procedures of grain size analysis and the reproducibility and accuracy of the Cahn sedimentation system were studied using test runs of eight deep-sea sediment samples and four samples of ground analytical quartz (Table 2). Each quartz sample contained a narrow size range of particles which had been separated out by repeated settling and decantation. The sediments used were near-surface samples from cores taken from the Panama Basin. The techniques for sample preparation and sample runs described in sections 6.1.1-6.1.3 were used.

2.1.4.1. Reproducibility

Reproducibility was assessed by recovering and rerunning the same sample a number of times. The frequency curves of four to five natural samples could be reproduced well (Figure 2a). For others, variations in general shape, presence of peaks, relative heights of the peaks, and positions and shapes of the peaks may occur (Figure 2b). There seems to be no way to generalize or systematize the variations observed. On the other hand, the quartz samples show excellent reproducibility (Figure 2c). If we can assume that the quartz samples received no preferential treatment in analysis, then this high reproducibility suggests that the source of variability in the natural samples are actual variations in the settling velocity distribution of the sample rather than analytical sources.

The possible sources of variations are:

1. Flocculation and/or disaggregation of cohesive particles while settling or during storage prior to settling.
2. Changes in the shape and size of material during recovery or resuspension.
3. Dissolution of silica or carbonate.
4. Losses of material during recovery.

Varying the amount of smoothing by either multi-point moving averages or by the smoothing parameters in the cubic spline fit algorithm does not significantly change these results.

While it seems reasonable to expect that careful laboratory preparation and running of multiple splits of samples will on occasion produce closely comparable frequency distributions, it is impossible to anticipate to what extent, if any, the effects of flocculation of cohesive material, of mineral

Table 2 Samples used in test runs on CAHN sedimentation balance.

Accession No.	Core No.	Depth in Core cm	Number of Runs	
			H_2O_2 Pre-treatment	No Pre-treatment
POO9729	Y69-108 MGl	0-1	3	0
POO9730	Y69-108 MGl	5-6	3	0
POO9731	Y69-108 MGl	15-16	4	0
GOO9224	Y69-108 MGl	0-2	0	1
GOO9225	Y69-108 MGl	10-12	3	2
GOO9226	Y69-106 MGl	2-4	3	2
GOO9227	Y69-106 MGl	7-8	3	2
GOO9228	Y69-106 MG2	0-2	3	2

Quartz Mode	Phi Interval Decanted for	Number of runs
A	4.5 - 5.0	3
B	6.0 - 6.5	1
C	7.5 - 8.0	3
D	8.0 - 8.5	3
A, B, C	Combination	1
A, B, C, D	Combination	3

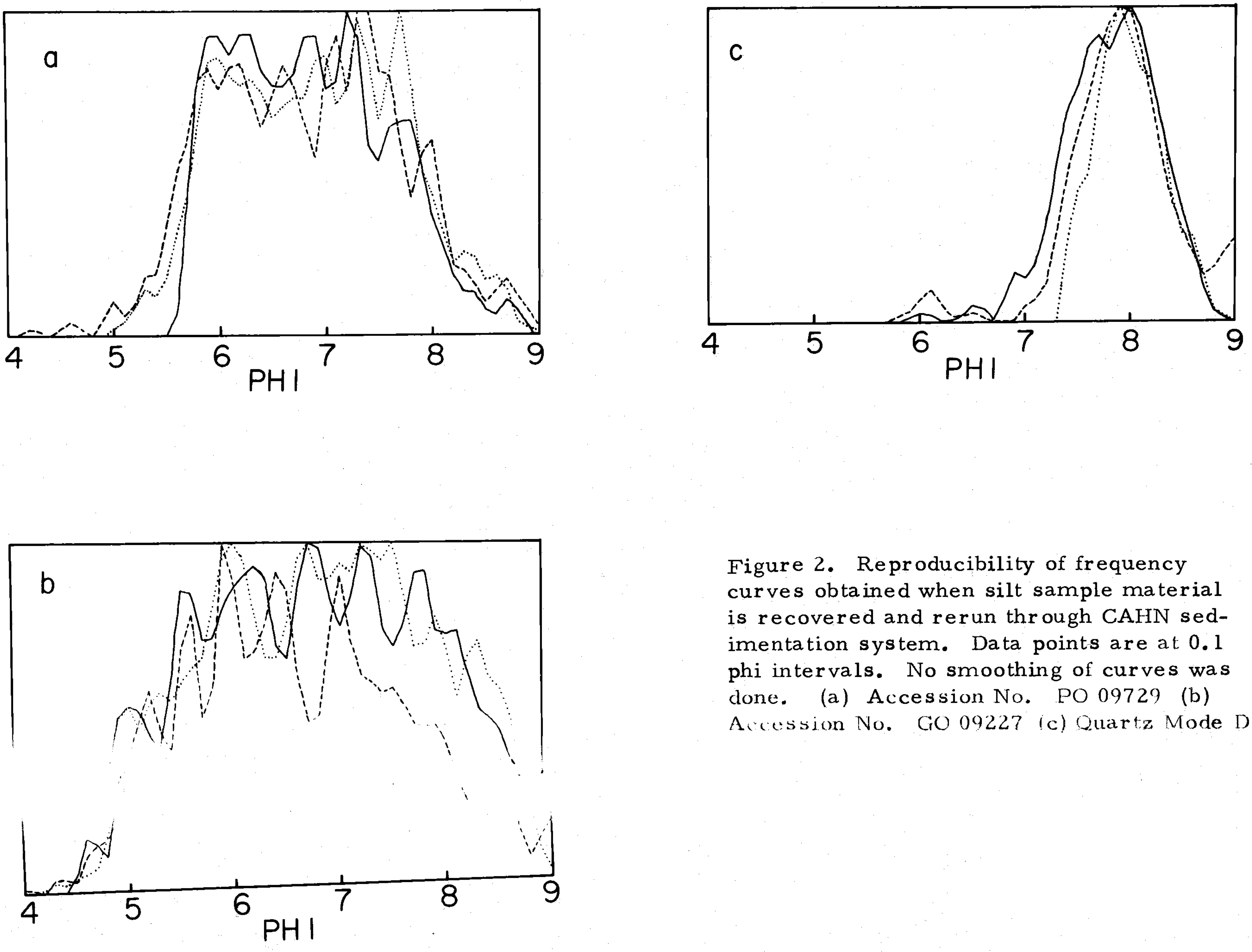


Figure 2. Reproducibility of frequency curves obtained when silt sample material is recovered and rerun through CAHN sedimentation system. Data points are at 0.1 phi intervals. No smoothing of curves was done. (a) Accession No. PO 09729 (b) Accession No. GO 09227 (c) Quartz Mode D

dissolution or precipitation, and of sample splitting have altered a given distribution. In light of this, it is unlikely that in the near future, the techniques of sedimentation analysis of silt sized deep-sea sediment on the CAHN will improve sufficiently that the graphical results can be used for purposes other than qualitative comparison.

This limitation might be overcome in future studies in one or more of three ways:

1) Flocculation effects might be reduced by running smaller samples and by truncating the size range studied at a coarser lower limit.
2) If the time required to digitize analog records could be reduced more runs of the same sample would be feasible and statistical comparisons of the curves might be possible.
3) The possibilities of quantitative comparison of broader portions of the curve might be pursued.

2.1.4.2. Smoothing

Raw data from natural and quartz sampes were run through SIZEBAL repeatedly to test the effects of moving multipoint smoothing averages and of the smoothing parameters in the cubic spline fitting routine on the shapes and positions of frequency curve models.

Use of the smoothing averages has the effect of removing small shoulder and tail peaks and of lowering the curve as a whole. The effects appeared in multiple as well as single mode runs (Figure 3).

Using the cubic spline fitting routine with the smoothing parameters equal to zero rather than the point-slope differentiating routine increases the roughness slightly, though no modes were moved, added or deleted. (Figure 4). The half-height width of the peaks are slightly reduced.

Increasing the values of smoothing parameters has the effect of moving coarse silt modes towards the fine end of the scale (Figure 4). At smoothing values recommended by the spline fit algorithm this displacement ranges from 0.2 to 0.5 phi units. Increasing the smoothing has the effect of filling in valleys in the curves and rounding the shoulders of peaks. Use of this routine to differentiate and smooth grain size curves is not recommended.

2.1.4.3. Pretreatment

Oxidation of organic matter with hydrogen peroxide treatment did not seem to effect the shape of the frequency curve in two out of four samples (Figure 5). In the other cases the variability among the pre-oxidation curves and among the post-oxidation curves precluded any comparison. The effects of organic matter removal are probably disaggregation of fecal pellets and

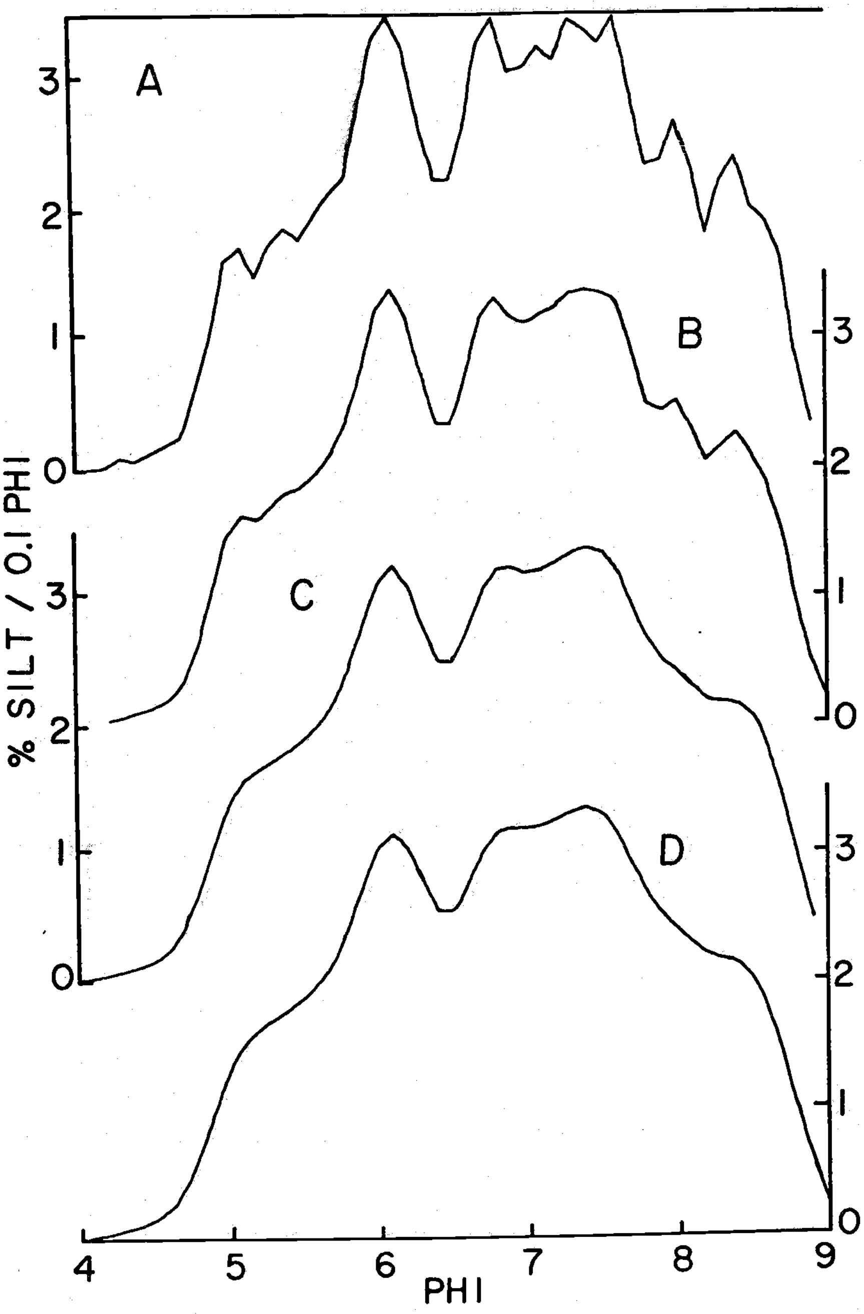


Figure 3. Effects of different smoothing functions on the frequency curves of one run of Accession No. GO 09227. Data points at tenth phi intervals. The frequency curves are attatched to the appropriate vertical scale.

a) No smoothing

b) 3-point moving average smooth of cumulative curve only.

c) 5-point moving average smooth of frequency curve only.

d) Both 3-point and 5-point moving averages used.

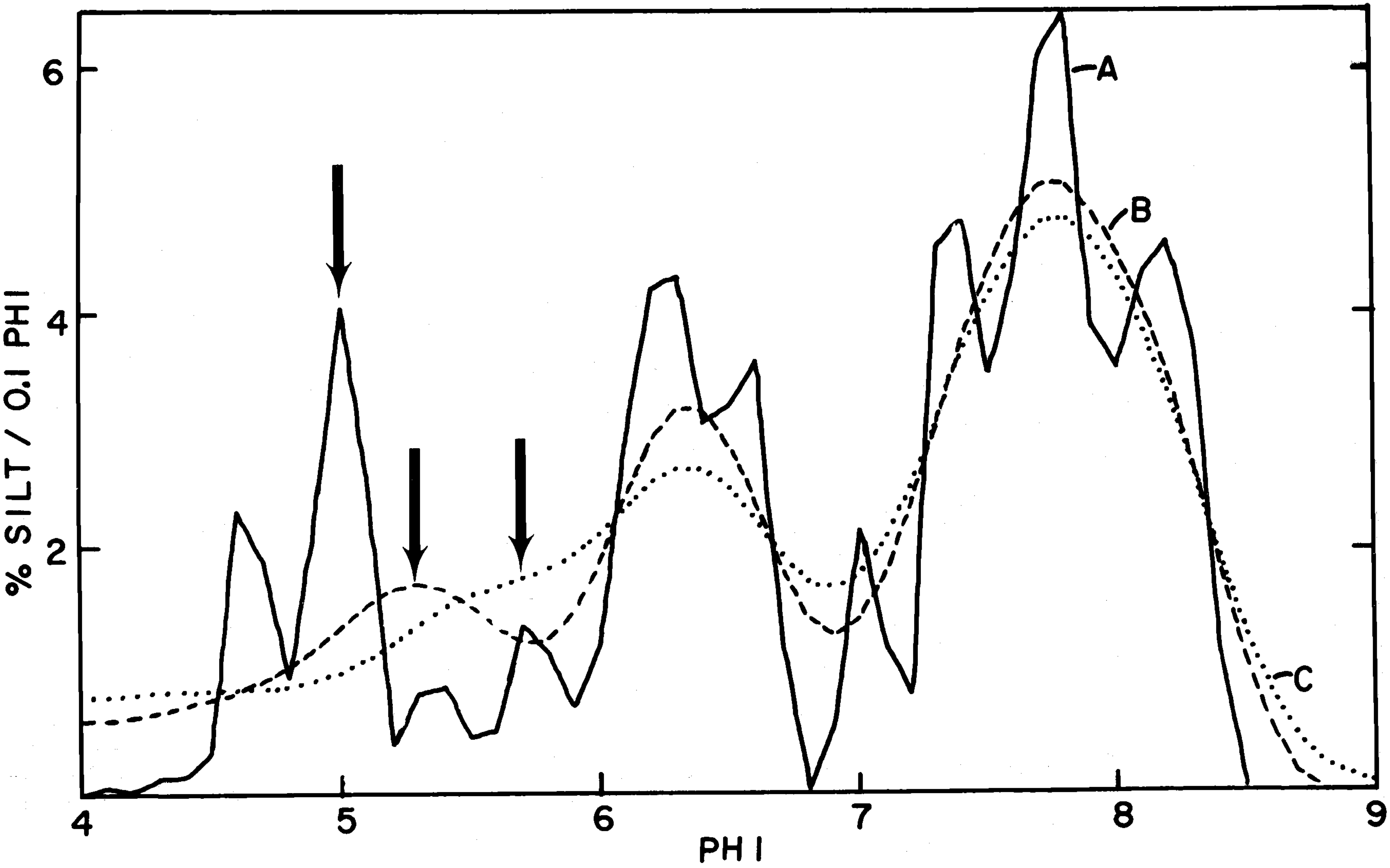


Figure 4. Effects of different values of the smoothing parameter S in the cubic spline fitting algorithm on the results of one run of Quartz Combination ABCD. Data points at tenth phi intervals. Vertical arrows show the displacement of the peak of the coarsest mode with the increase in smoothing parameter, S. a) S=0 b) S=5 c) S=10

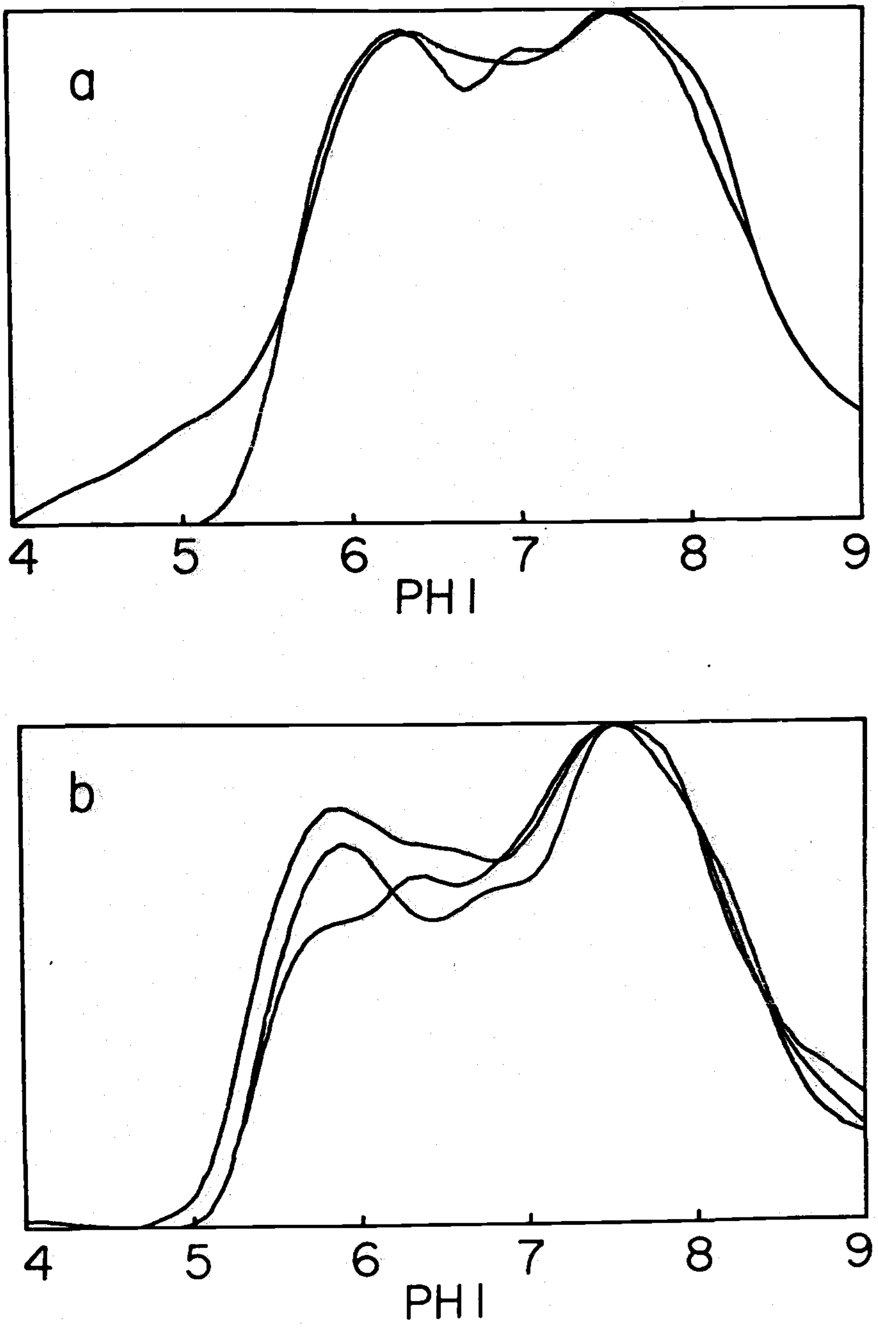


Figure 5. Effects of pretreatment of a natural sample (GO 09225) with hydrogen peroxide. Data points at tenth phi intervals; curves smoothed with both 3-point and 5-point moving averages.

a) Two runs of the same split with no organic material removed by H_2O_2 treatment.

b) Three runs of another split treated with H_2O_2.

unknown effects on the settling velocities of carbonate material and fragile silt-sized tests.

