

MACROGRANOMETER

The Macrogranometer is a computerized sedimentation balance for analysis of sand-sized water insoluble material. It uses gravity sedimentation from one level (stratified sedimentation) in water.

With the version MC 86, the measured data (PSI distribution) is displayed during sedimentation. After the analysis is completed, the graphical display can be printed out, and, if required, stored on a flexible disk. Then (=off line), by using our FORTRAN software on your computer, the stored data can be transferred to your FORTRAN computer.

Distributions of eight selectable variables, such as grain size, density, grain shape, and Reynolds' number, can be obtained. All variables are resolved into 401 logarithmically equidistant intervals. The directly measured variable is local settling rate, which can be converted into a newly introduced standard settling rate. Other calculated variables are: grain size, shape, and density, each expressed either directly or included in a variable Reynolds' number. Grain size is applicable if shape and density are known and can be assumed constant. For material with a constant and known grain size (a narrow sieve fraction), either a density distribution (if shape is taken constant), or a shape distribution (if density is taken constant) can be computed. To each variable, mean, spread, asymmetry and peakedness are calculated both as moment and percentile distribution characteristics. Optional software includes: separation of up to five mixed distribution components, each normally distributed (method of Dr. I. Clark and Dr. M.W. Clark); distribution adjustment to a sieve analysis; etc..

MEASURING RANGE

The measuring range depends on the material density, which contributes to the kinetic energy of sedimenting particles. However, near both the coarse and fine size limits, the analysis quality begins to suffer from marginal physical conditions.

Near the coarse size limit (particles coarser than 1mm, and especially coarser than 2mm), strong particle impact causes both a balance pan vibration and a dynamic load increase. Also, the coarsest particles, because of their relatively great mass, are available in a very low quantity by number, and show a poor statistical representativity. Fortunately, their sedimentation is so fast that this deficiency can easily be made up by the program segments Split Cumulation and Mean Analysis which average the repeated "split analyses" (see page 30). We strongly recommend this method.

Near the fine size limit, the particles do not have energy enough to surpass viscous forces of the surrounding water and to separate from each other. Though the sample introduction device (vibrating Venetian blind) helps disperse the particles when strongest concentrated (at the beginning of sedimentation), the amount of the finest sample tail must be minimum in order to reduce the mutual particle influence, i.e., low concentration of fine particles is required. This is why particular care has been devoted to developing the Macrogranometer's Underwater Balance. Its unusually high sensitivity enables 0.01% resolution even for 0.1 gram samples. Hints on how to choose optimum sample size are given in the Appendix "Sample Size".

material examples	typical density [g/cm ³]	grain size range [mm]
quartz, aluminum etc.	2.65	0.044 to 4.0
heavy minerals, abrasives, etc.	3.5	0.035 to 2.0
ores of iron metals, copper, etc.	5 - 8	0.025 to 1.0
heavy metals (lead, tungsten, platinum, gold)	15-22	0.016 to 0.5

SEDIMENTATION vs. SIEVING

Stratified sedimentation (=from one level) of a sand sized material in water yields excellent, continuous, and rapid particle separation. The Macrogranometer makes full use of this benefit; its large sedimentation space and advanced technology result in unprecedented accuracy, performance and comfort. This makes it superior both to classical sieving analyzers and to most settling tubes (for example: Emery's settling tube, Woods Hole Rapid Sediment Analyzer, etc).

Sedimentational size of a grain is controlled by its mass, volume (density) and shape, whereas the sieve and optical measures are one-level dimensions only.

Particle specific surface is proportional to both particle nonsphericity and fineness (=particle decrease); this proportionality is consistently valid for sedimentational size only, but not for sieve size which increases with nonsphericity, particularly with flatness. This is why the sedimentational size is consistent with particle specific surface, whereas sieve size of nonspherical grains biases specific surface calculated from it (see also page 6).

In sedimentation, particles separate in proportion to their settling rate and thus to their energy; in a stratified (=from one level) sedimentation of a homogeneous (=one density) material, the coarse particles move constantly apart from the finer ones leaving them behind. In sieving, the particles separate with inverse proportionality to their size: the finer the size the more sieves and coarse particles they must pass; having the lowest energy, the finest particles must pass all sieves and all coarser particles. The latter ones obstacles them and limits their access to sieve holes.

In sedimentation, the separation is controlled by the resistance of a fluid which reduces the settling rate continuously; settling rate even of a nonspherical sand sized particle is invariably given because the non-viscous fluid drag keeps it in a defined position. In sieving, the separation is controlled by the resistance of a solid which affects the nonspherical grain passing through a sieve hole discontinuously and abruptly; a random position of a nonspherical particle results into sizing randomness and ambiguity.

Sedimentation handles individual particles: it assigns a specific settling rate to each particle. Sieving handles particles grouped into intervals about at least ten times wider than is the sedimentational resolution. Sieve results, include error due to random grain position, limited grain access to sieve hole, large sieve intervals, low sample representativity of each sieve interval, etc.

Though sieving has some disadvantages, it represents a direct size measurement method. Therefore, it can not be replaced by sedimentation; similarly, sedimentation can not be replaced by sieving. Sedimentation and precision sieving combined provide additional information on density and/or shape distribution (see also Logarithmic Grain Size, PHI, page 6). For this purpose, exceptional care must be devoted to sieving quality in order to approach the accuracy level of sedimentation. Screens with galvanically deposited circular holes and wet (alcohol) sieving must be used.

MEASURING PRINCIPLE

A Venetian Blind on top of the sedimentation column is used as a sample release device to start sedimentation. Dry sample is evenly spread on the lamellae immersed in water about 7 mm deep. Floating particles are wet by a distilled water spray in order that all sink onto the lamellae. The open water surface is closed by a cover lid to avoid contact not only with open but also with enclosed air (bubbles are removed). The Sedimentation Column is made of heavy duty glass modules, the cross sectional diameter is 20 cm, the sedimentational length is 180 cm.

After the Venetian Blind released the sample for sedimentation upon operator's command on the system's keyboard, the grains start distributing along the sedimentation length. The underwater weight of a sample which is depositing on the Underwater Balance pan is sensed as a positive voltage of the HBM's 3073 Carrier Frequency Measuring amplifier. This voltage (maximum +10,000 Volts DC) is converted into binary numbers from 0 to 32767 by a high speed 16-bit analog-to-digital converter (ADC) of the Electronic Module's PCB with a rate of 10,000 measurements/second, which are integrated by the Electronic Module's microcomputer in two steps: (1) with a constant rate of 10 measurements/millisecond, providing 1 integrated measurement per millisecond; (2) with variable time intervals - corresponding to a series of equal intervals of settling rate logarithm, PSI (see page 4 - 5). No data smoothing is applied onto the measured results.

Except the manual sample introduction into the Venetian Blind, the whole remaining operation is accomplished in a computer dialogue displayed on a monitor. The operator enters commands or answers on a key board, and all necessary operations, such as sample removal from the Underwater Balance pan, are automatically executed according to the operational software; temperature is sensed at two levels, and entered into the analysis record which can be stored onto a diskette as a file.

VARIABLES

The word "variable" has, of course, many usages. In this Manual, if not clear from text (for example, variable as adjective means "changing") or otherwise specified, it is used in two meanings:

- 1 Independent or dependent variable of frequency distribution (independent variables page 4-13, dependent variables on this page later);
- 2 Changing values of sample and measuring environment properties used in the GRM program, the menu Variables (page 17 - 22); in order to emphasize this special meaning, the first letter is Capitalized, printed bold and underlined: Variable(s).