2.1.4.4. Accuracy

The accuracy of the CAHN analysis might best be tested by running through the system a series of samples containing particles which have been artificially manufactured out of material of known density to a known shape and then size graded. Sizes predicted from settling velocity measurements could then be compared with measured dimensions. This exercise might assess to what extent the principles and assumptions of Stokes'Equation are approached in the settling apparatus. Empirical corrections to the equation might be derived. To date such an ambitious experiment has not yet been undertaken.

In a smaller scale experiment the size of ground analytical grade quartz was measured in two ways. Subsamples of approximately one phi grain size width were obtained by repeated settling and decantation. Two fine silt sized subsamples were run through both the CAHN and a Coulter Counter. The Coulter Counter produces a voltage proportional to the volume of each particle; counts of particles within narrow volume limits can be made electronically and a volume distribution computed. When the output from both instruments is interpreted in terms of spherical quartz grains the frequency distributions are essentially identical (Figure 6). It can be inferred from this that the quartz grains have a high sphericity and that the effects of deviations from conditions of pure Stokes' settling are minor. Thus, for inert, spherical particles sedimentation analysis on the CAHN is a true predictor of grain size. Unfortunately, such particles only vaguely resemble those mixtures of cohesive and non-cohesive materials commonly found in marine sediments. More experimental work is needed to understand the true size properties of natural samples and their response in a settling tube.

2.2. Separation of size classes of silt-sized material for compositional studies

The separation of grain size classes within the silt range for composition studies has been mentioned in section 2.1.1.2. and can be done by decanting.

3. Analysis of coarse (> 0.063 mm diameter)sediment components

3.1. Instrumentation for size analysis and separation of size components

The analysis of the size distributions of material in the range of 2 mm to less than 63 microns in hydraulic diameter is performed by settling through a water filled column. This technique, although not new, has been

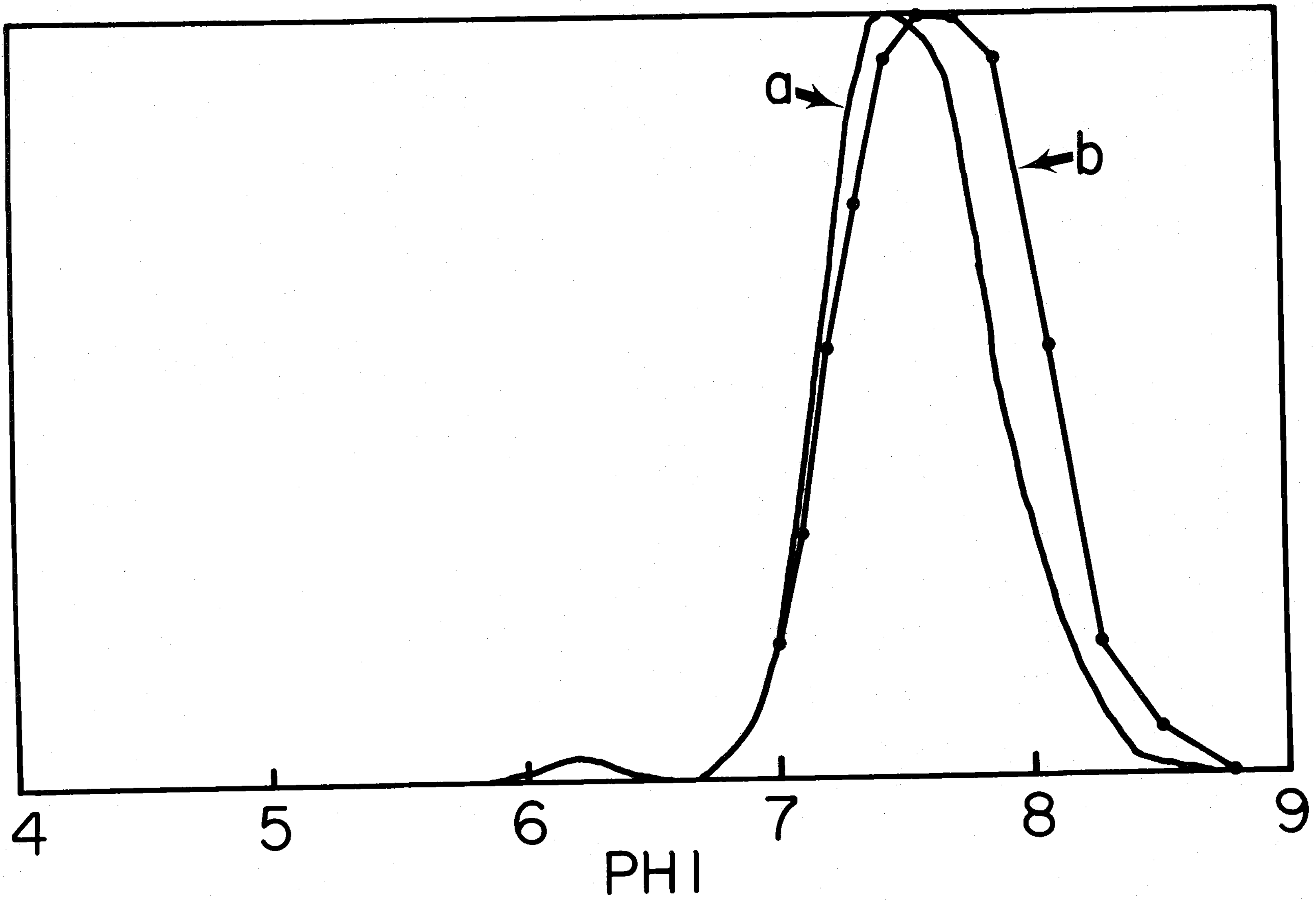


Figure 6. Frequency curves of Quartz Mode C produced by a) CAHN Sedimentation System and by b) Coulter Counter. Data points in CAHN frequency curves are at tenth phi intervals. Background noise from fluid in Coulter Counter runs was negligible. Data points in Coulter Counter frequency curves are the spherical equivalent diameters at the mid-points of the volume channels in which data was collected.

modified to reduce several sources of error and lower the amount of labor invested in each sample. The errors typically found in this technique are: 1) concentration effects, 2) wall effects, 3) time error in the introduction of the sample, 4) low mass resolution, and 5) inadequate definition of the size of the distribution due to wide digitizing intervals. The equipment was designed to minimize error contribution of each of these sources.

The analyzer consists of a polyvinylchloride tube 230 cm long with an inside diameter of 20 cm (Figure 7). It is supported by a wall mounted bracket at its top. The bottom 40 cm of the tube is removable and is interchangeable with the size separation unit described later. Attached to the upper mounting bracket is the semiconductor strain element and the sample introduction mechanism (Figures 8a and b). The sediment accumulation pan, fabricated from low density polyethylene, hangs from the semiconductor element by a length of cotton/dacron thread. The settling distance is approxiamtely 215 cm.

The sample introduction mechanism is mounted to a vertical shaft which allows it to rotate in the horizontal plane as well as to slide vertically. The holder may rest in one of three positions to facilitate sample loading. The sample is introduced by placing it on a removable pan and placing the inverted pan into the holder. The holder is later moved from the ready position into the run position where the holder settles on a pneumatic damper. As the holder reaches the end of its travel, the pan trips a micro-switch activating the digitizing equipment and immerses the sample in the water at the top of the column, releasing the sediment.

Size separation of individual modes in order to facilitate compositional examination is accomplished by interchanging the bottom portion of the settling tube and rerunning a split of the sample. The size fractionation unit (see Figures 9a and b) is designed to separate up to six size fractions during a single settling of a sample. The unit consists of six conical cups 64mm in diameter and 65mm high. An externally rotatable disk is used to occlude all but one of the sample cups during any selected time interval (corresponding to a particular size interval). Information on the modal distribution obtained from the cumulative weight versus settling velocity data are used to calculate a collection time window for each size fraction. At the completion of the size separation, a valve at the apex of each cup is opened and the individual size fractions are flushed into separate beakers for microscopical or chemical examination.

The digitizing system consists of a sampling rate programmer, an analog to digital converter and a high speed paper tape punch (Figure 6). The sample rate programmer has selectable digitizing rates from 400 samples per minute to one sample per minute. Additionally, the unit can be programmed to change its sampling rate after reaching a selected number

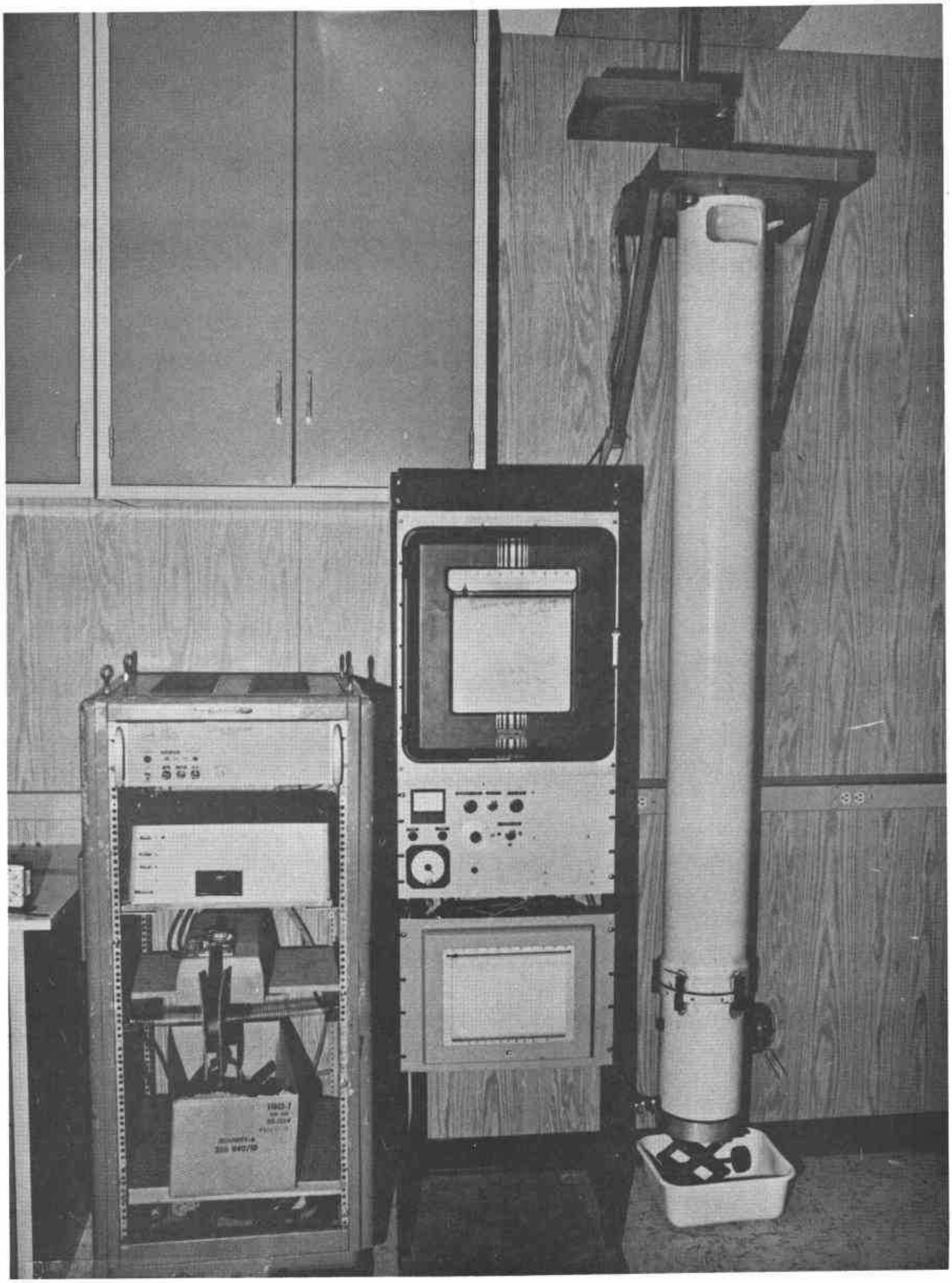


Figure 7. Large settling tube for size analysis and separation of size components of coarse grained sediment. Strip chart recorder and high speed paper tape punch are shown to the left of the 230 cm long and 20 cm wide settling tube (see section 7).

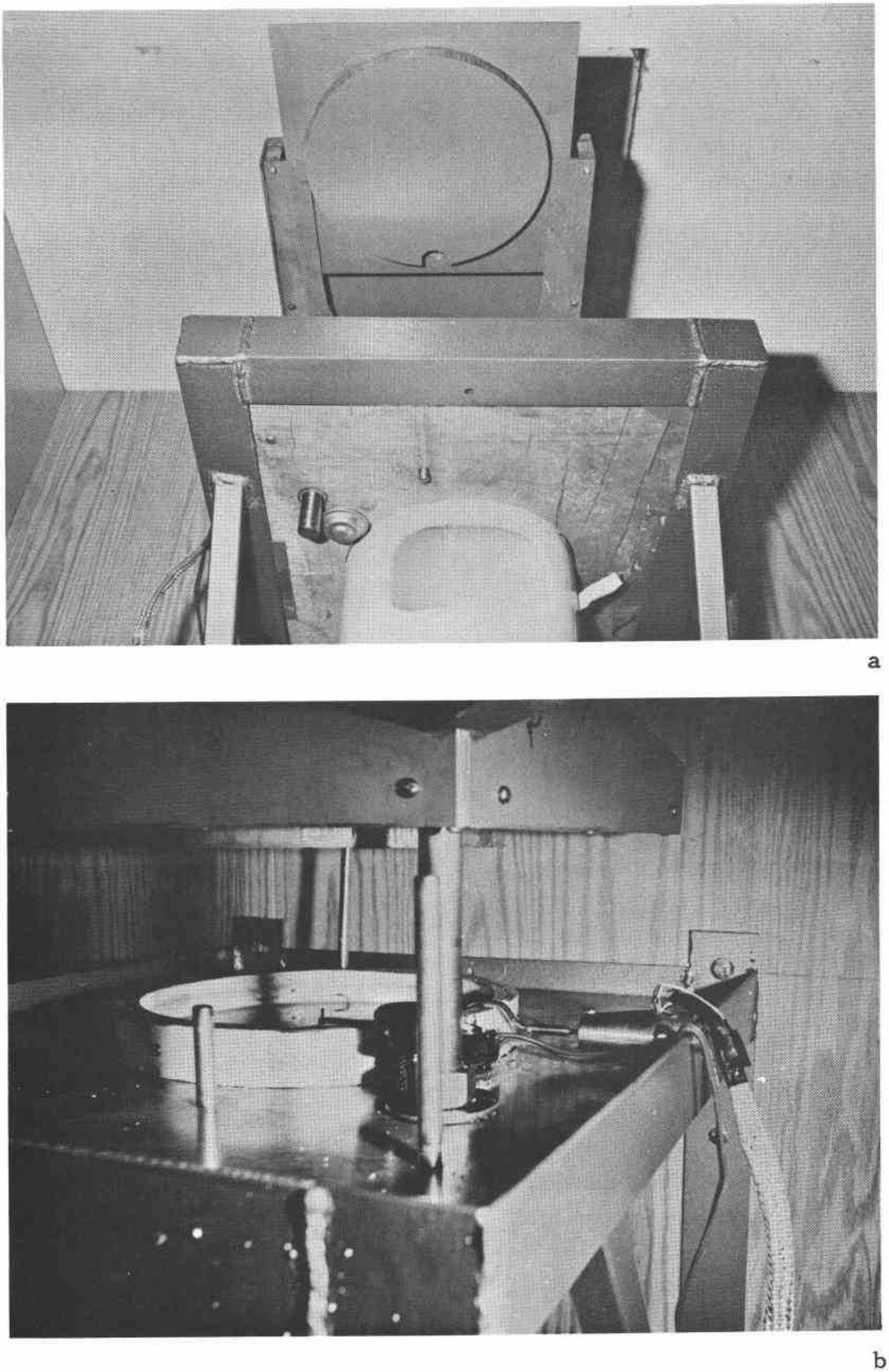
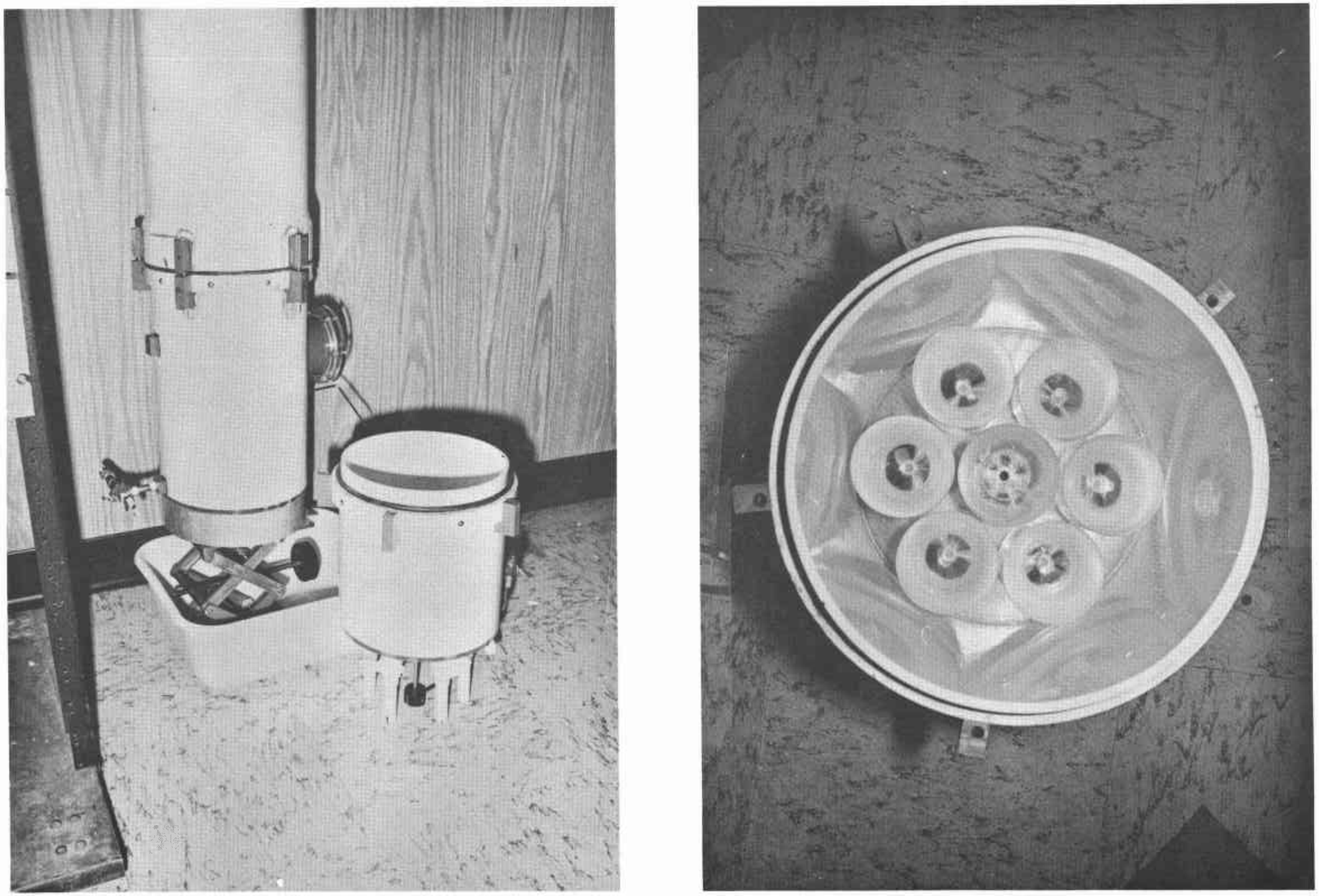


Figure 8. a and b. Top assemblies of large settling tube.



a

b

Figure 9. a. Details of bottom assemblies of large settling tube. The bottom assembly for size analyses is attached to the settling tube; the one for subsampling size classes is standing to its right.

b. View from above into 6 outlets to collect the various subsamples for compositional studies. The protecting disc which allows one to subsample has been removed.

of data points. The unit can be programmed for automatic shut-off after any predetermined number of data points up to a maximum of 47,000. The analog to digital conversion is 11 binary bits plus sign (2047 full scale). Currently, calibration yields 3.125 counts per milligram true weight on the pan. The system noise when referred to sample weight is 0.5 mg maximum deviation during a 10 minute period; however, this figure is dependent upon the building vibration level.

Many oceanic sediments with particles in the size range 63 mm to 2 mm contain material of biological origin. These biogenic particles include foraminifers, radiolarians and pelagic gastropods. Foraminifers and gastropods have internal cavities in their tests which retain air when placed directly in water. The technique described below is an attempt to wet the test cavity so that consistent mass estimates and settling velocities may be calculated. Tests not wetted internally tend to float on the surface of the column and fail to settle. Partially wetted tests settle much slower than their wetted counterparts and, hence, give broader distributions.

The sample is dried at 80°C for a period of 24 hours and a split of about 400 to 800 mg is placed in a 10 ml beaker. Approximately 5 ml of a reagent grade acetone is added and the sample placed into a vacuum desiccator which is then evacuated to 300 torr. The dessicator pressure is cycled every 30 seconds for a period of 3 minutes between ambient room pressure and 300 torr, after which time the remaining acetone is diluted with 3 to 4 ml reagent grade 95% ethanol and the pressure cycled as before. The supernatant is decanted, 5 ml of 2% aqueous solution of sodium hexametaphosphate is added and the pressure again cycled. The sample may be stored in this form in a closed container until the analysis can be run. Care must be exercised during the entire process not to allow the material to desiccate. Prior to placing the sample on the removable pan, excess fluid should be decanted. The sample pan's surface is moistened with a 10% aqueous solution of KODAK "PHOTOFLO." This treatment produces a surface tension sufficient to retain large particles while the pan is inverted prior to release into the column. Care must be taken to limit the amount of fluid present on the pan. Too much fluid may allow the sediment to drip off the pan while the pan is in inverted position.

3.2. Data reduction and presentation

3.2.1. Explanation of computer programs

The raw data output by the large settling tube consists of a sequence of integer numbers punched on to paper tape at varying time intervals. These numbers are proportional to the output voltage of the strain gauge, and hence are proportional to the weight of accumulated sediment on the collection pan at each given time. The FORTRAN program *GRAINSIZ processes this raw data for each sample, and produces the following types of final output (see Table 3).

Table 3 Example of data generated by the large settling tube system for size analyses of coarse (>0.063 mm diameter) components of pelagic sediments (compare Fig. 10).

```
SAVE FORCLAUSON                                              03/29/76  1311
TAPE 9  TAPE 8 ACCNO 007946
TEMP ISMOOTH W1 W2 W3 W4 W5 W6 WW1 WW2 WW3 IFPUNCH NOPLOTS
 22     3     1  2  3  5  9 12  1   2   4     0       0

           RAW DATA

   -1223   -1223   -1223   -1223   -1223   -1223   -1222   -1222   -1222   -1222
   -1222   -1222   -1221   -1221   -1221   -1221   -1221   -1220   -1213   -1219
 ~~-1221~~ -1213   -1219   -1216   -1213   -1216   -1215 ~~-1213~~ ~~-1221~~ -1214
   -1213 ~~-1213~~ -1212   -1212 ~~-1212~~ -1213   -1213   -1213   -1212   -1212
   -1212   -1211   -1212   -1212   -1211   -1212   -1211   -1211   -1211   -1211
   -1211   -1212   -1211   -1211   -1210   -1210   -1210   -1210   -1210   -1209
   -1209   -1209   -1208   -1209   -1208   -1208   -1208   -1208   -1207   -1206
   -1206   -1204   -1202   -1205   -1204   -1204   -1205   -1205   -1204   -1205
   -1204   -1204   -1204   -1203   -1201   -1200   -1200   -1196   -1132   -1190
   -1184   -1173   -1171   -1164   -1158   -1146   -1133   -1125   -1116   -1097
   -1092   -1071   -1059   -1035   -1020   -1001    -989    -971    -952    -934
    -929    -903    -854    -967    -873    -838    -821    -811    -796    -779
    -772    -754    -742    -729    -716    -709    -694    -681    -674    -666
    -655    -647    -637    -628    -620    -610    -601    -595    -538    -578
    -575    -569    -559    -555    -550    -543    -542    -537    -530    -532
    -525    -525    -517    -513    -507    -503    -499    -496    -493    -487
    -485    -483    -475    -473    -473    -468    -465    -476    -459    -458
    -456    -460    -451    -461    -444    -443    -440    -440    -438    -434
    -432    -471    -422    -426    -425    -424    -421    -419    -418    -417
    -415    -412    -410    -409    -405    -404    -399    -393    -356    -391
    -375    -359    -355    -359    -355    -351    -346    -342    -339    -336
    -332    -323    -325    -323    -319    -316    -313    -311    -308    -305
    -302    -293    -295    -293    -291    -289    -287    -284    -282    -280
    -277    -275    -273    -273    -271    -269    -267    -265    -263    -261
    -255    -253    -263    -254    -253    -252    -250    -249    -247    -245
    -244    -243    -242    -240    -239    -237    -237    -234    -233    -232
    -230    -223    -228    -226    -225    -223    -222    -221    -220    -219
    -217    -215    -215    -215    -214    -213    -213    -212    -210    -210
    -210    -203    -202    -207    -207    -205    -206    -205    -204    -202
    -202    -201    -193    -199    -197    -196    -195    -198    -193    -191
    -199    -190    -183    -188    -187    -187    -187    -186    -185    -153
    -182    -181    -180    -179    -177    -176    -174    -174    -172    -172
    -170    -169    -168    -167    -166    -165    -164    -163    -161    -160
    -159    -157    -156    -155    -153    -152    -152    -150    -149    -148
    -146    -145    -148    -143    -142    -141    -140    -139    -135    -137
    -135    -134    -134    -133    -132    -132    -134    -132    -127    -127
    -125    -126    -125    -125    -123    -122    -121    -120    -119    -118
    -113    -117    -117    -115    -114    -113    -112    -112    -111    -111
    -111    -110    -109    -108    -108    -106    -105    -104    -104    -103
    -103    -102    -101    -100     -99     -99     -98     -97     -96     -95
     -94     -94     -93     -92     -91     -90     -90     -89     -88     -87
     -87     -86     -85     -84     -83     -83     -82     -81     -79     -80
     -79     -79     -77     -77     -75     -75     -74     -77     -73     -72
     -72     -71     -70     -69     -68     -58     -67     -67     -66     -70
     -69     -68     -77     -63     -63     -61     -61     -61     -60     -59
     -59     -57     -57     -57     -56     -55     -55     -55     -54     -53
     -53     -52     -51     -50     -49     -49     -48     -48     -47     -47
     -46     -45     -45     -44     -43     -43     -42     -42     -41     -40
     -40     -40     -39     -38     -38     -37     -36     -35     -35     -35
     -34     -33     -32     -32     -30     -30     -29     -29     -28     -27
     -27     -26     -26     -25     -25     -24     -23     -23     -23     -22
     -21     -21     -20     -20     -20     -13     -19     -17     -18     -29
     -15     -15     -15     -14     -13     -12     -12     -12     -11     -11
     -10     -10      -9      -9      -8      -8      -7      -6      -6      -5
      -5      -4      -4      -4      -3      -3      -2      -3      -2      -2
      -1      -1       0       0       0       1       1       2       3       4
       4       5       5       6       6       5       6       6       7      12
      13      12      10       9       9       9      10      11      11      12
      12      12      13      13      13      13      13      14      15      15
      15      16      16      16      17      17      18      18      19      19
      20      20      20      21      21      21      22      22      22      23
      23      23      24      24      25      25      26      25      26      27
      27      28      28      28      29      29      30      30      30      30
      30      31      31      31      32      32      33      33      33      33
      34      34      34      34      35      36      35      36      37      37
      37      37      38      39      39      39      40      40      39      39
      40      40      41      41      42      41      42      42      42      43
      42      43      43      44      44      44      44      45      45      45
      45      46      45      46      46      47      47      47      48      49
      49      48      49      49      49      50      50      50      51      51
      52      52      53      53      53      53      54      54      54      55
      55      55      56      56      56      55      57      57      58      58
      58      58      58      58      59      59      59      60      60      61
      60      60      61      61      61      61      62      62      62      63
      63      63      63      63      63      64      64      64      65      65
      65      65      66      67      67      67      67      65      68      69
      69      68      69      69      70      70      70      70      70      71
      71      71      71      72      73      73      73      73      74      74
      74      74      75      75      75      75      76      75      75      75
      76      77      76      77      77      77      77      78      78      79
      79      79      79      79      80      80      81      80      81      81
      81      82      82      82      83      83      83      83      83      83
      84      84      84      84      85      85      85      86      85      85
      87      85      85      87      87      87      89      88      88      88
      89      89      89      90      90      89      91      90      91      91
      92      91      91      92      92      92
```