In studying frequency distributions, one must be aware of meaning and suitability of both the independent and dependent variables. The independent variable is that quantity which assumes a set of values, such as grain size. The dependent variable describes the amount of the independent variable to each of its value, such as frequency. The mathematical relationship defining the dependent variable is known as a function of the independent variable.

The independent variable in this Manual corresponds to the dispersity unit defined by Hans RUMPF (1975, page 8; Dispersitätsgröße in German language):

»Dispersity Unit is a physical quantity specified by a numerical value and unit dimension; this quantity can describe a particle collective by a distribution function.«

Five dispersity units are described on page 5 - 13 of this Manual: settling rate, grain size, grain density, grain shape and Reynolds' number. Their distributions can be calculated and plotted by the FORTRAN 'GRMPROC' program (page 35).

The frequency type (=dependent variable) can have zero through three dimensions (currently, the Macrogranometer provides frequency by mass only):

1 Volume - 3 dimensions (or its linear function mass which includes material density), is most commonly suitable for sand-sized materials, however, not always without doubt as some authors do; the suitability depends on how well the physical meaning of mass (it quantifies matter) is effective in a given application. In general, a mass (volume) frequency is suitable for closed sedimentation systems characterized by material conservation (the total sediment mass remains constant) if no substantial material loss due to solution etc. can occur.

2 Area - 2 dimensions (particle surface, cross sectional and projected areas etc.), is suitable if surface dependent physical properties, such as specific surface, permeability, adsorption and filtration properties etc., are to be obtained. It is interesting that specific surface can be obtained from two parameters of Rosin-Rammler distribution (in which the mass frequency is used) provided the mass frequency distribution of the given material does follow the Rosin-Rammler distribution closely enough (G. HERDAN, 1960, page 195).

3 Length - 1 dimension (intercept, chord), is rarely used except in few cases of scanning image analysis (then a conversion into volume frequency is applied).

4 Number - zero dimension (frequency by counts), is common in social statistics, to some degree in biometrics. Its justification implies that occurrence of items is independent of their geometry, particularly size. Geometric objects such as grains can rarely justify this frequency type. However, many counting devices such as the Coulter-Counter were developed due to convenient technology: one must always be sure about the frequency type resulting from these devices. A recalculation of number frequency is possible, however, some important terms must be met (such as a consistent and/or known grain shape, very narrow intervals of logarithmic grain size, etc.). If these conditions are not sufficiently satisfied, the converted results are likely to be erroneous.

If both the independent and dependent variables are suitably selected, the resulting distribution may closely approach the normal (=Gaussian) distribution type or its mixtures. The closeness of fit can be seen graphically in diagrams whose frequency on y-axis is transformed into the normal (Gaussian) distribution function as shown on Fig. 1; the resulting notation is in standard deviation units.

Figure 1

Logarithm used for independent variables

Similar to a percentage, logarithm gives a relative scaling to a variable. Without this scaling, the variable changes are linear and independent of any value; this is in conflict with physical nature of the variables in this paper. For example, linear change of grain size, say ± 1 millimeter around a mean size of 1 millimeter, dramatically distorts particularity of a material finer than 2 millimeters: the "coarse" interval, 1mm - 2mm, includes a coarse sand class only, whereas the "fine" interval, 0mm - 1mm, contains everything finer than 1mm *without* a fine limit: not only a medium and fine sand, silt, clay, and colloidal classes, but also molecular, atomic and subatomic sizes approaching indefinitely zero. The same change of ± 1 millimeter loses completely a physical (and common) sense for mean size smaller than 1 millimeter because zero and negative size does not exist.

Logarithmic notation also solves the zero value problem: whereas zero value of a quantity such as an object's size makes that quantity (and object itself) non-existent, still some "scientific" literature uses zero values in diagram scales and in mathematical operations with those quantities (such as using normal size distribution instead of log normal size distribution or normal PHI-size distribution). Logarithmic notation eliminates the zero from consideration in a natural way: any logarithm of zero is minus infinity...

Logarithmic scaling has long been applied unconsciously and intuitively as a common sense solution by introducing geometric progressions and scales (Archimedes, 287 - 212 b.C.). In ancient astronomy 2100 years ago, Hipparchus applied a geometric progression for brightness classification of stars; his method, slightly modified, is still in use today as the magnitude scale. In architecture, the golden section ratio controlled proportions first from esthetic reasons, but soon also from practical constructional advantages. Acoustic perception of doubled frequencies (halved wavelength) is known as octave interval which is a logarithm to the base 2 of tone frequency (one of the basic consonance principles in western musical harmony). In electroacoustics, telecommunication and electronics, various logarithms are defined, such as neper, decibel, decilog. Engineering notations are of logarithmic nature (e.g., electron radius being $2.82 \cdot 10^{-13}$ cm). Geologic time was also recognized to show equally significant changes in a logarithmic scale (G. F. PHILLIPS, 1958; Nature, v. 181, No. 4624, p. 1652-1653).

The first geometric (=in effect logarithmic) scale important for grain size was suggested by Julius von SPARRE (1858) and Peter von RITTINGER (1862, 1863, 1867): it requires that sieve intervals correspond to grains with doubled settling velocity. Apparently using Stokes' law, von SPARRE arrived at a scale with a quotient $2^{0.5}$ (page 376). Though one may object that the Newton's not Stokes' law was valid for 0.125" - 8" grain sizes, he surely presented a pioneer idea for a logarithmic settling velocity.

Independently of Europe, Johann August UDDEN (1898) suggested the first geometric grain size scale for soil and sediment classification in U.S.A.: its basic value was 1 mm, and coefficient was 2 (or $\sqrt{2}$). UDDEN (1914) extended it from 12 to 19 values; Chester K. WENTWORTH (1922) made it popular, and in 1933, justified the scale grades physically.

William Christian KRUMBEIN (1934, 1936) perfected this concept into the first truly logarithmic scale of grain size (PHI). Though KRUMBEIN (1937) introduced a scale based on decadic logarithm (ZETA scale), and V.P. BATURIN (1943) suggested another decadic log-scale (GAMMA-scale; Pierre WEYDERT, 1976, ignorant of Baturin's GAMMA scale, called it ALPHA scale), most geologists are using the PHI scale.

Jiri BREZINA (1963) introduced the logarithmic scaling to settling rate: his BETA was a decadic logarithm of settling rate in millimeter/second. In the present paper, he applies the log scaling also to grain density, shape, and Reynolds' number to simplify formulas and computation, however, without attempt to recommend the new logarithmic variables for common usage.

Recognizing the need for popular logarithmic scaling, Gerald V. MIDDLETON (1967) created his PSI unit in a way similar to the widely used PHI. He used the following features:

- 1 negative binary logarithm,
- 2 settling rate in cm/sec,
- 3 greek letter PSI (similar to PHI).

The Macrogranometer measures directly distribution of local PSI settling rate; from this, distributions of other independent variables can be calculated by its FORTRAN program. All independent variables are expressed in logarithm and resolved into 401 steps. Two logarithm types are used:

1 negative binary logarithm = -logarithm to the base 2, each step is 0.02 wide:

PSI (logarithmic settling velocity, three versions are available), PHI (logarithmic grain size), LRS (logarithmic grain density) and LSF (logarithmic Shape Factor); each step is 0.02 wide.

2 positive decadic logarithm = +logarithm to the base 10, each step is 0.01 wide: LRE (logarithmic Reynolds' number, three versions are available).

¹ In this Manual, the new logarithmic variables are expressed mostly in their non-logarithmic form in order to make reading convenient. For example, SF' is used instead of LSF, RS or Rs instead of LRS. However, the logarithmic form is always implied in all considerations.