Table 3 continued

```
     SMOOTHED DATA

1223.*  1223.*  1223.*  1223.*  1223.*  1222.*  1222.*  1222.*  1222.*  1221.*
1221.*  1221.*  1221.*  1221.*  1220.*  1220.*  1220.*  1219.*  1218.*  1219.*
1219.*  1218.*  1217.*  1216.*  1215.*  1215.*  1215.*  1215.*  1215.*  1214.*
1214.*  1213.*  1213.*  1213.*  1213.*  1213.*  1212.*  1212.*  1212.*  1212.*
1211.*  1211.*  1211.*  1211.*  1211.*  1211.*  1211.*  1211.*  1211.*  1211.*
1211.*  1211.*  1211.*  1210.*  1210.*  1210.*  1210.*  1209.*  1209.*  1209.*
1209.*  1208.*  1208.*  1208.*  1208.*  1208.*  1207.*  1207.*  1206.*  1206.*
1205.*  1204.*  1204.*  1204.*  1204.*  1204.*  1204.*  1204.*  1204.*  1204.*
1204.*  1203.*  1203.*  1202.*  1200.*  1199.*  1197.*  1194.*  1191.*  1187.*
1182.*  1176.*  1169.*  1162.*  1153.*  1144.*  1133.*  1122.*  1110.*  1096.*
1082.*  1067.*  1051.*  1035.*  1018.*  1002.*  -986.3  -969.6  -952.5  -935.6
-919.0  -902.3  -885.5  -869.3  -853.7  -838.6  -823.3  -809.7  -795.7  -781.8
-768.4  -755.2  -742.2  -729.8  -718.1  -706.8  -695.5  -684.6  -674.8  -665.3
-655.2  -646.5  -637.5  -628.6  -619.8  -611.2  -603.2  -595.5  -589.1  -580.9
-574.4  -569.2  -561.9  -556.7  -551.3  -546.8  -542.2  -537.6  -533.4  -529.7
-525.9  -521.3  -517.3  -512.8  -508.2  -503.8  -499.8  -496.0  -492.1  -488.4
-484.8  -481.3  -477.9  -474.3  -472.2  -469.8  -468.0  -466.1  -463.2  -460.3
-458.2  -456.5  -454.2  -451.6  -448.1  -444.6  -441.9  -439.6  -437.3  -434.8
-432.7  -430.4  -428.8  -425.8  -425.0  -423.3  -421.4  -419.6  -417.9  -416.3
-414.3  -412.2  -410.0  -407.5  -404.5  -401.1  -396.9  -391.9  -386.4  -380.9
-375.5  -370.1  -364.9  -360.0  -355.4  -351.1  -346.9  -342.9  -339.2  -335.7
-332.2  -328.7  -325.5  -322.5  -319.4  -316.3  -313.4  -310.6  -307.8  -304.8
-301.9  -299.0  -296.2  -293.6  -291.2  -288.9  -286.6  -284.3  -282.1  -279.9
-277.9  -275.9  -274.1  -272.4  -270.7  -268.8  -267.0  -265.3  -263.7  -262.1
-260.8  -259.0  -258.0  -256.7  -254.3  -252.3  -250.6  -248.9  -247.1  -245.6
-244.2  -242.9  -241.5  -240.2  -238.9  -237.4  -236.1  -234.6  -233.1  -231.8
-230.7  -229.0  -227.6  -226.2  -224.8  -223.5  -222.2  -221.0  -219.9  -218.8
-217.6  -216.6  -215.8  -214.9  -214.1  -213.3  -212.5  -211.9  -211.3  -210.8
-210.5  -210.7  -210.7  -209.4  -207.9  -206.8  -205.9  -204.8  -203.6  -202.6
-201.5  -200.5  -199.4  -198.7  -197.3  -196.4  -195.6  -194.8  -193.4  -192.0
-190.8  -190.1  -189.1  -188.2  -187.5  -186.9  -186.3  -185.5  -184.4  -183.3
-182.1  -181.0  -179.9  -178.6  -177.3  -176.0  -174.7  -173.6  -172.5  -171.4
-170.3  -169.1  -168.1  -167.9  -166.0  -164.9  -163.8  -162.6  -161.3  -160.0
-158.7  -157.3  -156.1  -154.8  -153.5  -152.4  -151.3  -150.2  -149.1  -147.9
-146.8  -145.9  -145.0  -143.8  -142.4  -141.2  -140.1  -139.0  -137.9  -136.9
-135.8  -134.9  -134.1  -133.7  -132.5  -132.1  -131.5  -130.4  -128.9  -127.6
-126.7  -125.8  -125.0  -124.1  -123.1  -122.1  -121.1  -120.2  -119.3  -118.4
-117.7  -117.0  -116.1  -115.2  -114.2  -113.3  -112.5  -112.0  -111.4  -110.9
-110.4  -109.7  -108.9  -108.1  -107.3  -106.3  -105.4  -104.6  -103.9  -103.2
-102.5  -101.3  -101.0  -100.2   -99.4   -98.6   -97.8   -96.9   -96.1   -95.2
 -94.4   -93.6   -92.8   -92.0   -91.2   -90.4   -89.7   -88.9   -88.1   -87.3
 -86.6   -85.3   -85.0   -84.2   -83.4   -82.7   -81.9   -81.1   -80.4   -79.7
 -79.0   -78.3   -77.4   -76.5   -75.7   -74.9   -74.1   -73.4   -72.7   -72.1
 -71.3   -70.6   -69.9   -69.1   -68.5   -68.1   -67.7   -67.8   -68.0   -68.4
 -68.5   -68.5   -68.2   -66.1   -64.2   -62.7   -61.7   -60.8   -59.9   -59.2
 -58.5   -57.8   -57.2   -56.6   -56.0   -55.5   -55.0   -54.5   -53.9   -53.2
 -52.6   -51.9   -51.2   -50.2   -49.5   -48.9   -48.3   -47.7   -47.2   -46.6
 -46.0   -45.3   -44.7   -44.0   -43.4   -42.8   -42.2   -41.7   -41.1   -40.5
 -40.0   -39.5   -38.9   -38.2   -37.6   -36.9   -36.2   -35.5   -35.0   -34.4
 -33.9   -33.0   -32.2   -31.5   -30.7   -29.9   -29.3   -28.7   -28.0   -27.4
 -26.8   -26.3   -25.7   -25.2   -24.7   -24.1   -23.5   -23.0   -22.5   -22.0
 -21.4   -20.9   -20.4   -19.9   -19.7   -19.3   -18.9   -18.8   -19.3   -19.4
 -18.0   -16.5   -15.4   -14.5   -13.5   -12.6   -12.1   -11.7   -11.2   -10.7
 -10.2    -9.3    -9.2    -8.7    -8.2    -7.6    -7.0    -6.4    -5.8    -5.3
  -4.8    -4.4    -4.0    -3.7    -3.3    -2.9    -2.6    -2.4    -2.0    -1.7
  -1.2    -0.8    -0.4      .0      .4      .9     1.5     2.2     2.9     3.5
   4.1     4.6     5.1     5.5     5.9     6.3     6.9     7.5     8.6     9.9
  10.8    11.1    10.9    10.5    10.1    10.1    10.3    10.7    11.1    11.6
  11.9    12.3    12.6    12.8    13.1    13.3    13.6    14.1    14.5    14.9
  15.3    15.7    16.0    16.4    16.9    17.3    17.9    18.2    18.7    19.2
  19.6    20.0    20.3    20.7    21.0    21.3    21.7    22.0    22.3    22.7
  23.0    23.4    23.8    24.2    24.7    25.1    25.4    25.8    26.2    25.7
  27.2    27.6    28.0    28.4    28.8    29.2    29.5    29.9    30.2    30.5
  30.9    31.6    32.2    32.3    32.3    32.5    32.8    32.9    33.1    33.3
  33.7    34.0    34.2    34.6    35.0    35.5    35.9    36.2    36.6    36.9
  37.2    37.6    38.0    38.5    38.8    39.1    39.4    39.5    39.5    39.7
  40.0    40.3    40.7    41.0    41.3    41.5    41.8    42.0    42.2    42.5
  42.7    42.9    43.3    43.6    43.9    44.1    44.3    44.7    44.9    45.1
  45.3    45.7    45.9    46.1    46.4    46.8    47.1    47.5    47.9    48.4

  48.7    48.9    49.0    49.2    49.4    49.8    50.1    50.4    50.8    51.3
  51.7    52.1    52.5    52.9    53.1    53.4    53.7    54.1    54.4    54.9
  55.2    55.5    55.8    56.0    56.2    56.5    56.8    57.2    57.5    57.8
  57.9    58.1    58.2    58.4    58.8    59.0    59.3    59.7    60.0    60.2
  60.3    60.5    60.7    60.9    61.1    61.4    61.7    62.0    62.3    62.6
  62.8    62.9    63.1    63.2    63.4    63.7    64.0    64.3    64.7    65.0
  65.4    65.8    66.2    66.5    66.8    67.1    67.4    67.7    68.0    68.3
  68.6    68.9    69.1    69.3    69.6    69.9    70.0    70.2    70.5    70.8
  71.2    71.6    72.2    72.9    73.2    73.2    73.3    73.5    73.7    73.9
  74.1    74.3    74.6    74.8    75.0    75.1    75.3    75.3    75.4    75.5
  75.9    76.3    76.5    76.7    76.9    77.2    77.4    77.7    78.0    78.3
  78.6    78.9    79.1    79.4    79.8    80.1    80.3    80.6    80.8    81.1
  81.4    81.7    82.0    82.3    82.6    82.9    82.9    83.1    83.2    83.4
  83.7    83.9    84.2    84.5    84.8    85.2    85.4    85.5    85.7    86.0
  86.2    86.3    86.5    86.8    87.0    87.3    87.6    87.9    88.1    88.4
  88.7    89.0    89.2    89.5    89.7    89.8    90.0    90.3    90.7    91.0
  91.2    91.0    91.0    92.0    92.0    92.0

           FRECPCTS BEFORE SMOOTHING

     0    .028    .042    .035    .070    .022    .004       0    .004    .040
  .040    .077    .021    .008    .014    .024    .025    .024    .012    .012
  .014    .014    .005    .003    .037    .040    .039    .050    .041    .054
  .123    .137    .002       0    .137    .505   1.357   2.647   4.365   5.911
 6.626   6.752   6.133   5.509   4.650   3.956   2.782   2.552   2.148   1.644
 1.722   1.553   2.532   1.237   1.109   1.001    .938    .930    .948    .836
  .745    .713    .742    .745    .723    .757    .621    .326    .706    .777
  .678    .931   1.057   1.081    .975    .990    .891    .993   1.022    .758
 1.137   1.020   1.137   1.046    .928    .865    .917    .872    .725    .902
  .831    .876    .864    .069

           FREQPCTS AFTER SMOOTHING

     0    .023    .033    .034    .028    .019    .009    .008    .014    .029
  .034    .032    .023    .016    .017    .021    .023    .021    .016    .014
  .012    .011    .010    .015    .028    .036    .041    .045    .053    .073
  .032    .085    .064    .092    .292    .765   1.623   2.845   4.256   5.502
 6.273   6.424   6.053   5.441   4.650   3.875   3.094   2.567   2.149   1.843
 1.737   1.753   1.855   1.479   1.238   1.026    .967    .973    .901    .837
  .777    .741    .735    .738    .726    .679    .609    .549    .633    .718
  .799    .923   1.020   1.076    .999    .977    .953    .955    .969    .948
 1.051   1.055   1.031   1.020    .959    .907    .880    .854    .820    .843
  .839    .770    .864    .060
```

```
PHI         CUM. PERCENT   FREQ. PERCENT

 .15                 0               0
 .20             .0279           .0279
 .25             .0701           .0325
 .30             .1054           .0335
 .35             .1355           .0291
 .40             .1574           .0191
 .45             .1616           .0095
 .50             .1616           .0079
 .55             .1659           .0143
 .60             .2064           .0288
 .65             .2467           .0342
 .70             .2876           .0319
 .75             .3049           .0228
 .80             .3124           .0162
 .85             .3262           .0165
 .90             .3504           .0207
 .95             .3762           .0225
1.00             .4001           .0207
1.05             .4124           .0169
1.10             .4239           .0137
1.15             .4381           .0125
1.20             .4520           .0108
1.25             .4569           .0124
1.30             .4598           .0149
1.35             .4986           .0277
1.40             .5366           .0353
1.45             .5750           .0411
1.50             .6251           .0453
1.55             .6661           .0534
1.60             .7200           .0732
1.65             .8474           .0919
1.70             .9804           .0853
1.75             .9928           .0544
1.80             .9828           .0920
1.85            1.1195           .2916
1.90            1.6247           .7555
1.95            2.3815          1.6232
2.00            5.6232          2.8445
2.05            9.3927          4.2555
2.10           15.9032          5.5021
2.15           22.5291          6.2376
2.20           29.2808          6.4045
2.25           35.4647          6.3531
2.30           40.9731          5.4410
2.35           45.6232          4.6495
2.40           49.5700          3.8749
2.45           52.7509          3.0942
2.50           54.2133          2.5669
2.55           57.0609          2.1498
2.60           58.7153          1.8428
2.65           60.4274          1.7975
2.70           61.3863          1.7626
2.75           64.5185          1.8553
2.80           65.7560          1.4792
2.85           66.8647          1.2382
2.90           67.8657          1.0255
2.95           68.8037           .9670
3.00           69.7376           .9328
3.05           70.6813           .9006
3.10           71.5173           .8372
3.15           72.2623           .7768
3.20           72.9753           .7408
3.25           73.7178           .7354
3.30           74.4623           .7382
3.35           75.1862           .7269
3.40           75.8431           .6787
3.45           76.5638           .6077
3.50           76.8895           .5490
3.55           77.5355           .6327
3.60           78.3722           .7181
3.65           79.0408           .7999
3.70           80.0411           .9252
3.75           81.0980          1.0005
3.80           82.1687          1.0359
3.85           83.1442           .9991
3.90           84.1342           .9766
3.95           85.0252           .9527
4.00           86.0178           .9545
4.05           87.0492           .9579
4.10           87.7984           .9485
4.15           88.9255          1.0505
4.20           90.0159          1.0554
4.25           91.1531          1.0806
4.30           92.1388          1.0199
4.35           93.1264           .9588
4.40           93.9925           .9571
4.45           94.9096           .8797
4.50           95.7812           .8539
4.55           96.5964           .8196
4.60           97.4081           .8427
4.65           98.2394           .8390
4.70           98.9755           .7697
4.75           99.9398           .8643
4.80          100.0000           .0602
```

```
                                                            ACCESSION NUMBER  TAPE 9

INMAN STATISTICS ..... MEDIAN  2.498            MEAN  2.997             DEVIATION    .896
                     SKEWNESS    .558           SECOND SKEWNESS   .908            KURTOSIS   .376

FOLK AND WARD STATISTICS .... MEAN  2.891                  SORTING   .822
                          SKEWNESS   .659                KURTOSIS   .865
```

1. Computer plotted cumulative and frequency curves of the sample's grain size distribution (see Figure 10).

2. A table containing the cumulative and frequency percentages at .05 phi intervals.

3. A table listing the grain size statistics calculated by the techniques of Inman (1952) and Folk and Ward (1957).

In addition, the program prints out various types of intermediate data, and has several options for punching raw data and/or frequency percent data on cards.

The computer program is internally documented, hence computational details need not be fully elaborated here. The following is a brief summary of the primary functions of the program's subroutines:

> SUBROUTINE READIN: This subroutine reads in the values put out by the strain gauge and converts this sequence of values (voltages) to a sequence of cumulative weight percentages. It also reads in control cards which contain parameters which determine output and data smoothing options used in subsequent subroutines. The subroutine is presently designed to handle up to 1104 data points per sample. This corresponds to approximately 32 minutes of data at the present sampling scheme. Each data set may be larger than 1104 data points but the excess data will not be reduced.
>
> SUBROUTINE SETIME: This subroutine associates a settling time with each data point. It assumes that the first data point occurs at 0.0 seconds, that the first 200 data points are taken at .666 second intervals, and that all subsequent data points are taken at 2.368 second intervals.
>
> SUBROUTINE GIBBSIZE: This subroutine calculates the grain size associated with the settling times which correspond to each data point. Grain sizes given are for spheres of density 2.65 g/cm^3. The following equation of Gibbs et al., (1971) is used to determine grain size from settling velocity:

$$r = \frac{0.055804v^2\rho_f + \sqrt{0.003114v^4\rho_f^2 + [g(\rho_s - \rho_f)][4.5\eta v + 0.008705v^2\rho_f]}}{[g(\rho_s - \rho_f)]}$$

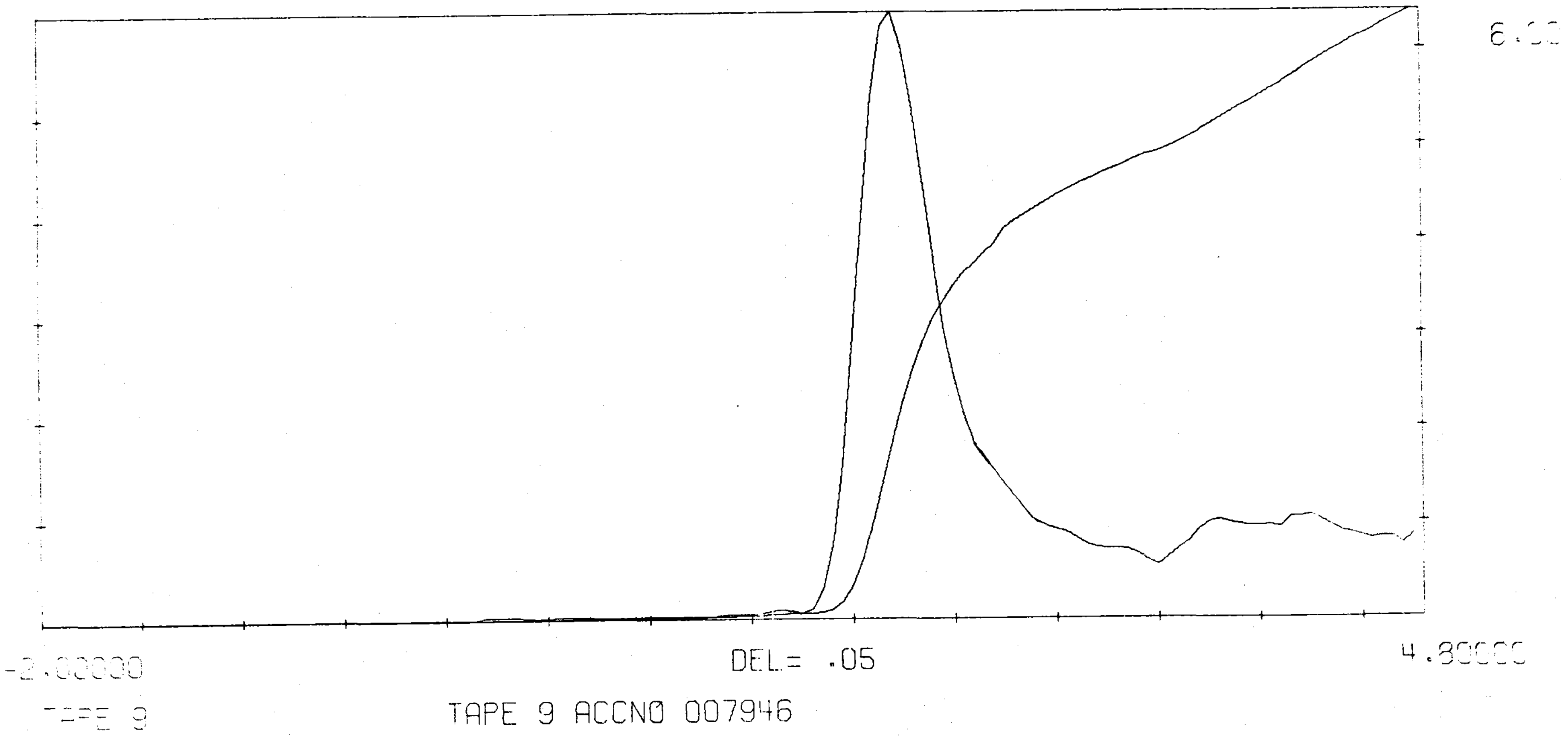


Figure 10. Size frequency of grain size data listed in Table 3. Units in phi, tick marks each 0.05 phi.

where: v = velocity in cm/sec.
η = dynamic viscosity of fluid in poise
g = acceleration of gravity (cm/sec^2)
r = sphere radius in cm.
ρ_f = density of fluid in g/cm^3
ρ_s = density of sphere in g/cm^3

It should be noted that the equation in Gibbs et al. is incorrect due to a printing error. The last term under the radical reads $v^2 \rho_s$ whereas it should read $v^2 \rho_f$. (M. D. Matthews, 1974, personal communication)

These grain sizes (in cm) are subsequently converted to sizes in terms of phi units, where

$$\text{phi} = -\log_2 \left(\frac{\text{diameter in mm}}{1\text{mm}} \right) \quad \text{(Krumbein, 1938)}$$

SUBROUTINE FIXENDS: This subroutine searches the data set to locate the start of significant accumulation of sediment on the collection pan. It then rescales the raw data. See comment cards 587 to 606 for details.

SUBROUTINE INTERPOL: This subroutine uses linear interpolation to determine the cumulative percentages at even .05 phi intervals, beginning at -2.00 phi (4mm) and ending at 5.05 phi (.0302 mm).

SUBROUTINE PTSMOOTH: This subroutine is a program option which may be used to smooth the raw input data. It uses an eleven point (maximum) smoothing function described by the following general formula:

$$\hat{V}_i = \frac{W_1V_{i-5}+W_2V_{i-4}+W_3V_{i-3}+W_4V_{i-2}+W_5V_{i-1}+W_6V_i+W_5V_{i+1}+W_4V_{i+2}+W_3V_{i+3}+W_2V_{i+4}+W_1V_{i+5}}{2W_1+2W_2+2W_3+2W_4+2W_5+W_6}$$

where V_i = unsmoothed value of variable V at data point i, and W_1 through W_6 are weighting factors which the data points before and after data point i are multiplied by and summed in order to return the smoothed value $\hat{V}_i$ for data point i.

If smoothing of the raw data is desired, the weighting factors are read in on the program control card. See comment cards 737-759 for additional details.

SUBROUTINE FVSMOOTH: This subroutine is a program option which may be used to smooth the derived frequency distribution. It is similar to SUBROUTINE PTSMOOTH except that it uses a five point (rather than an eleven point) smoothing function. This function is given by:

$$\hat{V}_i = \frac{WW_1 V_{i-2} + WW_2 V_{i-1} + WW_3 V_i + WW_2 V_{i+1} + WW_1 V_{i+2}}{2WW_1 + 2WW_2 + WW_3}$$

where WW_1, WW_2, and WW_3 are weighting factors.

See comment cards 791-796 for additional details.

SUBROUTINE HILOW: This subroutine limits the output data to the size range for which sediment was present in the sample.

SUBROUTINE FREQCALC: This subroutine takes the sequence of cumulative percentages from SUBROUTINE INTERPOL and differentiates this data to determine the frequency percentages in each .05 phi size class. It also calls SUBROUTINE FVSMOOTH if smoothing of the frequency curve is desired. See comment cards 864-872 for important details.

SUBROUTINE SETOUT: This subroutine prints out the final cumulative and frequency percent data. This data is punched onto cards, or output to a file, if desired.

SUBROUTINE GSPLOT: This subroutine plots the cumulative and frequency curves on the Calcomp plotter. Note: the frequency curve is plotted .025 phi to the right of its proper position. (See comment cards 864-872 for details.)

SUBROUTINE STATS: This subroutine calculates grain size statistics for each sample by the Inman and the Folk and Ward techniques. The following equations are used for these calculations:

Inman statistics:

Median = ϕ_{50}

Mean grain size = $\dfrac{\phi_{16} + \phi_{84}}{2}$

Phi standard deviation = $\dfrac{\phi_{84} - \phi_{16}}{2}$

$$\text{Skewness} = \frac{\text{Mean} - \text{Median}}{\text{Phi standard deviation}}$$

$$\text{Second skewness measure} = \frac{1/2\ (\phi_{95} + \phi_5) - \text{Median}}{\text{Phi standard deviation}}$$

$$\text{Kurtosis} = \frac{1/2\ (\phi_{95} - \phi_5) - \text{Phi standard deviation}}{\text{Phi standard deviation}}$$

Folk and Ward statistics:

$$\text{Mean} = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

$$\begin{array}{l}\text{Standard deviation} \\ \text{("sorting")}\end{array} = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

$$\text{Skewness} = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

$$\text{Kurtosis} = \frac{\phi_{95} - \phi_5}{2.44\ (\phi_{75} - \phi_{25})}$$

where ϕ_x = the phi value for which x percent of the sample is coarser.

Preparation of Control Cards

Two control cards per sample are required for program *Grainsiz. The first of these cards contains the accession number for the sample, all input parameters required for computation, and variables which control output and computational options. Card 2 contains any 40 character descriptive title for the sample. All input variables are integers with three exceptions. The ACCNO (the accession number), TITL(2) (the user's name), and the 40 character descriptive title are all alphanumeric. The integer variables must be right justified whereas the alphanumeric variables may appear anywhere in the designated field.

The variables are:

TEMP: The temperature of the fluid during the settling tube run. Must be an integer between 20 and 29°C.

ACCNO: The sample's accession number, or any other identifier. May be any seven characters, including blanks.

ISAVE: A one digit integer which reduces control card preparation in computer runs involving more than 1 sample.

> If ISAVE is zero, all the required input variables must be input for each sample.
>
> If ISAVE is non-zero, only TEMP, ACCNO, and the 40 character title must be input for the second through last samples. All other variables will be assumed to be the same as for the first sample.

TITL(2): The user's name. May be up to eight characters long. If left blank, the output will be labeled with the name Chriss.

ISMOOTH: A one digit integer which determines whether data is to be smoothed, as well as when in the program the smoothing is to occur.

> If ISMOOTH is zero (or blank), no smoothing is performed.
>
> If ISMOOTH is 1, raw data is smoothed.
>
> If ISMOOTH is 2, frequency percent data for each .05 phi interval are smoothed.
>
> If ISMOOTH is 3, both the raw data and the frequency data are smoothed.

W1 through W6: Two digit integers. These are the weighting factors used in smoothing the raw data. They may be left blank if ISMOOTH is zero, blank, or 2. At least one must be non-zero if ISMOOTH equals 1 or 3 (raw data to be smoothed).

WW1 through WW3: Two digit integers. These are the weighting factors used in smoothing the frequency percent data. They may all be left blank if ISMOOTH is zero, blank, or 1. At least one must be non-zero if ISMOOTH is 2 or 3 (frequency data to be smoothed).

NOSTATS: A one digit integer. If non-zero, calculation of grain size statistics is suppressed. If zero (or blank), statistics are calculated.

NOPLOTS: A one digit integer. If non-zero, plotting of cumulative and frequency curves is suppressed. If zero (or blank), plotting is done.

IFPUNCH: A one digit integer which controls punching of data or output of data to a file. Equipping LUN 40 to the card punch produces punched output whereas equipping LUN 40 to a file outputs the data to a file.

If IFPUNCH is zero (or blank), data is not punched onto cards or output to a file.

If IFPUNCH is 1, raw data only is punched or output to a file.

If IFPUNCH is 2, phi values and corresponding frequency percentages are punched or output to a file.

If IFPUNCH is 3, both raw data and frequency data are punched or output to a file.

IMPORTANT: If punched output is desired, the punched output must be labeled. See section regarding this under program execution.

Control Card Set Up

Card 1:

COL.	VARIABLE
1-2	TEMP
4-10	ACCNO
12	ISAVE
14-21	TITL(2)
23	ISMOOTH
25-26	W1
28-29	W2
31-32	W3
34-35	W4
37-38	W5
40-41	W6

Card 1 continued:

COL.	VARIABLE
43-44	WW1
46-47	WW2
49-50	WW3
52	NOSTATS
54	NOPLOTS
56	IFPUNCH

Card 2:

COL.	VARIABLE
1-40	Descriptive title for sample. Up to 40 characters.

REPEAT CARDS 1 AND 2 FOR EACH SUBSEQUENT SAMPLE

Program Execution

Prior to execution of *GRAINSIZ, the raw (unformatted) paper tape data must be run through the assembly language program *SJRUN in order to produce data in a format compatible with FORTRAN programs. See writeup on *SJRUN for instructions on use of this program.

Execution of *GRAINSIZ itself is most conveniently performed from remote teletype terminals. For teletype operation, the control cards must be stored under some file name, and the actual data set must be stored under another file name. Running procedure from teletype is as follows:

#Equip, 7 = (Name of file containing 2 control cards per sample)

#Equip, 6 = (Name of file containing raw data output from *SJRUN. A "nines card" must separate the data sets from separate samples. This "nines card" will automatically be supplied by *SJRUN and consists of the integer 9999 in any position of the data field. It may be in the last field of the last card containing true data, or may be on a separate card following the data set.

#Equip, 40 = PUN (if punched output is desired)

(see Note below regarding labels.)

or #Equip, 40 = ("some file name") if output is to be directed to a saved file. Note: This file name must have been created prior to program execution.

```
#LOAD, *BGRAINSI, L=*GLIB (CR)

RUN (CR)

(Computer will now respond by typing RUN again)

(Finally, it will respond "End of FORTRAN Execution")

#LOGOFF
```

Note: (CR) means "press carriage return."

*BGRRAINSI is the binary version of *GRAINSIZ

*GLIB is a program library containing plotting subroutines specific to the OS-3 operating system.

The following commands are required if punched and interpreted output is desired. The last two may be omitted if the output is to be punched but not interpreted.

```
#LABEL,40/<USER NAME>
#LABEL,40/<JOB NUMBER>
#LABEL,40/INTERPRET
```