Variable 3:

Logarithmic Grain Size, PHI

Synonym of 'grain': particle

Due to its direct measurement, grain size is the natural variable of sieving. Sedimentation, however, is capable of providing accurate data which enable to calculate grain size with unprecedented resolution. Correctly, such a grain size should be indicated as sedimentational grain size. Because sedimentation of sand sized particles is resisted in proportion to specific surface, and the specific surface is proportional to *both* the particle fineness *and* nonsphericity, the sedimentational grain size, in contrast to sieve size, is consistent with specific surface (nonsphericity is inversely proportional to sieve size because it causes an apparent coarsening of sieved particles). Whereas even the most precise sieving can not approach sedimentation in accuracy and resolution, sieving can not replace sedimentation and sedimentation can not replace sieving in all situations. But sedimentation *combined* with precise sieving can yield considerably enhanced information (see also 'Sedimentation vs. Sieving', page 2).

According to W.C. KRUMBEIN (1934), the grain size is expressed in negative binary logarithm (=logarithm to the base 2), PHI (English transcription of the greek letter Ø):

$$PHI = -\log_2 d_{[mm/mm]}$$

The Macrogranometer's range: the coarse limit is -2.00 PHI (=2⁺² mm = 4.0 mm),
the fine limit is +5.00 PHI (=2⁻⁵ mm = 0.015625 mm).

Our FORTRAN software calculates grain size from settling rate according to the equations (1) through (7) of J. BREZINA (1979), which enable us to include a specified grain shape. As a hydraulically effective characteristic, Shape Factor (SF) of Arthur Thomas COREY (1949) and J.S. McNOWN + J. MALAIKA (1950) is used. It is defined as a dimensionless ratio number relating the minimum, medium and maximum mutually perpendicular particle dimensions, *a*, *b*, *c* respectively, known as the Corey's Shape Factor (in this paper, the original symbol "SE" is preferred to "CSF" used in recent publications of some authors):

$$SF = a.(b.c)^{-0.5}$$

According to definition, the maximum value 1.0 is reached if *a* = *b* = *c*. This maximum is valid not only for isometrical (naturally worn, irregular) particles but also for smooth spheres. However, physically, and hydrodynamically in particular, smooth spheres behave much differently from isometrical particles which do have some surface roughness. Because the surface roughness, due to lack of both data and measuring method, could not be treated separately in the equations (1) through (7) of J. BREZINA (1979), and the available data being valid for irregular naturally worn particles, the less common smooth spheres became the hydrodynamic shape factor (indicated by SF') greater (SF' about 1.18) than isometrical (rough) particles, such as a cube (SF' about 1.0). Correctly, a roughness coefficient, hydrodynamically consistent with the Shape Factor, should be developed and used jointly with it. In this paper, the hydrodynamic Shape Factor (values up to 1.0) is a compound coefficient including basic shape and roughness. Roughness reduction or absence causes an SF' increase up to about 18% (for isometrical particles up to SF'=1.18).

The most typical SF' values of beach and river sands are approximately SF'=0.65. Medium within the actual shape of natural sand, this value is closer in characteristic than a value which refers to smooth spheres (1.18). For standardization reasons, we recommend SF'=0.65 and *Rs* (density) = 2.65 g/cm³ for routine usage. Only if both the particle shape and density are fairly constant and correctly specified, can the variable grain size be correctly calculated.

The PSI - PHI conversion implies a change of distribution type (J. BREZINA, 1963). The following four diagrams demonstrate this effect as described below. Fig. 2 shows three normal (=Gaussian) PSI distributions with identical standard deviation: S.D. = 1.0 PSI, but each with a different mean: MEAN = -1 PSI, -2 PSI, -3 PSI. Plotted on a PSI probability chart, these distributions are parallel straight lines. The Y axis is scaled in standard deviation units instead of percentage (see Figure 1). Figures. 3, 4 and 5 show the three PSI distributions from Fig. 2 converted into PHI distributions with various Shape Factor values: SF = 1.2 through 0.1 by 0.1 step. Note that these PHI distributions are bent toward coarser size (=smaller or more negative PHI values) which means a negative PHI skewness (see Fig. 8). Also, the bending increases the general slope of the PHI distribution curves which means an increasing (and changing) standard deviation (see also Fig. 7).

Variable 1 + 2: Logarithmic Settling Velocity, PSI; Local and Standard

*Synonyms of 'setling': sedimentation, fall;**Synonyms of 'velocity': rate.*

Settling velocity is the most natural dispersity variable measured by sedimentation. In the Macrogranometer, the depositing sample is weighed at sedimentation time instants which correspond to a series of 0.02-intervals of settling rate logarithm, PSI (English transcription of the greek letter Ψ) according to G.V. MIDDLETON, 1967:

$$PSI = -\log_2 v = -\text{logarithm to the base 2 of settling velocity in centimeter/second.}$$

The Macrogranometer's range: the fast limit is -5.00 PSI (=2⁺⁵ cm/sec = 32.000 cm/sec),
the slow limit is +3.00 PSI (=2⁻³ cm/sec = 0.125 cm/sec).

PSI is a very useful dispersity variable for two main reasons:

1 Most of the well known negative PHI distribution skewness of some water deposited medium sands does not occur in PSI distribution of the same material as shown by Jiri BREZINA (1963) by transformations between log grain size and log settling rate (he used his BETA settling rate). The negative skewing effect is shown on pages 6 - 10 (Fig. 1 - 4 and Fig. 7).

2 Settling rate is free of assumption about a constant shape and/or density, and can very efficiently be converted into another dispersity variable.

However, because the measuring terms - gravity acceleration and temperature - may vary, the PSI values referring to the measured data are valid for the local measuring terms only, and - strictly speaking - are not compatible with PSI data measured at a different temperature and/or under a different gravity acceleration. In order to recognize this effect, we call the measured PSI local PSI, and introduce a standard PSI valid for internationally acceptable standard terms (the conversion can be accomplished by our FORTRAN program):

distilled water, temperature 24.00°C, gravity acceleration 980.665 gal.

The main advantage of the standard PSI is that it is internationally comparable. Of course, the conversion involves a slight inaccuracy due to current estimation and non-constancy with grain size of both particle shape and density; however, the possible error is usually lower than ± 0.01 PSI.

Nevertheless, a more important error of any PSI may be introduced by impurity of the distilled water used for sedimentation. All conversions assume that the distilled water is free of dissolved admixtures; in particular, dissolved gas decreases strongly kinematic viscosity and density of water, which are calculated from the measured temperature for absolutely pure water.

The term "distilled water" is recently used even for water purified by other methods than distillation including boiling and vapor condensation. These other methods based on filtration, ionic exchange and/or (electro)osmosis may meet highest purity requirements common in analytical chemistry, but they do not remove dissolved gas (air). Water purified this way should be called demineralized or deionized but not distilled. The dissolved gas can be removed (de-aerated) by boiling (the higher temperature action can be supported by vacuum) and vibration (ultrasonic treatment). Also, special care must be given to the way in which the de-aerated water is transported and filled into the sedimentation column (disturbance and mixing with air must be avoided).

Standard PSI is a compound (bivariate) variable because it is defined only if two of the three quantities (PHI, *Rs*, SF) are constant, and the remaining one becomes a PSI joint variable. This is why three versions of the standard PSI (=for three material types) are recognized, identified by File Name Extension, and can be calculated (see also the three Reynolds' number versions, page 13):

PSI JOINT VARIABLE	CONSTANT	File Name EXTENSION
PHI	<i>Rs</i> , SF	.SPH
<i>Rs</i>	PHI, SF	.SRS
SF	PHI, <i>Rs</i>	.SSF

NORMAL (GAUSSIAN) PSI DISTRIBUTIONS

mean = -1PSI, -2PSI, -3PSI
standard deviation = 1PSI

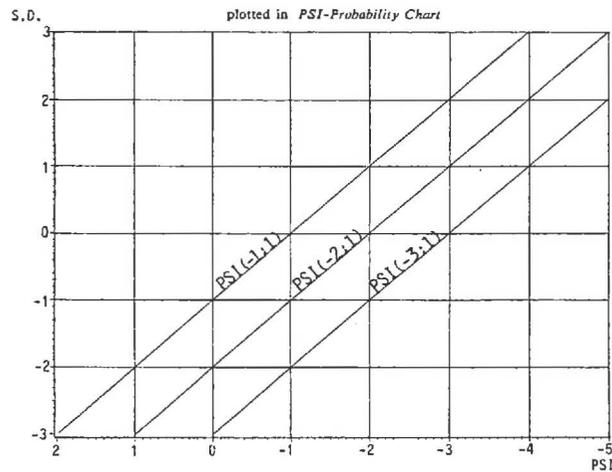


Figure. 2

NORMAL (GAUSSIAN) PSI DISTRIBUTIONS

mean = -1PSI, standard deviation = 1PSI
converted into PHI Distributions with
variable shape factor: SF=1.2 through 0.1 by 0.1-steps

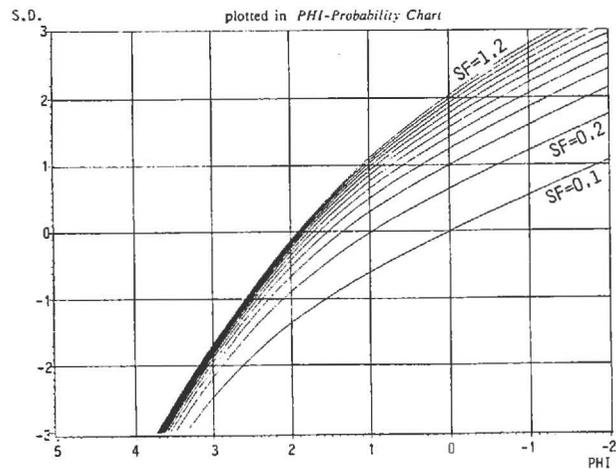


Figure. 3

NORMAL (GAUSSIAN) PSI DISTRIBUTIONS

mean = -3PSI, standard deviation = 1PSI
converted into PHI Distributions with
variable shape factor: SF=1.2 through 0.1 by 0.1-steps

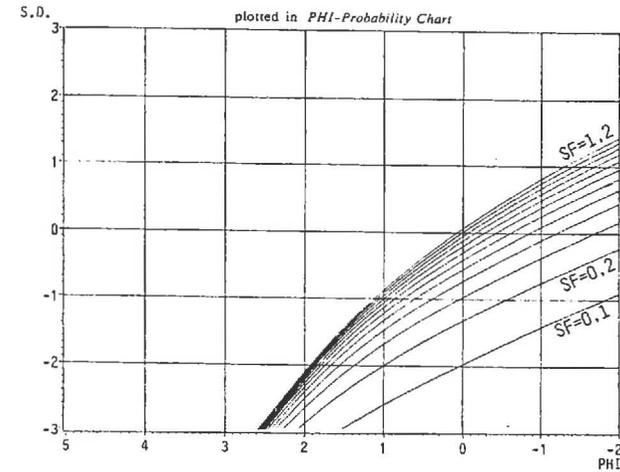


Figure 4

NORMAL (GAUSSIAN) PSI DISTRIBUTIONS

mean = -2PSI, standard deviation = 1PSI
converted into PHI Distributions with
variable shape factor: SF=1.2 through 0.1 by 0.1-steps

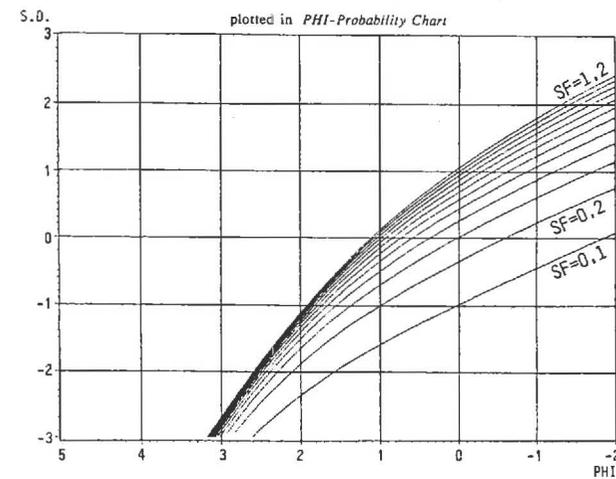


Figure 5

Due to the fact that sedimentologists are currently using settling rate formulas for smooth spheres only (this implies a hydraulic equivalence to smooth spheres), distortions of natural sand size distributions calculated this way from settling tube data are inevitably disqualifying the results by this simplification as follows:

1 Size is reduced in proportion to grain size and nonspherical shape; for example, irregular (naturally worn) particles with nominal diameter 4mm and SF=0.6 are then equivalent to smooth spheres with diameter 2mm only (see Fig. 6).

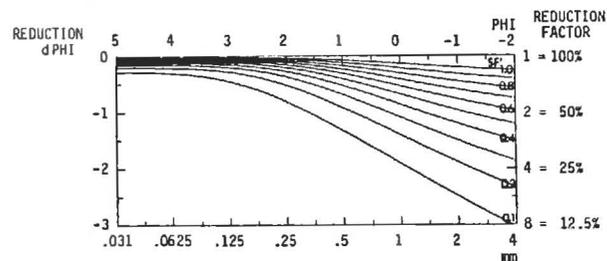


Figure 6

2 Spread (PHI standard deviation) becomes greater (a worse sorting) toward coarser particles and in proportion to nonspherical shape (see Fig. 7).

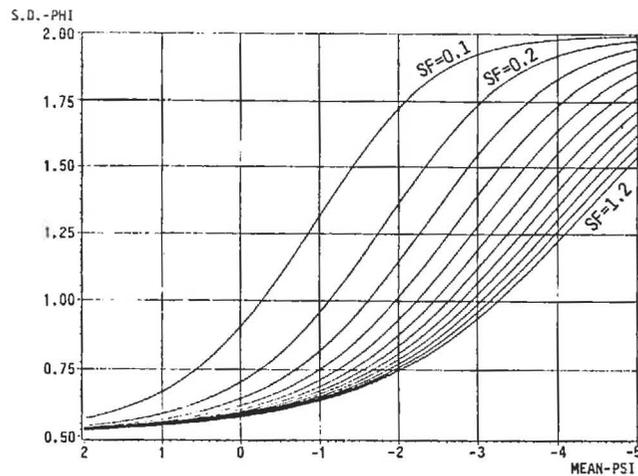


Figure 7

3 Asymmetry characterized by skewness becomes (in PHI notation) more negative with nonspherical particles toward finer particles (see Fig. 8).