3.2.2. Program listing

The program listings for GRAINSIZ and *SJRUN can be found on the following pages:

```
      PROGRAM GRAINSIZ
C
C
C ***********WRITTEN BY TERRY CHRISS, OCEANOGRAPHY, OREGON
C ***********STATE UNIVERSITY, 1975
C
      COMMON CUMPCT(1110),NEWV(1110)
      REAL NEWV
      INTEGER TEMP
      INTEGER W1,W2,W3,W4,W5,W6,WW1,WW2,WW3
      REAL MINPHI,HIPHI,LOWPHI
      DIMENSION TIME(1110)
      DIMENSION DPHI(1110)
      DIMENSION DDPHI(150),DCUMPCT(150)
      DIMENSION FREQPCT (150)
      DIMENSION FCUMPCT(1110)
      DIMENSION TITL(10),TITLL(5)
C
C
C *********CALLS TO SUBROUTINES FOLLOW
C *********
C
C
C
C THE FOLLOWING TWO CALL STATEMENTS HAVE THE EFFECT
C OF RETURNING THE CURRENT DATE AND TIME TO TITL(9) AND TITL(10)
C THEY ARE SPECIFIC TO THE OS-3 OPERATING SYSTEM AT OSU.
C
      CALL DATE (TITL(9))
      CALL ARMYTIME (TITL(10))
C
C FOLLOWING STATEMENTS AUTOMATICALLY DIRECT OUTPUT TO THE
C LINE PRINTER
C
      CALL UNEQUIP(30)
      CALL EQUIP(30,8HLP      )
C
      TITL(1)=8HSAVE FOR
C FOLLOWING STATEMENT MAKES TITL(3) TO TITL(8) BLANK
      DO 3 I=3,8
3     TITL(I)= 8H
C
C
      II=1
C
 1    CALL READIN (TEMP,ACCNO,TITL,NPTS,ISMOOTH,W1,W2,
     1 W3,W4,W5,W6,TITLL,NOSTATS,NOPLOTS,IFPUNCH,WW1,WW2,WW3,II)
C
C THE FOLLOWING STATEMENT INSURES THAT THE FOLLOWING CALL
C STATEMENTS ASSOCIATED WITH THE PLOTTING ROUTINE ARE ONLY
C CALLED ONCE PER COMPUTER RUN, NOT ONCE PER SAMPLE
C
      IF (II .NE. 1) GO TO 40
C
C  FOLLOWING STATEMENT BYPASSES PLOTTING COMMANDS IF FLOTTING
C  IS NOT DESIRED.
C
      IF (NOPLOTS .NE. 0) GO TO 40
C
C *********************************************************
C  THE FOLLOWING TWO STATEMENTS HAVE THE EFFECT OF EQUIPPING
C  LUN NUMBER 10 TO THE CALCOMP PLOTTER.
C
```

```
      CALL UNEQUIP(10)
      CALL EQUIP(10,8HPLOT     )
C
C FOLLOWING FIVE CALL STATEMENTS ARE FOR THE
C PLOTTING OF FREQUENCY CURVES AND CUMULATIVE CURVES .
C THEY ARE PLACED HERE, RATHER THAN IN SUBROUTINE GSPLOT BECAUSE
C THEY ARE ONLY TO BE CALLED ONCE PER COMPUTER RUN, NOT
C ONCE PER SAMPLE.
C THEY ARE SPECIFIC TO THE 0S-3 OPERATING SYSTEM AT OSU
C
      CALL PLOTINT(-6.,6.,10)
      CALL PLOTSYMB(0.,0.,.21,TITL,0.,80)
      CALL PLOT(0.,0.,-3)
      CALL ROTATEXY
      CALL PLOT(1.0,-26.0,-3)
C ***************************************************************
C
C
C
 40   CALL SETIME (TIME,NPTS)
C
      CALL GIBBSIZE (TIME,DPHI,TEMP,NPTS)
C
      CALL FIXENDS (DPHI,FCUMPCT,NPTS,MINPHI)
C
      CALL INTERPOL(DPHI,FCUMPCT,DDPHI,DCUMPCT,NPTS,MINPHI,
     1 HIPHI,LOWPHI,ISMOOTH,W1,W2,W3,W4,W5,W6)
C
      CALL HILOW(DDPHI,LOWPHI,HIPHI,L,M,NN)
C
      CALL FREQCALC (DCUMPCT,DDPHI,L,M, NN,FREQPCT,ISMOOTH,
     1 WW1,WW2,WW3)
C
      CALL SETOUT(ACCNO,TITL,DDPHI,DCUMPCT,FREQPCT,HIPHI,LOWPHI,
     1 L,M,DELPHI,IFPUNCH)
C
C THE FOLLOWING STATEMENT BYPASSES THE PLOTTING SUBROUTINE
C WHEN PLOTTING IS NOT DESIRED
C
      IF (NOPLOTS .NE. 0) GO TO 41
C
      CALL GSPLOT(TITLL,DCUMPCT,FREQPCT,DDPHI,LCWPHI,HIPHI,DELPHI
     1 ,M,ACCNO)
C
C THE FOLLOWING STATEMENT BYPASSES THE GRAIN SIZE STATISTICS
C SUBROUTINE WHEN STATISTICS ARE NOT DESIRED
C
 41   IF(NOSTATS .NE. 0) GO TO 42
C
      CALL STATS(TITLL,DCUMPCT,FREQPCT,DDPHI,LOWPHI,HIPHI,DELPHI,
     1 M,ACCNO)
C
 42   II=II+1
      GO TO 1
      END
C
C
C
C :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
      SUBROUTINE READIN (TEMP,ACCNO,TITL,NPTS,ISMOOTH,W1,
     1 W2,W3,W4,W5,W6,TITLL,NOSTATS,NOPLOTS,IFPUNCH,WW1,WW2,WW3,II)
C
C ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C
C
C
C THIS SUBROUTINE READS IN THE DIGITIZED VOLTAGES PUT OUT BY
C THE STRAIN GAUGE AND CONVERTS THIS SEQUENCE OF VOLTAGES TO A
C SEQUENCE OF CUMULATIVE WEIGHT PERCENTAGES
C
C IT ALSO READS IN THE ACCESSION NUMBER OF THE SAMPLE, A
C DESCRIPTIVE TITLE FOR THE SAMPLE, AS WELL AS THE SMCOTHING
C FACTORS TO BE USED IN SUBROUTINES PTSMOOTH ANC FVSMCOTH
C
C THIS INFORMATION AS WELL AS THE RAW DATA IS PRINTED OUT
C FROM THIS SUBROUTINE
C
      COMMON CUMPCT(1110),NEWV(1110)
      REAL NEWV
      REAL MINVOLT
```

```
      DIMENSION VOLT(1110),VOLTDIFF(1500)
      REAL LASTITL
      DIMENSION JVOLT(1110)
C FOLLOWING EQUIVALENCE STATEMENT IS SIMPLY TO REDUCE MEMORY
C REQUIREMENTS OF THE PROGRAM.  WE ARE DONE USING JVOLT
C PRIOR TO THE USE OF VOLTDIFF.
      EQUIVALENCE(JVOLT,VOLTDIFF)
C
      DIMENSION TITL(10),NULL(6),TITLL(5)
      INTEGER TEMP
      INTEGER W1,W2,W3,W4,W5,W6,WW1,WW2,WW3
C  NOTE:  IN FOLLOWING READ STATEMENT, ISMOOTH DETERMINES
C  WHETHER SMOOTHING IS TO BE PERFORMED ON THE
C  RAW DATA (INPUT VOLTAGES), THE FREQUENCY PERCENTAGES,
C  ON BOTH OF THESE, OR NOT AT ALL.  SEE COMMENT CARDS FOLLOWING
C  STATEMENT 400 (CARD 350) FOR DETAILS.
C
C  W1 THROUGH W6 ARE WEIGHTING FACTORS FOR THE SMOOTHING ROUTINE
C CALLED PTSMOOTH WHICH IS A MAXIMUM ELEVEN POINT
C SMOOTHING FUNCTION WHICH IS APPLIED TO THE RAW DATA.
C
C WW1,WW2,WW3 ARE WEIGHTING FACTORS FOR THE SMOOTHING ROUTINE
C CALLED FVSMOOTH WHICH IS A MAXIMUM FIVE POINT SMOOTHING
C FUNCTION WHICH MAY BE APPLIED TO THE FREQUENCY
C PERCENTAGE DATA.
C
C IF NOSTATS AND NOPLOTS ARE ZERO (OR BLANK), BOTH GRAIN
C SIZE STATISTICS AND PLOTS OF SIZE DISTRIBUTIONS ARE DONE.
C IF NOSTATS AND NOPLOTS ARE NON-ZERO, CALCULATION OF
C STATISTICS AND PLOTTING OF DISTRIBUTIONS IS SUPPRESSED.
C
C IF IFPUNCH IS ZERO, DATA IS NOT PUNCHED ONTO
C CARDS.  IF IFPUNCH IS 1, RAW DATA ONLY IS PUNCHED ON CARDS.
C IF IFPUNCH IS 2, PHI VALUES AND CORRESPONDING FREQUENCY
C PERCENTAGES ARE PUNCHED.  IF IFPUNCH IS 3,
C BOTH RAW DATA AND FREQUENCY DATA IS PUNCHED.
C
C IF ISAVE IS ZERO, TITL(2),ISMOOTH, WEIGHTING FACTORS,NOSTATS,
C NOPLOTS, AND IFPUNCH MUST BE INPUT FOR EACH SAMPLE.
C IF ISAVE IS NON-ZERO, THESE PARAMETERS MUST ONLY BE
C INPUT FOR THE FIRST SAMPLE.  THEY WILL BE ASSUMED TO BE
C THE SAME FOR ALL SUBSEQUENT SAMPLES.  THUS FOR THE
C SECOND TO LAST SAMPLES, ONLY THE TEMP AND
C THE ACCESSION NUMBER, AS WELL AS THE 40 LETTER
C TITLE NEED BE INPUT.
C
C  TITL(2) SHOULD BE THE NAME OF THE USER.  IT IS USED
C  TO LABEL THE PLOTS. TITL(4) THROUGH TITL(8) IS A 40 CHARACTER
C  DESCRIPTIVE LABEL FOR EACH  SAMPLE.
C
      READ(7,7) TEMP,ACCNO,ISAVE,TITL(2),ISMOOTH,W1,W2,W3,W4,W5,W6,
     1 WW1,WW2,WW3,NOSTATS,NOPLOTS,IFPUNCH,(TITLL(J),J=1,5)
C
 7    FORMAT(I2,1X,A7,1X,I1,1X,A8,1X,I1,1X,9(I2,1X),3(I1,1X),/,5A8)
C
C THE FOLLOWING STATEMENT CHECKS FOR AN END OF FILE ON
C LOGICAL UNIT 7 (LUN 7) ON WHICH THE HEADER CARDS ARE BEING
C READ.  AN END OF FILE ON LUN 7 INDICATES THAT THE PREVIOUS
C DATA SET WAS THE FINAL DATA SET.  IF SO, WE TERMINATE EXECUTION
C OF THE PROGRAM.
      IF(EOF(7)) GO TO 30
      GO TO 31
C  THE FOLLOWING PLOTTING STATEMENT IS TO CLEAR OUT
C  THE PLOTTING BUFFER.
30    CALL PLOT(10.,26.0,-3)
      CALL EXIT
 31   CONTINUE
C
C NEXT STATEMENT INSURES THAT PLOT WILL BE LABELED WITH THE
C NAME CHRISS IN THE CASE THAT TITL(2) IS LEFT BLANK.
C
      IF(TITL(2) .EQ. 8H        ) TITL(2) = 8H CHRISS
C
C FOLLOWING IS A ROUTINE TO SAVE THE INPUT PARAMETERS
C FROM THE FIRST SAMPLE.
C
      IF(II .NE. 1) GO TO 8888
      LASTITL=TITL(2)
      LISMOOTH=ISMOOTH
      LASTW1=W1
      LASTW2=W2
      LASTW3=W3
      LASTW4=W4
      LASTW5=W5
```

```
      LASTW6=W6
      LASTWW1=WW1
      LASTWW2=WW2
      LASTWW3=WW3
      LNOSTATS=NOSTATS
      LNOPLOTS=NOPLOTS
      LIFPUNCH=IFPUNCH
8888  IF (ISAVE .EQ. 0) GO TO 8900
      TITL(2)=LASTITL
      ISMOOTH=LISMOOTH
      W1=LASTW1
      W2=LASTW2
      W3=LASTW3
      W4=LASTW4
      W5=LASTW5
      W6=LASTW6
      WW1=LASTWW1
      WW2=LASTWW2
      WW3=LASTWW3
      NOSTATS=LNOSTATS
      NOPLOTS=LNOPLOTS
      IFPUNCH=LIFPUNCH
8900  CONTINUE
C
C NOTE:  THE PROGRAM IS PRESENTLY SET UP FOR
C REDUCTION OF UP TO 1104 DATA POINTS PER DATA SET.  THIS
C CORRESPONDS TO 32 MINUTES OF DATA AT THE PRESENT
C SAMPLING SCHEME (SEE SUBROUTINE SETIME).  IF MORE THAN 1104
C DATA POINTS ARE PRESENT IN THE DATA SET, THE EXCESS DATA
C IS DUMPED INTO A DUMMY VARIABLE CALLED NULL.  IT IS NOT
C REDUCED.
C
C NEXT SECTION READS THE RAW DATA PUT OUT BY THE STRAIN GAUGE
C
C
      M=1
      N=6
      DO 10 K=1,184
C
      READ (6,1) (JVOLT(I),I=M,N)
1     FORMAT(X,6I6)
C
C NEXT STATEMENT CHECKS FOR ¬NINES¬ CARD WHICH INDICATES THE
C END OF THE DATA SET.  A ¬NINES¬ CARD WILL ALWAYS BE READ
C EXCEPT FOR THE SPECIAL CASE IN WHICH EXACTLY 1100 DATA
C POINTS COMPRISE THE DATA SET.
C
      DO 421 I=M,N
      IF(JVOLT(I).EQ.9999) GO TO 12
 421   CONTINUE
      M=M+6
      N=N+6
10    CONTINUE
C
C NEXT SECTION CHECKS TO SEE IF DATA SET IS LARGER THAN
C 1104 DATA POINTS.  IF SO, IT CONTINUES READING DATA UNTIL
C A NINES CARD IS READ, BUT ALL THIS EXCESS DATA IS DUMPED
C INTO THE DUMMY VARIABLE NULL.
C
      IF(I.LE.185) GO TO 12
 423  READ(6,1)(NULL(J),J=1,6)
      DO 422 IQ=1,6
      IF(NULL(IQ).EQ.9999) GO TO 12
      GO TO 423
422   CONTINUE
12    NPTS=I-1
C
C NEXT SECTION CHANGES JVOLTS FROM INTEGER TO REAL.
      IJ=0
      DO 20 I=1,NPTS
      IJ=IJ+1
      VOLT(IJ)=JVOLT(I)
20    CONTINUE
      NPTS=IJ
C
C
C *****NEXT SECTION IS USED TO CALCULATE
C *****DIFFERENCES BETWEEN SUCCESSIVE DATA POINTS, SO
C *****THAT BAD DATA WILL BE APPARENT.  PRINTING OF
C *****THIS LIST OF DIFFERENCES HAS BEEN ELIMINATED
C *****IN THIS VERSION, BUT CAN BE RESTORED BY ADDING THE
C *****APPROPRIATE WRITE STATEMENT.
C
      VOLTDIFF(1)=0.0
```

```
      DO 3000 I=2,NPTS
 3000 VOLTDIFF(I)=VOLT(I)-VOLT(I-1)
C
C NEXT SECTION PRINTS OUT TABLE OF RAW DATA AS WELL AS
C THE INPUT CONTROL PARAMETERS.
C
      WRITE(30,200) (TITL(J),J=1,2), (TITL(J),J=9,10)
 200  FORMAT(1X,2A8,40X,2A8)
      WRITE(30,7777)
7777  FORMAT(1H )
      WRITE(30,6) ACCNO,(TITLL(J),J=1,5)
 6    FORMAT(1X,A7,1X,5A8)
      WRITE(30,7777)
      WRITE(30,4)
 4    FORMAT(1X,≠TEMP ISMOOTH W1 W2 W3 W4 W5 W6 WW1 WW2 WW3 ≠,
     1≠IFPUNCH NOPLOTS≠)
      WRITE(30,5) TEMP,ISMOOTH,W1,W2,W3,W4,W5,W6,WW1,WW2,WW3,
     1 IFPUNCH,NOPLOTS
      WRITE(30,7777)
      WRITE(30,9996)
9996  FORMAT(10X,≠RAW DATA≠)
      WRITE(30,7777)
      WRITE(30,9997)(VOLT(I),I=1,NPTS)
9997  FORMAT(X,10(F6.0,1X))
 5    FORMAT(2X,I2,5X,I1,3X,7(1X,I2),2X,I2,2X,I2,5X,I1,7X,I1)
C FOLLOWING SECTION IS FOR PUNCHED OUTPUT, IF DESIRED.
      IF (IFPUNCH .EQ. 0) GO TO 400
      WRITE(40,200) (TITL(J),J=1,2), (TITL(J),J=9,10)
      WRITE(40,6) ACCNO,(TITLL(J),J=1,5)
      WRITE(40,4)
      WRITE(40,5) TEMP,ISMOOTH,W1,W2,W3,W4,W5,W6,WW1,WW2,WW3
      IF(IFPUNCH .EQ. 1) GO TO 500
      GO TO 400
 500  WRITE(40,9996)
      WRITE(40,9997) (VOLT(I),I=1,NPTS)
 400  CONTINUE
C
C
C ****** NEXT SECTION CALLS SMOOTHING SUBROUTINE, IF DESIRED
C         IF ISMOOTH EQUALS 0, NO SMOOTHING IS PERFORMED
C         IF ISMOOTH EQUALS 1, RAW DATA IS SMOOTHED
C         IF ISMOOTH EQUALS 2, FREQUENCY PERCENTS AT .05 PHI
C         INTERVALS ARE SMOOTHED
C         IF ISMOOTH EQUALS 3, BOTH RAW DATA AND FREQUENCY
C         PERCENTAGES AT .05 PHI INTERVALS ARE SMOOTHED
C         NOTE:  SMOOTHING OF FREQUENCY PERCENTAGES IS DONE
C         FROM SUBROUTINE FREQCALC.
C
      IF (ISMOOTH .EQ. 1) GO TO 9998
      IF (ISMOOTH .EQ. 3) GO TO 9998
      GO TO 9999
C
9998  CALL PTSMOOTH (VOLT,NPTS,W1,W2,W3,W4,W5,W6)
C
C NEXT SECTION WRITES OUT SMOOTHED RAW DATA
C
      WRITE(30,7777)
      WRITE(30,6666)
6666  FORMAT(10X,≠SMOOTHED DATA≠)
      WRITE(30,7777)
      WRITE(30,5557) (VOLT(I),I=1,NPTS)
5557  FORMAT(1X,10(F6.1,1X))
      WRITE(30,7777)
C
C
C NEXT SECTION MAKES ALL VOLTAGES POSITIVE BY SUBTRACTING THE
C VOLTAGE AT THE ORIGIN
9999  MINVOLT=VOLT(1)
      DO 2 I=1,NPTS
2     VOLT(I) =VOLT(I) - MINVOLT
C
C
C
C
C
C   THIS SECTION CHECKS TO SEE THAT THE VOLTAGE IS CONTINUOUSLY EITHER
C   INCREASING OR CONSTANT.  IF THE VOLTAGE DECREASES
C   (THEREBY INDICATING A DECREASE IN WEIGHT ON THE PAN-- WHICH
C   CAN ONLY BE DUE TO NOISE IN THE SYSTEM),
C   THE VOLTAGE OF THE ABERRANT DATA POINT IS SET EQUAL
C   TO THE VOLTAGE OF THE PREVIOUS DATA POINT.
C
C
      DO 9 I=1,NPTS
9     IF (VOLT(I+1) .LT. VOLT(I)) VOLT(I+1)=VOLT(I)
```

```
C
C
C NEXT SECTION CALCULATES THE WEIGHT PERCENT OF THE TOTAL SEDIMENT
C WHICH HAD ACCUMULATED AT THE EACH DATA POINT
      VOLTRNGE=VOLT(NPTS)-VOLT(1)
C
C
      DO 3 I=1,NPTS
3     CUMPCT(I)=(VOLT(I)/VOLTRNGE) * 100
      RETURN
      END
C
C
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
      SUBROUTINE SETIME(TIME,NPTS)
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C
C THIS SUBROUTINE ASSOCIATES A SETTLING TIME WITH EACH
C DATA POINT
C IT ASSUMES THAT THE FIRST 200 DATA POINTS ARE TAKEN AT .6666 SECOND
C INTERVALS, THAT SUBSEQUENT DATA POINTS ARE TAKEN AT 2.3680 SECOND
C INTERVALS, AND THAT THE FIRST DATA POINT OCCURS AT 0.0 SECONDS.
C
      DIMENSION TIME(1110)
      DO 1 I=1,200
1     TIME(I)=  I * .6666
      DO 2 I=201,NPTS
2     TIME(I)=120. +((I-200.)*2.368)
       RETURN
       END
C
C
C
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
       SUBROUTINE GIBBSIZE(TIME,DPHI,TEMP,NPTS)
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C THIS SUBROUTINE CALCULATES THE GRAIN SIZE ASSOCIATED WITH
C THE TIMES WHICH CORRESPOND TO EACH DATA POINT.  GRAIN SIZES
C GIVEN ARE FOR QUARTZ SPHERES OF DENSITY 2.65.  FORMULA
C USED IS GIVEN IN GIBBS, MATTHEWS, AND LINK, 1971,
C JOURNAL OF SEDIMENTARY PETROLOGY, VOL. 41, NO. 1.
C HOWEVER, THE LAST TERM IN THE EQUATION FOR R ON PG. 10
C OF THE PUBLICATION IS INCORRECT.  IT SHOULD READ
C (.008705 V**2)*PF NOT (.008705 V**2)*PS.
C
C    SYMBOLS USED ARE:
C               V=VEL. IN CM/SEC
C               NU=DYNAMIC VISCOSITY OF FLUID IN POISE
C               G=ACCEL. OF GRAVITY IN CM/SEC**2
C               R=RADIUS OF SPHERE IN CM
C               PF=DENSITY OF FLUID IN GRAM/CM**3
C               PS=DENSITY OF SPHERE IN GRAM/CM**3
C               L=LENGTH OF SETTLING TUBE IN CM
C               T=TEMPERATURE IN DEGREES CENTIGRADE
C
C
       REAL G, NUU(10)
       REAL NU
       REAL PF
       INTEGER T(10)
       INTEGER TEMP
       DIMENSION PFF(10)
       REAL L
       DIMENSION V(1110),DPHI(1110),R(1110),D(1110)
       DIMENSION TIME(1110)
C
```

```
C
C FIRST SECTION CONSTRUCTS AN ARRAY WHICH CONTAINS
C THE VISCOSITIES AND DENSITIES OF FRESH WATER AT DIFFERENT
C TEMPERATURES
C
C THIS SECTION COULD ALSO BE MODIFIED TO GIVE VISCOSITIES AND
C DENSITIES FOR WATER OF DIFFERENT SALINITIES, IF ONE
C WERE INTERESTED IN DETERMINING SETTLING TIME VS SIZE FOR
C SALT WATER
C
C
      T(1)=20
      T(2)=21
      T(3)=22
      T(4)=23
      T(5)=24
      T(6)=25
      T(7)=26
      T(8)=27
      T(9)=28
      T(10)=29
C
C ********** VALUES FOR DENSITY AND VISCOSITY OF FLUID
C*********** ARE FROM WINEGARD,C.I., U.S.G.S. PROF. PAPER
C ********** 700B,PAGES B161 TO B166.
C ********** THIS PAPER ALSO GIVES VISCOSITY AND DENSITY FOR
C ********** WATERS OF DIFFERENT SALINITY.  HERE WE USE
C ********** SALINITY OF 0.000.
      NUU(1)=.01005
      NUU(2)=.00981
      NUU(3)=.00958
      NUU(4)=.00936
      NUU(5)=.00914
      NUU(6)=.00894
      NUU(7)=.00874
      NUU(8)=.00855
      NUU(9)=.00836
      NUU(10)=.00818
C
C
      PFF(1)=.998230
      PFF(2)=.998019
      PFF(3)=.997797
      PFF(4)=.997565
      PFF(5)=.997323
      PFF(6)=.997071
      PFF(7)=.996810
      PFF(8)=.996539
      PFF(9)=.996259
      PFF(10)=.995971
      DO 3 J=1,10
      IF (TEMP .EQ. T(J)) GO TO 4
3     CONTINUE
4     NU=NUU(J)
      PF=PFF(J)
C
      PS=2.65
C    ****  G IS GIVEN FOR OCEANOGRAPHY BUILDING AT OSU
      G=980.57236
      L=212.00
C ****************************************************************;
C NEXT SECTION CALCULATES THE SETTLING VELOCITIES CORRESPONDING
C TO EACH DATA POINT
      DO 1 I=1,NPTS
1     V(I)=L/TIME(I)
C     A,B,C,E, AND U ARE CONSTANTS AND ARE CALCULATED
C     NOW TO REDUCE THE SIZE OF THE EQUATION RELATING
C     RADIUS AND SETTLING VELOCITY
      A=.055804 * PF
      B=.003114 * (PF**2)
      C=G*(PS-PF)
      E=4.5 * NU
      U=.008705 * PF
C
C
      DO 2 I=1,NPTS
      R(I)=((A*(V(I)**2)+SQRT(B*(V(I)**4)+C*(E*V(I)+U*(V(I)**2)))))/C
C     D IS DIAMETER IN MILLIMETERS
      D(I)=R(I)*20
C PHI=-LOG TO THE BASE 2 OF THE DIAMETER IN MILLIMETERS
C DPHI IS THE DIAMETER IN PHI UNITS
      DPHI(I)= ALOG(D(I))/ALOG(.500)
2     CONTINUE
      RETURN
```

```
C
C
C   THIS SUBROUTINE IS A GENERAL PURPOSE SUBROUTINE WHICH
C   CAN BE USED FOR SMOOTHING ANY DISTRIBUTION, EITHER
C   OF A CUMULATIVE OR FREQUENCY NATURE.  V IS THE VARIABLE
C   WHOSE VALUE WE WISH TO SMOOTH, W1 THROUGH W6 ARE WEIGHTING
C   FACTORS WHICH THE DATA POINTS BEFORE AND AFTER THE DATA
C   POINT IN QUESTION ARE MULTIPLIED BY AND THEN SUMMED TO
C   ARRIVE AT A NEW SMOOTHED VALUE FOR THE VARIABLE AT DATA
C   POINT I.  IF ALL OF THE WEIGHTING  VALUES ARE
C   NON-ZERO, THE RESULT IS AN ELEVEN POINT SMOOTHING FUNCTION.
C   HOWEVER, BY LETTING W1 EQUAL ZERO, WE REDUCE THE SMOOTHING
C   FUNCTION TO A NINE POINT SMOOTH.  IF BOTH W1 AND W2 ARE ZERO,
C   THE RESULTING SMOOTHING FUNCTION IS A SEVEN POINT SMOOTH.
C   LIKEWISE, IF W1,W2,AND W3 ARE ALL ZERO, WE HAVE A FIVE POINT
C   SMOOTHING FUNCTION.
C   ** IMPORTANT NOTE:  BECAUSE OF THE PARTICULAR ALGORITHM USED
C   FOR SMOOTHING, THE FIRST FIVE AND THE LAST FIVE DATA POINTS
C   ARE NOT SMOOTHED.  THIS MAY NOT BE VERY IMPORTANT IN A CASE
C   WHERE THERE ARE MANY DATA POINTS, BUT COULD LEAD TO SOME
C   FUNNY LOOKING DATA IN A SITUATION WHERE THERE ARE VERY FEW
C   DATA POINTS.  THIS COULD EASILY BE ALTERED SO THAT THESE
C   FIRST FIVE AND LAST FIVE DATA POINTS ARE SMOOTHED, ALTHOUGH
C   WITH A SMOOTHING FUNCTION OF SMALLER SIZE THAN THE REST OF
C THE DATA POINTS. USE SUBROUTINE FVSMOOTH TO AVOID THIS PROBLEM.
      COMMON CUMPCT(1110),NEWV(1110)
      REAL NEWV
      INTEGER W1,W2,W3,W4,W5,W6
      DIMENSION V(1110)
      N=NPTS-5
      DO 10 I=6,N
      A=W1*(V(I-5)  +  V(I+5))
      B=W2*(V(I-4)  +  V(I+4))
      C=W3*(V(I-3)  +  V(I+3))
      D=W4*(V(I-2)  +  V(I+2))
      E=W5*(V(I-1)  +  V(I+1))
      F=W6*V(I)
 10   NEWV(I)= (A+B+C+D+E+F)/  (2*(W1+W2+W3+W4+W5)  +  W6)
      DO 11 I=6,N
 11   V(I)=NEWV(I)
      RETURN
      END
C
C
C
C
C!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
      SUBROUTINE FVSMOOTH(V,L,M,NN,WW1,WW2,WW3)
C
C!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C
C SEE SUBROUTINE PTSMOOTH FOR COMMENTS.  THIS SUBROUTINE IS
C VERY SIMILAR EXCEPT THAT THE MAXIMUM SIZE OF THE SMOOTHING
C FUNCTION IS FIVE DATA POINTS, RATHER THAN ELEVEN AS IN
C SUBROUTINE PTSMOOTH.  THE RESULT IS THAT IN SUBROUTINE
C FVSMOOTH, ONLY THE FIRST TWO AND LAST TWO DATA POINTS
C ARE NOT SMOOTHED.
C
      REAL NEWV
      COMMON CUMPCT(1110),NEWV(1110)
      INTEGER WW1,WW2,WW3
      DIMENSION V(1110)
      J=L+2
      K=M-2
      DO 10 I=J,K
      A=WW1*(V(I-2)  +  V(I+2))
      B=WW2*(V(I-1)  +  V(I+1))
      C=WW3* V(I)
 10   NEWV(I)= (A+B+C) / (2*(WW1+WW2) + WW3)
      DO 11 I=J,K
 11   V(I)=NEWV(I)
      RETURN
      END
C
C
C
C
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