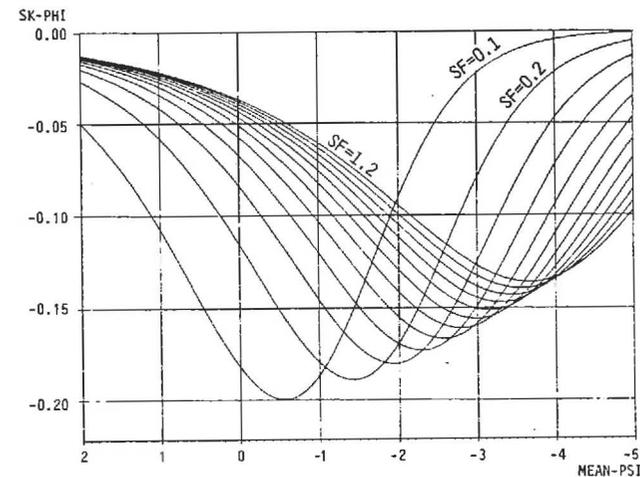


Figure 8

In order to minimize the distortions due to shape factor ignorance, Jiri BREZINA (1979) introduced a hydrodynamic equivalence to a rotational ellipsoid specified by a shape factor. This equivalence includes not only the same standard settling rate, particle volume and density, but also the same basic shape; it leads to the hydrodynamic shape factor 'SF' explained on page 6.

Variable 4: Logarithmic Grain Density, LRS

Density is related to *specific gravity*:
density has dimension $[g/cm^3]$, *specific gravity's* dimension is unity

$$LRS = +\log_2 R_s$$

LRS is a 3-character abbreviation of $\log_2 R_s$, where R stands for the greek letter RHO, and the subscript s for 'solid'.
The symbol R_s was introduced in classical work of A.T. COREY (1949), and has consistently been used in papers such as E.F. SCHULZ, R.H. WILDE and M.L. ALBERTSON (1954), and B.C. COLBY + R.P. CHRISTENSEN (1957).

The Macrogranometer's FORTRAN software can efficiently determine a density distribution of equally sized heterogeneous materials, such as a narrow sieved heavy mineral concentrate, without tedious separations as in heavy liquids with various density. Combined density distributions of various sieve fractions provide valuable information about the size-density distribution relationship. A FORTRAN program for a three dimensional plot is under development (available in September 1986).

The determination accuracy of a density distribution depends on the following factors:

- 1 Relative equivalence of sieve intervals: if expressed in millimeters, the intervals must form a geometric series, if expressed in PHI notation, they must form an arithmetic series.
- 2 Narrowness of sieve intervals: sieve intervals smaller than 0.25 PHI are recommended (the millimeter size ratio should be smaller than 1.189 or greater than 0.841);
- 3 Sieve quality: galvanically deposited (=not woven) screens with circular holes are best;
- 4 Sieving quality: wet sieving increases screening performance (screening with denaturated alcohol enables a faster work than with water due to easier drying).
- 5 Limited shape variation of particles coarser than 0.2mm (or of particles with settling rate faster than about 2 cm/sec, = PSI < -1); the settling rate of particles finer than 0.2 mm is almost not affected by current shape variation (SF between 1.18 and 0.2).

Factors 3 and 4 improve sieving separation capability which decreases toward finer size; because the best sieving can at best approach a separation capability of about ± 3 micron, the almost maximum permissible sieve interval of 0.2 PHI can be extended down toward fine size up to the interval 4.4 to 4.2 PHI (=0.047 to 0.041 mm) which only corresponds to the interval width of 6 micron. Factors 3, 4 and 5 combined result in an optimum size range between 0.08mm and 0.3mm, which allows a sieve size interval of 0.1 PHI.

If, with coarser particles, the shape variation is so great that it significantly affects the settling rate, the following method helps determine the shape factor:

- 1 The narrow sieved fraction is separated into narrow density intervals in heavy liquids;
- 2 Each sieve + density fraction is analyzed by the Macrogranometer.
- 3 The resulting PSI distributions of samples with homogeneous size and density are converted into LSF distributions (see the next dispersity variable, page 12).
- 4 The mean SF-values calculated by the LSF program segment can be entered as a "variable constant" for each density interval for calculation of the density distribution (shape, in some degree, is dependent on particle's mineral composition [i.e. density] and size, mean SF-values of each distribution will probably correlate well with LRS and PHI).

The PSI-LRS conversion implies a change of distribution type, similar to the PSI-PHI conversion. This effect will be treated in a later edition of this Manual.

Variable 5: Logarithmic Shape Factor, LSF

Shape Factor of A.T. COREY (1949) and J.S. McNOWN + J. MALAIKA (1950) is used
(see PHI Grain Size, page 6 of this Manual)

$$LSF = -\log_2 SF$$

LSF is a 3-character abbreviation of $-\log_2 SF$;
L stands for logarithm, SF stands for Shape Factor;
this negative binary logarithm is consistent with PHI

The Macrogranometer's FORTRAN software can determine a grain shape distribution of equally sized and homogeneous (=equally sized) material, such as narrow sieved one mineral fraction without a complicated optical measurement of grain shape. The settling rate will be interpreted in terms of shape factor for grains with a constant size and density. If the narrow sieved fraction does not consist of one but more variously heavy minerals, the heavy liquid separation is unavoidable in order to obtain homogeneous subsamples, each with a narrow density interval of equally sized material. A FORTRAN program for a three dimensional plot will be available in October 1986.

The determination accuracy of a shape distribution depends on the factors 1 through 4 listed for density distribution (Grain Density, page 11), and on two additional ones:

- 5 Relative equivalence of the density intervals: if expressed in g/cm^3 , the intervals must form a geometric series; expressed in binary logarithm, they must form an arithmetic series.
- 6 Narrowness of the density intervals: expressed in g/cm^3 , they should be in ratio less than 1.1 or 0.9 for a low accuracy, or 1.05 or 0.95 for a higher accuracy; expressed in LSF notation, the interval should be smaller the 0.14 for a low accuracy, or smaller than 0.07 for a higher accuracy.

Note that the sedimentational method of shape determination loses its sensitivity (and validity) with decreasing grain size as shown in Fig. 5 of J. BREZINA (1979): PSI settling rate curves for various SF values converge toward finer particle size.

Therefore, the Shape Factor calculation is limited to coarser particles which provide sufficient SF resolution due to fairly wide PSI-difference. For example, the PSI-difference between SF 1.2 and 0.1 of equally sized and dense particles decreases 3-times (from 2.35 PSI to 0.77 PSI) if the particle size decreases 32-times (which corresponds to a 5 PHI difference); this is valid for every density. A density change causes an inversely proportional shift of the grain size square root:

PSI-difference for equally sized grains with SF=1.2 and 0.1:		
density $[g/cm^3]$	2.35 PSI Difference	0.77 PSI Difference
2.5	4.000 mm=-2.0 PHI	0.125 mm=+3.0 PHI
5.0	2.828 mm=-1.5 PHI	0.088 mm=+3.5 PHI
10.0	2.000 mm=-1.0 PHI	0.063 mm=+4.0 PHI
20.0	1.414 mm=-0.5 PHI	0.044 mm=+4.5 PHI

The PSI-LSF conversion implies a change of distribution type, similar to the PSI-PHI conversion. This effect will be treated in a later edition of this Manual.

Variable 6, 7, 8: Logarithmic Reynolds' Number, LRELRE is a 3-character abbreviation of $\log_{10} Re$

In order to quantify hydrodynamic circumstances leading to turbulent or laminar flow, Osborne REYNOLDS (1883) defined a dimensionless ratio between inertia and viscous forces of a flowing fluid as follows:

$$Re = LV/n,$$

where L [cm] was a cross sectional diameter of a flow, V [cm/sec] was flow velocity, and n [cm²/sec] was kinematic viscosity of the fluid.

This ratio became one of the most important numbers in hydrodynamics used particularly for consideration of dynamic similarity of models.

In Reynolds' number of *sedimenting particle*, a relative motion between a solid (particle) and the surrounding fluid assigns the function of the cross sectional flow diameter (L) to the particle size (d). This way, the Reynolds' number becomes a significant characteristic of sedimenting particles and of their sedimentation regime. The ratio nature of the Reynolds' number indicates the suitability of its logarithmic scaling.

Because the Reynolds' number is a *compound (bivariate) variable*, it is defined together with a joint variable (size, density or shape). Our FORTRAN program makes possible to determine an LRE distribution not only for the *joint variable PHI* (density and SF are taken constant: RPH distribution) but also for the *joint variable density* (PHI and SF are taken constant: RRS distribution²), and for the *joint variable shape* (PHI and density are taken constant). Therefore, similar to the standard PSI (page 5), three LRE versions for three material types can be calculated; the distribution type is identified by File Name Extension according to the joint variable (see also page 21):

LRE JOINT VARIABLE	CONSTANT	File Name EXTENSION
PHI	Rs, SF	.RPH
Rs	PHI, SF	.RRS
SF	PHI, Rs	.RSF

The PSI-RPH conversion implies a **change of distribution type** which is a compromise between PSI and PHI distribution types (*a medium skewing effect between PSI and PHI*). The choice of LRE may be justified when the PSI distribution shows the same but opposite skewing as the PHI distribution of the same population.

² This term does not have anything to do with the Rosin-Rammler-Sperling, RRS, distribution; in order to avoid confusion, for the Rosin-Rammler-Sperling distribution, the more popular shorter abbreviation "RR distribution" will be used (see also page 3).

MACROGRANOMETER MC86. PARTS:**1 Sedimentation System** (sedimentation length 180 cm)

- 1.1 Two air shock absorbers
- 1.2 Carrying steel ring, chromium plated
- 1.3 Sedimentation column of two heavy duty glass modules
- 1.4 Venetian Blind
- 1.5 Underwater Electronic Balance
- 1.6 Flange disks of acrylic glass, two ones 30 cm, one 20 cm nominal diameter
- 1.7 Accessories (couplers, screwing hardware, tubing etc.)

2 Control Electronic Box

- 2.1 Cabinet
- 2.2 CFM (=Carrier Frequency Measuring) Amplifier
- 2.3 PCB (=Printed Circuit Board) with CPU (MC6809), 64kByte RAM, 4kByte monitor program in EPROM, floppy disk controller, parallel and serial interfaces
- 2.4 PCB with a fast 16-bit ADC, sensor circuitry for temperature and Underwater Electronic Balance position, control circuitry for the Venetian Blind opening and for sample removal from the Underwater Electronic Balance pan, calendar + clock with battery back up
- 2.5 Two Floppy Disk Drives for double density double sided 5 $\frac{1}{4}$ " minidiskettes (each 370 kByte diskette can store more than 100 PSI analyses)
- 2.6 Power Supply
- 2.7 Rear Panel with power switch, power supply filter, and connectors
- 2.8 Cable Distributor and cables

3 Monitor (in some versions integrated in item 2; 12" diagonal, monochrome amber)**4 Keyboard** (PAT 09: with 19 programmable function keys and cursor keys)**5 Printer** (near letter quality matrix, DINA4 paper format, 132 character/line)**6 Software** (written on two 5 $\frac{1}{4}$ "-diskettes; available in compiled code only, not in source):

- 6.1 Operational Software compiled from ASSEMBLER language of the MC6809 (under the FLEX 9.1 Operating System) for PSI analyses (GRM program).
- 6.2 Transfer (TFR) program compiled from ASSEMBLER language of the MC6809 for transferring of data files (and of our FORTRAN program in source) to the buyer's FORTRAN computer.
- 6.3 Processing Software compiled from FORTRAN 77 language (GRMPROC3 program) for conversion of local PSI distributions into those of standard PSI settling rate, PHI grain size and related variables (density, shape factor and Reynolds' number) on a buyer's FORTRAN computer; this software must be compiled on the buyer's FORTRAN computer, however, the copied source code must be deleted after compilation; the buyer is responsible for providing an RS 232C serial line to his FORTRAN computer, and for hardware and software conditioning of receiving preparedness of his computer.

7 Technical Documentation in a ring binder

- 7.1 Macrogranometer Operation Manual (this brochure)
- 7.2 Operation Manual to the CFM amplifier by HBM, Darmstadt
- 7.3 Computer System Manuals (ELTEC System 7000, Eurocom System II V7.2)

NEEDED TOOLS and MATERIALS

1 For installation:

13mm open end wrench (2 each); 12mm, 6mm, 4mm, 2.5mm, 2mm, and 1.4mm hexagonal keys (1 each);

100 liter distilled (not demineralized only) water stored at the level of the settling column top; plastic tubing 16mm inner diameter, long enough to connect the distilled water container outlet to the bottom of the settling tube; compressed air (minimum: 2 bar pressure, approx. 10 liter/minute).

2 For operation:

Medium screwdriver (bar length of at least 70 mm ; tip: 1mm by 5mm), little screwdriver (tip: 0.5mm by 3mm).

TYPICAL SEQUENCE OF WORK

1 Prepare samples to be analyzed (see Appendix), **and a working note book** to record sample and analysis data (see Step 9, page 21).

2 Prepare instrument

2.1 ELECTRONIC CONTROL UNIT:

a) **Set switches** on the front panel of the **Carrier Frequency Measuring (=CFM) Amplifier** to the introductory operative position.

Two switches of the CFM Amplifier are always to be set as follows:

#3 The bridge excitation switch S1 (=3 alternate positions switch) - 2.5 V (=middle position);

#8 The bridge selector switch S21 (=3 alternate positions switch) - inductive half bridge (=lower position).

Four controls (three switches and one indicator) will be **used during instrument operation**;

introductory positions of the **three switches** are as follows:

#10 Range selection switch S2 (=10 active and 1 inactive alternate positions) - a low amplification (=a broad range, such as maximum 50 mV/V is preferred);

#12 Bridge zero fine adjustment P1 (=continuous 10-revolution potentiometer) - its position results from electronic balance zeroing (page 19);

#13 Bridge zero coarse adjustment S4 (=zero and ± 5 alternate position switch) - its position results from electronic balance zeroing (page 19); however, a zero-close position is to be pursued.

b) **Insert diskettes** into pertinent floppy disk drives: the program diskette into the left drive (=drive 0), the data diskette into the right drive (=drive 1), both diskettes must be positioned with their upper side facing to the left; **lock** both diskettes in the slots.

2.2 **UNDERWATER BALANCE:** check its horizontal position; if inclined more than about 10° from horizontal position, do not clean the Venetian Blind then (=action 2.3), but after the end of action 5 (page 14).

2.3 **VENETIAN BLIND:** clean and close the lamellae by hand (this action is prohibitive if the Underwater Balance is tilted: some grains could fall into the inner parts of the Balance); remove excessive water, or refill water if incomplete (remove bubbles in the Venetian Blind).

3 Switch on:

3.1 **MONITOR** - pull the switch on the lower right corner;

3.2 **PRINTER** if joined to system (some printers, such as Epson LX80, however, must have their serial cable disconnected when transfer to and from the host computer is applied);

3.3 **ELECTRONIC CONTROL UNIT** - raise the toggle switch on the rear panel; 10 minutes are needed to warm up the CFM amplifier. *longer 30 minutes*

RESPONSE:

1 ELECTRONIC CONTROL UNIT - a green light appears on the top of the CFM amplifier; the left floppy disk drive (with a program diskette) has a red diode which will light when that drive is in operation; in fact, the FLEX 9.1 Operating System is loaded from this diskette into the computer's memory.