```
C
         SUBROUTINE HILOW(DDPHI,LOWPHI,HIPHI,L,M,NN)
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C
C
C FOLLOWING SECTION INSURES THAT ONLY THOSE VALUES
C OF DDPHI AND DDCUMPCT PRIOR TO END OF ACCUMULATION
C ARE OUTPUT.
C IT SIMPLY ELIMINATES THE OUTPUT OF DATA FOR ALL VALUES
C OF DDPHI WHICH ARE GREATER THAN HIPHI, IN ADDITION ELIMINATING
C VALUES OF DDPHI WHICH ARE LESS THAN LOWPHI
C
      REAL LOWPHI
      DIMENSION DDPHI(150)
      DO 1 I=1,143
      IF (DDPHI(I) .EQ. LOWPHI) L=I
      IF (DDPHI(I) .EQ. HIPHI) M=I
1     CONTINUE
      NN= M-L+1
      RETURN
      END
C
C
C
C
C  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
        SUBROUTINE FREQCALC(DCUMPCT,DDPHI,L,M,NN,FREQPCT,ISMOOTH,
     1 WW1,WW2,WW3)
C
C  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C
C
C   THIS SUBROUTINE TAKES THE CUMULATIVE PERCENTAGES
C   IN DATA ARRAY DCUMPCT AND DIFFERENTIATES THIS DATA
C   TO DETERMINE THE FREQUENCY PERCENTAGES IN EACH .05 PHI          .
C   INTERVAL.
C   IT ESTIMATES DERIVITIVES USING THE DIFFERENCE BETWEEN DATA PT
C   I AND DATA POINT I-1 AS ESTIMATE OF THE DERIVITIVE AT POINT I
C****
C**** NOTE:WHEN PLOTTED, THIS WILL HAVE THE EFFECT OF SHIFTING
C**** THE FREQUENCY CURVE ONE-HALF DIGITIZING UNIT TO THE
C**** RIGHT OF THE CUMULATIVE CURVE.  IF DESIRED,
C**** THE SUBROUTINE GSPLOT CAN BE MODIFIED SO THAT
C**** THE FREQUENCY CURVE IS PLOTTED IN THE PROPER POSITION
C**** WITH RESPECT TO THE CUMULATIVE CURVE.
C
C     THIS SUBROUTINE ALSO SMOOTHS THE FREQUENCY CURVE, IF DESIRED
C
      DIMENSION FREQPCT (150), DCUMPCT(150)
      DIMENSION DDPHI(150)
      INTEGER WW1,WW2,WW3
C
C FOLLOWING SECTION INITIALLY SETS ALL FREQPCTS EQUAL TO 0.0 .
C THIS IS TO INSURE THAT NO VALUES OF FREQPCT ARE CARRIED
C OVER FROM THE PREVIOUS SAMPLE.
C
      DO 1 I=1,M
1     FREQPCT(I)=0.0
C
C
C NEXT SECTION ESTIMATES  DERIVITIVES BY METHOD DESCRIBED IN FIRST FEW
C COMMENT CARDS. NOTE THAT FREQPCT(L) REMAINS ZERO,
C`AS THIS IS THE FREQUENCY PERCENT AT THE DATA POINT DEFINED
C AS THE BEGINNING OF ACCUMULATION
      K=L+1
      DO 2 I=K,M
    2 FREQPCT(I)=(DCUMPCT(I)-DCUMPCT(I-1))
      WRITE(30,6666)
6666  FORMAT(1H ,10X,≠ FREQPCTS BEFORE SMOOTHING≠)
      WRITE(30,6669)
6669  FORMAT(1H )
      WRITE(30,6667) (FREQPCT (I),I=L,M)
6667  FORMAT(1X,10(F6.3,1X))
      WRITE(30,6669)
C
```

```
C NEXT SECTION CALLS SMOOTHING SUBROUTINE FVSMOOTH,
C IF SMOOTHING OF THE FREQUENCY CURVE IS DESIRED.
C
      IF (ISMOOTH .EQ. 2) GO TO 4
      IF (ISMOOTH .EQ. 3) GO TO 4
      GO TO 5
C
 4    CALL FVSMOOTH(FREQPCT,L,M,NN,WW1,WW2,WW3)
 5    CONTINUE
C
      WRITE(30,6668)
6668  FORMAT(1H ,10X,≠FREQPCTS AFTER SMOOTHING≠)
      WRITE(30,6669)
      WRITE(30,6667)  (FREQPCT(I),I=L,M)
      WRITE(30,6669)
      WRITE(30,6669)
      RETURN
      END
C
C
C
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
       SUBROUTINE SETOUT(ACCNO,TITLL,DDPHI,DCUMPCT,FREQPCT,
     1 HIPHI,LOWPHI,L,M,DELPHI,IFPUNCH)
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C
C
C THIS SUBROUTINE PRINTS OUT THE FINAL CUMULATIVE AND FREQUENCY
C PERCENTAGE DATA. IT ALSO PUNCHES THIS DATA ONTO CARDS, IF
C DESIRED.
C
C
       DIMENSION TITLL(5),DDPHI(150),DCUMPCT(150),FREQPCT(150)
       REAL HIPHI,LOWPHI
C   ************
C DELPHI IS THE INTERPOLATION INTERVAL
       DELPHI=.05
C ************
       WRITE(30,9)
  9    FORMAT(10X,≠PHI≠,7X,≠CUM. PERCENT≠,3X,≠FREQ. PERCENT≠)
       WRITE(30,7777)
7777   FORMAT(1H )
       WRITE(30,7777)
       WRITE  (30,10)  (DDPHI(I),DCUMPCT(I),FREQPCT(I),I=L,M)
10     FORMAT (2X,F12.2,2X,F12.4,2X,F12.4)
       WRITE(30,7778)
7778   FORMAT(1H0)
       WRITE(30,7778)
       WRITE(30,7778)
C
C NEXT SECTION IS FOR PUNCHED OUTPUT
       IF(IFPUNCH .EQ. 2) GO TO 11
       IF(IFPUNCH .EQ. 3) GO TO 11
       GO TO 12
 11    WRITE(40,9)
       WRITE(40,10)  (DDPHI(I),DCUMPCT(I),FREQPCT(I),I=L,M)
 12    CONTINUE
       RETURN
       END
C
C
C
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
        SUBROUTINE GSPLOT(TITLL,CUMWTP,FREQP,X,LOPHI,HIPHI,
     1  DELPHI,NPOINTS,ACCNO)
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C
C THIS SUBROUTINE PLOTS THE CUMULATIVE AND FREQUENCY CURVES
C ON THE CALCOMP PLOTTER.  IT WAS WRITTEN BY KEN KEELING AND
```

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C NICK PISIAS AT OSU.  IT USES PLOTTING COMMANDS
C AND SUBROUTINES IN THE OS-3 FORTRAN LIBRARY
C AT OREGON STATE UNIVERSITY.  REFER TO: GEMPERLE AND KEELING,
C 1970, GEOPHYSICAL DATA REDUCTION AND PLOTTING COMPUTER
C PROGRAMS, TECHNICAL REPORT NO. 180, REFERENCE 70-10,
C SCHOOL OF OCEANOGRAPHY, OREGON STATE UNIVERSITY
C
C
C
C
      REAL LOPHI
      INTEGER  PENUP, PENDOWN, END
      DIMENSION TITLL(5),CUMWTP(150),FREQP(150),X(150)
      INTEGER COUNT
      DATA  (COUNT=0)
C
C X IS ARRAY OF X AXIS VALUES TO PLOT CUMWTP AND FREQP AGAINST.
C IN THIS CASE, IT IS THE ARRAY OF PHI VALUES.
C CUMWTP IS AN ARRAY OF Y AXIS VALUES
C FREQP IS ANOTHER ARRAY OF Y AXIS VALUES
C N AND NPOINTS ARE THE DIMENSIONS OF X,CUMWTP, AND FREQP
C
C NEXT STATEMENT DEFINES LOPHI TO BE -2.00 SO THAT
C ALL PLOTS WILL HAVE THE SAME LEFT AXIS.
C THIS FACILITATES SAMPLE TO SAMPLE COMPARISONS.
C
      LOPHI= -2.00
C
      COUNT = COUNT + 1
      PENDOWN = 2
      PENUP = 3
      END = -3
      AMAX = 0.
      N = NPOINTS
      ADJUST = LOPHI
      RLENGTH = (HIPHI-LOPHI)/0.5
      SCALER= 2.0
      DO 10 I = 1,N
      IF (FREQP(I) .GT. AMAX) AMAX = FREQP(I)
10    CONTINUE
      REMEBER = RLENGTH
      IF(RR.GT.REMEBER)REMEBER = RR
      LENGTH = IFIX(RLENGTH)
      KCOUNT = MODF(COUNT,3)
      IF(KCOUNT.EQ.1)SHIFT = 0.0
      IF(KCOUNT.EQ.2)SHIFT = 9.0
      IF(KCOUNT.EQ.0)SHIFT = 18.0
      FSCALE = 6. / AMAX
      YFIRST = (AMAX - FLOAT (IFIX (AMAX))) * FSCALE
      YNEXT = ( 6. - YFIRST ) / FLOAT ( IFIX (AMAX))
      AMAX = FLOAT ( IFIX (AMAX))
      ENCODE (8,100,RTYSCALE) AMAX
  100 FORMAT (F8.2)
      CSCALE = 6. / CUMWTP(N)
      ENCODE(5,1000,RLOPHI)LOPHI
      ENCODE(5,1000,HHIPHI)HIPHI
      ENCODE(8,2000,DDELPHI)DELPHI
 1000 FORMAT(F5.2)
 2000 FORMAT(≠DEL=≠,F4.2)
      CALL PLOTSYMB(-.4,-.5+SHIFT,.21,RLOPHI,0.,8)
      CALL PLOTSYMB(RLENGTH/2.,-.5+SHIFT,.21,DDELPHI,0.,8)
      CALL PLOTSYMB(RLENGTH-.4,-.5+SHIFT,.21,HHIPHI,0.,8)
      CALL PLOTSYMB (0.,-1.0+SHIFT,.21,ACCNO,0.,8)
      CALL PLOTSYMB(4.,-1.0+SHIFT,.21,TITLL,0.,40)
      CALL PLOT (0.,SHIFT,PENUP)
      DO 15 I = 1,5
      YINCRE = I + SHIFT
      CALL PLOT (0.,YINCRE,PENDOWN)
      CALL PLOT (-.05,YINCRE,PENDOWN)
      CALL PLOT (.05,YINCRE,PENDOWN)
   15 CALL PLOT (0.,YINCRE,PENDOWN)
      CALL PLOT (0.,6.0+SHIFT,PENDOWN)
      CALL PLOT (RLENGTH,6.0+SHIFT,PENDOWN)
      Y = 6. - YFIRST + SHIFT
      CALL PLOT (RLENGTH,Y,PENDOWN)
      CALL PLOT (RLENGTH-.05,Y,PENDOWN)
      CALL PLOT (RLENGTH+.05,Y,PENDOWN)
      CALL PLOTSYMB (RLENGTH,Y,.21,RTYSCALE,0.,8)
      CALL PLOT (RLENGTH+.05,Y,PENUP)
      CALL PLOT (RLENGTH,Y,PENDOWN)
      J = AMAX - 1
      DO 16 I = 1,J
      YNOW = Y - YNEXT * I
      CALL PLOT (RLENGTH,YNOW,PENDOWN)
      CALL PLOT (RLENGTH-.05,YNOW,PENDOWN)
```

```
      CALL  PLOT  (RLENGTH+.05,YNOW,PENDOWN)
   16 CALL  PLOT  (RLENGTH,YNOW,PENDOWN)
      CALL  PLOT  (RLENGTH,0.+SHIFT,PENDOWN)
      CALL  PLOT(FLOAT(LENGTH),.0+SHIFT,PENDOWN)
      CALL  PLOT(FLOAT(LENGTH),0.05+SHIFT,PENDOWN)
      CALL  PLOT(FLOAT(LENGTH),-.05+SHIFT,PENDOWN)
      CALL  PLOT(FLOAT(LENGTH),0.0+SHIFT,PENDOWN)
      DO 17 I = 1,LENGTH
      XINCRE = LENGTH - I
      CALL  PLOT  (XINCRE,0.+SHIFT,PENDOWN)
      CALL  PLOT  (XINCRE,-.05+SHIFT,PENDOWN)
      CALL  PLOT  (XINCRE,.05+SHIFT,PENDOWN)
   17 CALL  PLOT  (XINCRE,0.+SHIFT,PENDOWN)
      CALL  PLOT  (0.,0.+SHIFT,PENDOWN)
      CALL  PLOT  (SCALER*(X(1)-ADJUST),CUMWTP(1)*CSCALE+SHIFT,PENUP)
      DO 20 I=2,N
20    CALL  PLOT(SCALER*(X(I)-ADJUST),CUMWTP(I)*CSCALE+SHIFT,PENDOWN)
      CALL  PLOT(SCALER*(X(N-1)-ADJUST),FREQP(N-1)*FSCALE+SHIFT,PENUP)
      DO 30 I=3,N
      J = N - I + 1
30    CALL  PLOT  (SCALER*(X(J)-ADJUST),FREQP(J)*FSCALE+SHIFT,PENDOWN)
      IF(KCOUNT.NE.0)GO TO 40
      CALL  PLOT(0.0,0.0,END)
      CALL  PLOTINT(REMEBER+5.0,0.0,10)
      RR = 0.0
      RETURN
   40 RR = REMEBER
      RETURN
      END
C
C
C
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
      SUBROUTINE STATS(TITLL,CUMWTP,FREQP,X,LOPHI,HIPHI,
     1  DELPHI,NPOINTS,ACCNO)
C
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C
C
C
C
C THIS SUBROUTINE CALCULATES GRAIN SIZE STATISTICS
C BY THE INMAN AND THE FOLK AND WARD TECHNIQUES.
C IT WAS WRITTEN BY NICK PISIAS AT OSU.
C
C THESE TECHNIQUES ARE DESCRIBED IN THE FOLLOWING PUBLICATIONS:
C
C  INMAN, 1952, JOUR. SEDIMENTARY PETROLOGY, V. 22,NO. 3
C  FOLK AND WARD, 1957, JOUR. SEDIMENTARY PETROLOGY, V. 27,NO. 1
C
C
C
      DIMENSION TITLL(5),CUMWTP(150),FREQP(150),X(150)
      REAL LOPHI
      REAL MEANI,MEDI,KURTI,KURTF,MEANF
C
C
      LOPHI=-2.00
C
C
      PHISTART = LOPHI
      P = DELPHI
      N = NPOINTS
      FF = 0.0
      DO 2030 JJ = 1, N
 2030 FF = FF + FREQP(JJ)
      DO 2040 I=1,N
      R=5.-CUMWTP(I)
      IF(R.LT.0.) GO TO 2042
      H=R
2040  M=I
C
C NOTE: P5, P16, P25, ETC. ARE THE PHI VALUES AT THE 5TH, 16TH,
C 25TH, ETC. PERCENTILES.
C
2042  P5=P*H/(H-R)+X(M)
      DO 2045 I=M,N
      R=16.-CUMWTP(I)
      IF(R.LT.0) GO TO 2047
      H=R
```

```
2045  MM=I
2047  P16=P*H/(H-R)+X(MM)
      DO 2050 I=MM,N
      R=25.-CUMWTP(I)
      IF(R.LT.0.) GO TO 2052
      H=R
2050   M=I
2052  P25=P*H/(H-R)+X(M)
      DO 2055 I=M,N
      R=50.-CUMWTP(I)
      IF(R.LT.0.) GO TO 2057
      H=R
2055  MM=I
2057  P50=P*H/(H-R)+X(MM)
      DO 2060 I=MM,N
      R=75.-CUMWTP(I)
      IF(R.LT.0.) GO TO 2062
      H=R
2060  M=I
2062  P75=P*H/(H-R)+X(M)
      DO 2065 I=M,N
      R=84.-CUMWTP(I)
      IF(R.LT.0.) GO TO 2067
       H=R
2065  MM=I
2067  P84=P*H/(H-R)+X(MM)
      DO 2070 I=MM,N
      R=95.-CUMWTP(I)
      IF(R.LT.0.) GO TO 2072
      H=R
2070  M=I
2072  P95=P*H/(H-R)+X(M)
C
C
C NEXT SECTION CALCULATES INMAN STATISTICS
C
      MEANI=0.5*(P16+P84)
      MEDI=P50
      DEVI=0.5*(P84-P16)
      SKEWI=(MEANI-MEDI)/DEVI
      SK2I=(0.5*(P5+P95)-MEDI)/DEVI
      KURTI=(0.5*(P95-P5)-DEVI)/DEVI
C
C   NEXT SECTION CALCULATES FOLK AND WARD STATISTICS
C
      MEANF=(P16+P50+P84)/3.
      SORTF=(P84-P16)/4.+(P95-P5)/6.6
      SKEWF=(P16+P84-2.*P50)/(2.*(P84-P16))+(P5+P95-2.*P50)/(2.*
     2     (P95-P5))
      KURTF=(P95-P5)/(2.44*(P75-P25))
C
C NEXT SECTION WRITES OUT THE CALCULATED GRAIN SIZE
C STATISTICS.
C
      WRITE(30,2002)ACCNO
2002  FORMAT(31X,≠ ACCESSION NUMBER  ≠,A7//)
      WRITE(30,2004)MEDI,MEANI,DEVI,SKEWI,SK2I,KURTI
2004  FORMAT(≠0 INMAN STATISTICS ..... MEDIAN ≠,F6.3,11X,≠MEAN ≠,
     2 F6.3,8X,≠ DEVIATION ≠,F6.3,/,24X,≠SKEWNESS ≠,F6.3,10X,
     3 ≠SECOND SKEWNESS ≠,F6.3,8X,≠ KURTOSIS≠,F6.3)
      WRITE(30,2006)MEANF,SORTF,SKEWF,KURTF
2006  FORMAT(≠0 FOLK AND WARD STATISTICS .... MEAN ≠,F6.3,12X,
     2 ≠ SORTING ≠,F6.3,/,26X,≠ SKEWNESS ≠,F6.3,11X,≠ KURTOSIS ≠,F6.3)
      WRITE(30,2007)
 2007 FORMAT(1H1)
      RETURN
      END
```