2 PRINTER - its status lights appear: they should indicate 'on line' (otherwise the on line must be activated by pushing a toggle switch).

3 MONITOR - its status light appears, the first portion of the Screen 1 is displayed during the FLEX loading within a few seconds:

Eurocom Control V5.3
FLEX 9.1

MAY 25, 1986

PRESS "PROG" AND "L" SIMULTANEOUSLY

4 Press "PROG" and "L" keys simultaneously as requested:

RESPONSE 1 (Screen 1 Continuation):

F1-F19 loaded

EXPLANATION:

The function keys F1 through F19 were loaded.

RESPONSE 2 (a next Screen 1 continuation, a few seconds later):

```
*****
*
*» Start GRM with F1-key                stop with ESC-KEY *
*
*» Start TFR with F2-key                stop with ESC-KEY *
* Enter COPY COM1; FILENAME.DAT        on IBM-Computer *
*
*
*» Show .DAT-files with F11-key         *
*
*****
+++ ■
```

EXPLANATION:

Asterisk frame is a FLEX Menu with 3 choices selectable by function keys F1, F2, F11;

+++ is a prompt of the FLEX Operation System environment;

■ is a flashing cursor.

5 Press F1-key to enter *Granometer (GRM) environment*

RESPONSE 1:

GRM is displayed for a few seconds.

EXPLANATION:

GRM confirms the *GRANOMETER (GRM) ENVIRONMENT*. Various autonomous *program segments (menus)* are used in this environment to perform several independent groups of operations. Each operation, usually together with related ones, can be called by typing a one-character key which initiates a pertinent Menu (program segment). Nevertheless, the F1-key opens first the *Variables menu* (see *Response 2*, page 18). The following menus (program segments) are available:

GRM PROGRAM SEGMENTS (MENUS) AND COMMANDS

Key	Menu Label	Page
V	<u>V</u> ariables (available also by Space Bar).....	18 - 22
	RTN... Update of automatically appearing Variables.....	18
0	<u>Z</u> ERO Balance (a zero, not the letter O).....	23
A	<u>A</u> nalysis (available from Variables environment only).....	25
	Blank Space (pressing Space Bar).....	26
	B..... Beginning of deposition on the Underwater Balance pan.....	26 - 27
	E..... End of sedimentation record.....	27 - 28
L	<u>L</u> ast voltage (anytime after Analysis, but before Balance Clear).....	28
W	<u>W</u> rite File (available from Variables environment only).....	29
S	<u>S</u> plit (available from Variables environment only).....	29
M	<u>M</u> ean (available from Variables environment only).....	29
B	<u>B</u> alance Clear.....(use <u>L</u> ast Voltage first).....	30
R	<u>R</u> ead File (available from Variables environment only).....	30
N	<u>N</u> ew Display.....	31
H	<u>H</u> istogram.....	31
P	<u>P</u> rint Screen.....	32
T	<u>T</u> ime Change.....	33
D	<u>D</u> ate and Time Update.....	33
C	<u>C</u> onstants.....	33
F	<u>F</u> LEX Operating System entrance(GRM data retained); <u>C</u> AT Catalog, <u>D</u> EL Delete File	
ESC	<u>E</u> scape to FLEX Operating System (GRM data lost)	34

Each GRM MENU is enclosed in the following frame:

Macrogranometer	SFB-313 KIEL	Granometry/RTE
	FILENAME.EXT	Date 23.05.86
		Time 09.43.15

Inf : Enter Command Cmd : ■

The top line includes the user's name in the middle, the system name Macrogranometer on the left and the system producer "Granometry" as well as RTE, the software & electronics subsupplier on the right; below, current date and day time appear upon an updating action (page 32). The bottom line, known as STATUS LINE, displays an information prompt, such as "Enter Command", in a MESSAGE FIELD on the left; operator's typing is possible in a COMMAND FIELD on the right (see editing Variables, page 18).

RESPONSE 2 (few seconds after GRM was displayed):

GRM is overwritten by the VARIABLES menu used as the main GRM menu, for example:

Macrogranometer	GRANOMETRY	Granometry/RTE
<u>V</u> ariables		Date 30.07.86 Time 20:07:55■
Sample Name 1 . . .	Load Balance . 0.000	
Sample Name 2 . . .	Temp. Blind . . 26.50	
Sample Number . . .	Temp. Balance . 24.49	
File Name	Temp. Mean. . . 25.49	
Amplif. Range . . .	Temp. Diff. . . 2.01	
Sample Weight . . .	Mean # 0	
Sample Density. URR	Split # 0	
PHI URR	
PSI - Begin . . -5.00	
PSI - End . . . 3.00	PSI - Steps . . 401	
Inf : Are you sure ?	Cmd : V■	

The screen shows three columns within the GRM menu frame:

left hand column middle column
manually entered variables automatically appearing variables can be updated by Return-key
or can be edited under MODE; by Space Bar);

upper right corner (part of the GRM Menu Frame)

Date and Time are always displayed updated, except: after Analysis before Writing a file, and after Reading a file, before a new File Name is entered; check the values and correct them if necessary as described in Step 30, Time Change, page 32.

6 Press Mode key to enter EDITING MODE environment
(This key is located inside the cursor direction key pad)

RESPONSE:

1 Cursor goes into the edit field at the top of the manually entered variables (left hand column):
Sample Name 1 . . ■

2 The status line reads: inf : move cursor

EXPLANATION:

In the EDIT MODE environment, you can enter and/or change the manually entered Variables (left hand column), however, not yet now directly on the screen itself but after picking the selected field of the requested variable to the command field (typing Variable is described in the Step 9, page 19). Mode key is a two position toggle switch; if you do not wish to edit Variables (you have checked them already), press the Mode key again: the Editing Mode will be cancelled; then go to Step 13, page 22.

7 Move Cursor if needed up to the Variable to be selected by cursor direction keys

EXPLANATION:

Move cursor within the edit field of the Variables up and down by using the cursor directional keys in order to select the variable you wish to specify or change. The up and down keys move the cursor by single line, the left upwards and right downwards keys position the cursor into the first and last line respectively; the left and right keys are inoperative. The selection is accomplished by leaving the cursor on the line of the Variable required.

Wait until the Step 8 before entering on the screen. If you accidentally do that, the edit field will be overwritten by the Step 8 and 9 without harm. Do not be upset by some character remainders from the directly typed text even after overwriting: they will be not written into the floppy disk file.

8 Press "Right Margin" key to pick the field of the selected variable. (The right margin key is located on the right top of the cursor direction key pad.)

RESPONSE:

- 1 The status line reads: **Inf : Edit Variable**
2 Cmd : ■ ("Cmd :." is highlighted by inverse display)

EXPLANATION:

1 Cmd : becomes highlighted by inverse display which indicates cancelling of the command mode and introduction of the **EDIT MODE**.

2 ■ (=cursor) appears next to "Cmd :." and includes the selected Variables field. If there was no real character in the Variables field, then only the colon will be picked from that field and shown inverse; it will be overwritten by Steps 9 and 10.

3 Inf : Edit Variable = confirmation of the Edit Mode.

9 Type the Variable value you wish.

RESPONSE:

An existing text, if any, will be overwritten by typing.

EXPLANATION:

The Variables Menu contains information about sample and changing environment which influences the analysis; together with some unchanging data referring to the instrument's site ("Constants"), the information will be included into the header of the Analysis data file.