*SJRUN

The program SJRUN takes the raw, unformatted punched paper tape data and converts it to a BCD format so it can be accessed by the data reduction programs. This program is in CDC-3300 COMPASS language and is compiled as an overlay for ease of operation. During the conversion two output files are generated, one for the formatted data and the second for abnormalities present in the raw data. Equip LUN 11 to file containing raw data. The output files are equipped to LUNS 20 and 21 (formatted data and errors data respectively). To run the program, type *SJUN on teletype while in control mode. A listing of the first line of data points and the number of lines of data points of each sample is output to help monitor the program.

```
         IDENT     FIXTAPE
         ENTRY     FIXTAPE
         ENTRY     ZEROFIX

         INCLUDE   *SYSMAC

         STATBDEF


FIXTAPE  UJP       IMPURE

FIX.20   EQU       *
         ENA       0
         STA       CNT

FIX.01   EQU       *
         RTJ       CHAR
         UJP       AA.00
         UJP       AA.11
         UJP       AA.1X
         UJP       AA.0X
         UJP       AA.1XE
         UJP       AA.0XE
AA.00    EQU       *
         RTJ       TIME
         77        AA.00.C
         UJP       FIX.01
AA.11    EQU       *
         RTJ       TIME
         77        AA.11.C
         UJP       FIX.03
AA.1X    EQU       *
         RTJ       TIME
         77        AA.1X.C
         UJP       FIX.06
AA.0X    EQU       *
         RTJ       TIME
         77        AA.0X.C
         UJP       FIX.01
AA.1XE   EQU       *
         RTJ       TIME
         77        AA.1XE.C
         UJP       FIX.01
AA.0XE   EQU       *
         RTJ       TIME
         77        AA.0XE.C
         UJP       FIX.01


FIX.06   EQU       *
         STA       C1

FIX.05   EQU       *
         RTJ       CHAR
         UJP       BB.00
         UJP       BB.11
         UJP       BB.1X
         UJP       BB.0X
         UJP       BB.1XE
         UJP       BB.0XE
BB.00    EQU       *
         RTJ       TIME
         77        BB.00.C
         UJP       FIX.08
BB.11    EQU       *
         RTJ       TIME
         77        BB.11.C
         UJP       FIX.05
BB.1X    EQU       *
         RTJ       TIME
         77        BB.1X.C
         UJP       FIX.02
BB.0X    EQU       *
         RTJ       TIME
         77        BB.0X.C
         UJP       FIX.09
BB.1XE   EQU       *
         RTJ       TIME
         77        BB.1XE.C
         UJP       FIX.05
```

```
BB.0XE   EQU     *
         RTJ     TIME
         77      BB.0XE.C
         UJP     FIX.07


FIX.08   EQU     *
         STA     C2
         RTJ     STORE

FIX.12   EQU     *
         LDA     CNT
         INA     1
         STA     CNT
         ASG     1999
         UJP     FIX.07
         UJP     FIX.23

FIX.07   EQU     *
         RTJ     CHAR
         UJP     CC.00
         UJP     CC.11
         UJP     CC.1X
         UJP     CC.0X
         UJP     CC.1XE
         UJP     CC.0XE
CC.00    EQU     *
         RTJ     TIME
         77      CC.00.C
         UJP     FIX.21
CC.11    EQU     *
         RTJ     TIME
         77      CC.11.C
         UJP     FIX.04
CC.1X    EQU     *
         RTJ     TIME
         77      CC.1X.C
         UJP     FIX.06
CC.0X    EQU     *
         RTJ     TIME
         77      CC.0X.C
         UJP     FIX.07
CC.1XE   EQU     *
         RTJ     TIME
         77      CC.1XE.C
         UJP     FIX.07
CC.0XE   EQU     *
         RTJ     TIME
         77      CC.0XE.C
         UJP     FIX.07


FIX.21   EQU     *
         RTJ     CHAR
         UJP     DD.00
         UJP     DD.11
         UJP     DD.1X
         UJP     DD.0X
         UJP     DD.1XE
         UJP     DD.0XE
DD.00    EQU     *
         RTJ     TIME
         77      DD.00.C
         UJP     FIX.22
DD.11    EQU     *
         RTJ     TIME
         77      DD.11.C
         UJP     FIX.07
DD.1X    EQU     *
         RTJ     TIME
         77      DD.1X.C
         UJP     FIX.06
DD.0X    EQU     *
         RTJ     TIME
         77      DD.0X.C
         UJP     FIX.07
DD.1XE   EQU     *
         RTJ     TIME
         77      DD.1XE.C
         UJP     FIX.07
DD.0XE   EQU     *
         RTJ     TIME
         77      DD.0XE.C
         UJP     FIX.07
```

```
FIX.22    EQU       *
          RTJ       CHAR
          UJP       EE.00
          UJP       EE.11
          UJP       EE.1X
          UJP       EE.0X
          UJP       EE.1XE
          UJP       EE.0XE
EE.00     EQU       *
          RTJ       TIME
          77        EE.00.C
          UJP       FIX.23
EE.11     EQU       *
          RTJ       TIME
          77        EE.11.C
          UJP       FIX.07
EE.1X     EQU       *
          RTJ       TIME
          77        EE.1X.C
          UJP       FIX.06
EE.0X     EQU       *
          RTJ       TIME
          77        EE.0X.C
          UJP       FIX.07
EE.1XE    EQU       *
          RTJ       TIME
          77        EE.1XE.C
          UJP       FIX.07
EE.0XE    EQU       *
          RTJ       TIME
          77        EE.0XE.C
          UJP       FIX.07

FIX.23    EQU       *
          LDI       CNT,X1
          ENA       9999
          STA       ARRAY,X1
          UJP,I     FIXTAPE

FIX.02    EQU       *
          LDQ       C1
          AQJ,EQ    FF.SAM
FF.DIF    EQU       *
          RTJ       TIME
          77        FF.DIF.C
          UJP       FIX.06
FF.SAM    EQU       *
          RTJ       TIME
          77        FF.SAM.C
          UJP       FIX.05

FIX.03    EQU       *
          STA       C1

FIX.09    EQU       *
          RTJ       CHAR
          UJP       GG.00
          UJP       GG.11
          UJP       GG.1X
          UJP       GG.0X
          UJP       GG.1XE
          UJP       GG.0XE
GG.00     EQU       *
          RTJ       TIME
          77        GG.00.C
          UJP       FIX.24
GG.11     EQU       *
          RTJ       TIME
          77        GG.11.C
          UJP       FIX.09
GG.1X     EQU       *
          RTJ       TIME
          77        GG.1X.C
          UJP       FIX.06
GG.0X     EQU       *
          RTJ       TIME
          77        GG.0X.C
          UJP       FIX.08
GG.1XE    EQU       *
```

```
          RTJ       TIME
          77        GG.1XE.C
          UJP       FIX.20
GG.0XE    EQU       *
          RTJ       TIME
          77        GG.0XE.C
          UJP       FIX.20

FIX.24    EQU       *
          STA       C2

FIX.10    EQU       *
          RTJ       CHAR
          UJP       HH.00
          UJP       HH.11
          UJP       HH.1X
          UJP       HH.0X
          UJP       HH.1XE
          UJP       HH.0XE
HH.00     EQU       *
          RTJ       TIME
          77        HH.00.C
          UJP       FIX.20
HH.11     EQU       *
          RTJ       TIME
          77        HH.11.C
          UJP       FIX.09
HH.1X     EQU       *
          RTJ       TIME
          77        HH.1X.C
          UJP       FIX.25
HH.0X     EQU       *
          RTJ       TIME
          77        HH.0X.C
          UJP       FIX.10
HH.1XE    EQU       *
          RTJ       TIME
          77        HH.1XE.C
          UJP       FIX.20
HH.0XE    EQU       *
          RTJ       TIME
          77        HH.0XE.C
          UJP       FIX.20

FIX.25    EQU       *
          STA       C3
          RTJ       STORE
          LDA       C3
          STA       C1
          UJP       FIX.12

FIX.04    EQU       *
          STA       C1

FIX.11    EQU       *
          RTJ       CHAR
          UJP       II.00
          UJP       II.11
          UJP       II.1X
          UJP       II.0X
          UJP       II.1XE
          UJP       II.0XE
II.00     EQU       *
          RTJ       TIME
          77        II.00.C
          UJP       FIX.08
II.11     EQU       *
          RTJ       TIME
          77        II.11.C
          UJP       FIX.11
II.1X     EQU       *
          RTJ       TIME
          77        II.1X.C
          UJP       FIX.05
II.0X     EQU       *
          RTJ       TIME
          77        II.0X.C
          UJP       FIX.08
II.1XE    EQU       *
          RTJ       TIME
          77        II.1XE.C
          UJP       FIX.07
```

```
II.0XE   EQU      *
         RTJ      TIME
         77       II.0XE.C
         UJP      FIX.07


STORE    UJP      IMPURE
         LDA      C2
         ANA      40B
         STA      SIGN
         LDAQ     C1
         ANQ      37B
         SHA      24-6
         SHAQ     6
         LDA      SIGN
         ASE      40B
         XOQ,S    -0
         LDI      CNT,X1
         STQ      ARRAY,X1
         UJP,I    STORE


         EUA
CHAR     UJP      IMPURE
         RTJ      NEXT
         UJP      FIX.23
         AEU
         ASE      0
         UJP      CH.0
         UJP      CHAR
CH.0     EQU      *
         ASE      377B
         UJP      CH.1
         ENA      1
         RAD      CHAR
         UJP      CHAR-1
CH.1     EQU      *
         UJP      CH.4
         ENI      7,X1
         ENI      0,X2
         SHA      23
         AZJ,GE   *+2
         INI      1,X2
         IJD      *-3,X1
         TIA      X2
         SHA      23
         AZJ,GE   CH.4
         ENA      2
         RAD      CHAR
CH.4     EQU      *
         ENA      2
         RAD      CHAR
         EUA
         SHA      24-8
         AZJ,LT   CHAR-1
         ENA      1
         RAD      CHAR
         UJP      CHAR-1


TIME     UJP      IMPURE
         STA      TIME.A
         LDA,I    TIME
         STA      TIME.I
         ENA      1
         RAD,I    TIME.I
         RAD      TIME
         LDA      TIME.A
         UJP,I    TIME


ZEROFIX  UJP      IMPURE
         ENI      ZEROCNT1,X1
         ENA      0
         STA      ZEROIT1,X1
         IJD      *-1,X1
         ENI      ZEROCNT2,X1
         ENA      0
         STA      ZEROIT2,X1
         IJD      *-1,X1
         UJP      ZEROFIX


NEXT     UJP      IMPURE
```

```
           SSH         NX.ONOFF
           UJP         NX.2ND
           LDI         NX.INDEX,X1
NX.CHECK   ISG         62+IMPURE,X1
           UJP         NX.FIRST
           ENA         NX.ARRAY
           ENQ         62
           READ        11
           SHA         FPBIT-EODBIT
           AZJ,LT      NX.END
           SHA         EODBIT-EOFBIT
           AZJ,LT      NX.END
           XOQ,S       -0
           INQ         62
           SHAQ        24
           SWA         NX.CHECK
           ENI         0,X1
           STI         NX.INDEX,X1

NX.FIRST   EQU         *
           LDA         NX.ARRAY,X1
           SHA         -12
           UJP         NX.GOOD

NX.2ND     EQU         *
           LDI         NX.INDEX,X1
           LDA         NX.ARRAY,X1
           ANA         377B
           INI         1,X1
           STI         NX.INDEX,X1
NX.GOOD    EQU         *
           AEU
           ENA         1
           RAD         NEXT
           EUA
           UJP,I       NEXT

NX.END     EQU         *
           ENA         0
           UJP,I       NEXT


TTYNEXT    UJP         IMPURE
           ENA         1
           RAD         TTYNEXT
           CTI
           UJP,I       TTYNEXT


NX.ONOFF   OCT         52525252
NX.INDEX   DEC         62+IMPURE
NX.ARRAY   BSS         65

ZEROIT1    EQU         *
TIME.A     BSS         1
TIME.I     BSS         1
C1         BSS         1
C2         BSS         1
C3         BSS         1
SIGN       BSS         1
ZEROCNT1   EQU         *-ZEROIT1-1


           COMMON
ZEROIT2    EQU         *
CNT        BSS         1
ARRAY      BSS         2000
AA.00.C    BSS         1
AA.11.C    BSS         1
AA.1X.C    BSS         1
AA.0X.C    BSS         1
AA.1XE.C   BSS         1
AA.0XE.C   BSS         1
BB.00.C    BSS         1
BB.11.C    BSS         1
BB.1X.C    BSS         1
BB.0X.C    BSS         1
BB.1XE.C   BSS         1
BB.0XE.C   BSS         1
CC.00.C    BSS         1
CC.11.C    BSS         1
CC.1X.C    BSS         1
CC.0X.C    BSS         1
CC.1XE.C   BSS         1
```

```
CC.0XE.C BSS       1
DD.00.C  BSS       1
DD.11.C  BSS       1
DD.1X.C  BSS       1
DD.0X.C  BSS       1
DD.1XE.C BSS       1
DD.0XE.C BSS       1
EE.00.C  BSS       1
EE.11.C  BSS       1
EE.1X.C  BSS       1
EE.0X.C  BSS       1
EE.1XE.C BSS       1
EE.0XE.C BSS       1
FF.DIF.C BSS       1
FF.SAM.C BSS       1
         BSS       4
GG.00.C  BSS       1
GG.11.C  BSS       1
GG.1X.C  BSS       1
GG.0X.C  BSS       1
GG.1XE.C BSS       1
GG.0XE.C BSS       1
HH.00.C  BSS       1
HH.11.C  BSS       1
HH.1X.C  BSS       1
HH.0X.C  BSS       1
HH.1XE.C BSS       1
HH.0XE.C BSS       1
II.00.C  BSS       1
II.11.C  BSS       1
II.1X.C  BSS       1
II.0X.C  BSS       1
II.1XE.C BSS       1
II.0XE.C BSS       1
ZEROCNT2 EQU       *-ZEROIT2-1

         END
```

4. REFERENCES

Anderson, J. U., 1963, An improved pretreatment for mineralogical analysis of samples containing organic matter, in Clays and Clay Minerals, v. 10. Proc. 10th National Conf. on Clays and Clay Minerals, 1961, pp. 380-388.

Blatt, H., G. Middleton, R. Murray, 1972, Origin of Sedimentary Rocks. Prentice-Hall Inc., New Jersey, 634 pp.

Cahn Instrument Company, 1975, Instruction manual for the Cahn automatic electrobalance, Cahn Division, Ventron Instruments Corp., Paramount, California.

Dauphin, J. P., 1972, Size distribution of chemically extracted quartz used to characterize fine-grained sediments. Unpublished Master's Thesis, Oregon State University, Corvallis, Oregon.

Folk, R. L. and W. C. Ward, 1957, Brazos River Bar: a study in the significance of grain size parameters. J. Sed. Petrol. 27: 3-27.

Friedman, G. M., 1961, Distinction between dune, beach, and river sands from their textural characteristics. J. Sed. Petrol. 31:514-529.

Gibbs, R. J., M. D. Matthews, and D. A. Link, 1971, The relationship between sphere size and settling velocity, J. Sed. Petrol. 41:7-18.

Inman, D. L., 1952, Measures for describing the size distributions of sediments. J. Sed. Petrol. 22:125-145.

Krumbein, W. C., 1938, Size frequency distribution of sediments and the normal phi curve. J. Sed. Petrol. 8:84-90.

Krumbein, W. C. and F. J. Pettijohn, 1938, Manual of Sedimentary Petrology, Appleton-Century-Crofts, Inc., N. Y., 549 pp.

Müller, G., 1967, Methods in Sedimentary Petrology. Hafner Publishing Co., New York - London, 283 pp.

Oser, R. K., 1972a, Textural analysis of fine-grained sediments: pelagic sediments of the northwest Pacific. Unpublished M. S. thesis, Oregon State University, Corvallis, Oregon.

Oser, R. K., 1972b, Sedimentary components of northwest Pacific pelagic sediments. J. Sed. Petrol. 42:461-467.

Poole, D. M., 1957, Size analysis of sand by a sedimentation technique. J. Sed. Petrol. 27:460-468.

Royse, C. F., 1970, An Introduction to Sediment Analysis, Arizona State University, 180 pp.

Swift, D. J. P., J. R. Schubel, and R. W. Sheldon, 1972, Size analysis of fine grained suspended sediments: a review. J. Sed. Petrol. 42:122-134.