Three types of manually entered Variable values are distinguished:

1 Strings - allow for unscrutinized text of any alphanumeric and/or special characters up to maximum of 15 characters. They represent your notices which will be stored with the analysis data on floppy disk. The strings are used for the following Variables (examples of values are in *italics*):

Sample Name 1	Nigeria, Antia
Sample Name 2	Quartz 2-.3mm
Sample Number	ABC001
Amplifier Range	1

Sample Name 1 is used for a general sample identification, such as country, project, department or working team;
Sample Name 2 is used for a specific sample identification, such as city, locality, borehole site, operator or material category;
Sample Number should include a running analysis number with a unique sample identification.
Amplifier Range records the Amplifier Range reading of the CFM amplifier. It corresponds to a sample weight according to the following scheme (valid roughly for material with quartz density):

Sample Weight	Amplifier Range
5 - 10 gram	5
2 - 5 gram	2
1 - 2 gram	1
0.5 - 1.0 gram	0.5
0.2 - 0.5 gram	0.2
0.1 - 0.2 gram	0.1
0.05 - 0.1 gram	0.05

2 Parameters are those Variables which modify an action or data processing. The program checks them for character legality and numeric value according to formal restrictions specified below. Still, the operator is responsible for their correctness. Maximum 6 digits for 5 numerals and decimal point, or three characters VAR are allowed as shown below. Decimal *point (not a comma)* must always be used even if zeroes follow, for example, instead of '3 ', 3, or 3.0 or 3.00 must be entered.

Variable	Unit	Default Value	V a l u e	
			minimum	maximum
Sample Weight	[gram]	-	0.01	1 digit before decimal point, eg. 9.999
Sample Density	[g/cm ³]	VAR	1.1	22.5
PHI		VAR	-2.00	+6.00
PSI - Beginning		-5.00	-5.00	<PSI-End
PSI - End		+3.00	>PSI-Beg	+3.00

Sample Weight refers to air dry weight of your specimen. The Sample Weight should match the Amplifier Range recorded under string values. The Sample Weight value will be used for "weighing" SPLITS when averaged by MEAN Analysis if these program segments are applied. However, even if these program segments are not used, the sample weight knowledge is important for a later evaluation of analysis quality: samples excessively large regarding their fineness (grain size value of the 10 percent from the fine distribution tail; see Appendix "Sample Size") may distort the analysis due to strong particle interaction and streaming during sedimentation. Usually, an excessive weight results in coarsening and positive skewing of PSI/PHI distributions.

Recommendation: do not analyze too large samples. To estimate a suitable sample weight, follow the nomograph of J. BREZINA (1970; 1979, page 16, Fig. 9). As a rule, your samples can always be analyzed in parts not exceeding 2 gram. If your material is too coarse to be represented by these 2 gram samples, split the main sample into parts of maximum 2 gram and apply the SPLIT and MEAN program segments (page 29).

The Parameters Sample Density, PHI, and particle shape (Shape Factor SF) are *mutually interdependent* quantities. If one of them is required to be variable, the remaining two must be specified constant by a number and vice versa as follows:

	PHI	density	shape
1	VAR	Const	Const
2	Const	VAR	Const
3	Const	Const	VAR

Shape will be specified in the GRMPROC (=data processing) FORTRAN program.

Sample Density: default value is VAR. In most cases, when the material consists of almost equally dense minerals such as quartz, feldspars, calcite etc (their density is close to 2.65 [g/cm³]), enter a constant density value. If, however, you have good reasons to assume the density is variable in your material, and you wish to determine the density distribution, analyze a narrow sieve fraction: the GRMPROC3 FORTRAN program can convert the measured PSI distribution of equally sized material into density distribution; for this purpose, do not change the default value VAR, but specify a constant value for PHI (arithmetic mean of the sieve interval in PHI is a good compromise).

PHI: default value is VAR (case 1). This is the most common case - the PSI distribution analysis will be converted into a PHI grain size distribution analysis. For this purpose, however, the material should have a consistent density and in some degree a constant shape; the decision about constancy is the operator's responsibility. If however, either density or shape should be out of constancy requirements, for example a significantly high heavy minerals content (more than 2% or 5%) is included, the PHI grain size must be made constant in order to determine the variable density distribution from PSI settling rate distribution (case 2: VAR density).

PSI - Beginning: default value is -5.00 (minimum). This value can be increased by an amount that may not be equal to or greater than PSI - End value: in that case the analysis can not be performed (the Venetian Blind does not open by space bar). With unknown samples, the PSI - Beginning should not be specified in Variables because it can easily and accurately be determined during Analysis sedimentation (by typing B before first grains reach the Underwater Balance pan; see Step 18, page 23). If specified too large, PSI - Beg can be improved during Analysis sedimentation by typing B; if, however, specified too small, it can not be improved during the Analysis sedimentation but later during the GRMPROC3 program. PSI - Beginning value does not harm the analysis record - it has a marking function only to find the upper ('fast') particle limit.

PSI - End: default value is +3.00 (maximum). Be careful by specifying too small a PSI - End because it would terminate the sedimentation record too early: then, if some particles have still not been deposited, they can not be recorded and the analysis becomes disqualified. The PSI - End value can be decreased either by typing a smaller value in Variables by an amount that may not be equal to or smaller than the PSI - Beginning (see above), or, during Analysis sedimentation, by typing E (page 23) when no deposition (deposit increase) is observed. After the sedimentation is terminated, a deposit increase can be recorded anytime later before the Balance Clear program segment (or another Analysis) is applied by typing L - Last Voltage; however, this action is not capable to recover a pertinent sedimentation time which ceased to be counted when PSI - End became active (the Last voltage can not record a specific PSI value of the maximum weight; see this program segment later).

3 File Name is the analysis identification of data to be stored in a file on floppy disk. File Name may consist of no more than 6 characters. Allowed are letters (at least one letter must form the first digit) and numerals, but no special characters, such as a blank space, period, colon, comma, etc.. Upper and lower case letters are not distinguished.

File Name Extension is a three character File Name continuation separated by . (=period). It is automatically assigned and currently not accessible for editing to avoid misinterpretation. The GRM program always assigns .DAT extension (for PSI local, see page 5), the GRMPROC FORTRAN program assigns the following 9 extensions according to the calculated dispersity variable:

.SPH	for PSI Standard	(page 5)	with joint variable	PHI (grain size),
.SRS	for PSI Standard	(page 5)	with joint variable	Rs (density),
.SSF	for PSI Standard	(page 5)	with joint variable	SF (Shape Factor),
.RPH	for LRE	(page 13)	with joint variable	PHI (grain size),
.RRS	for LRE	(page 13)	with joint variable	Rs (density),
.RSF	for LRE	(page 13)	with joint variable	SF (Shape Factor);
.PHI, .LRS, .LSF		(page 6-10, 11 and 12 respectively)	are self explanatory.	

File Name is obligatory: it must always be entered. In order not to overwrite an existing file, a new File Name must be chosen. To avoid an accidental lost of existing file, check the File Names you have used on the current diskette. We strongly recommend keeping a working note book to record files of all floppy disks (every floppy disk can store about 100 Data files, each with one analysis). Example of column labels and few lines of such a working note book is as follows:

DISK NUMBER	FILENAME	DATE	TIME	TEMPE-RATURE	SAMPLE IDENTIFICATION	WEIGHT [gram]	SPLIT	MEAN
001	NGT001	10.05.86	16:07	20.35	Nigeria, Ant.1	0.985	1	-
001	NGT002	10.05.86	16:15	20.43	Nigeria, Ant.2	0.964	2	-
001	NGT003	10.05.86	16:30	20.48	Nigeria, Ant.3	0.971	3	-
001	NGT004	10.05.86	16:37	20.42	Nigeria, Ant.1+2+3	2.920	-	3

If you are still not sure about File Names occurring on a data diskette, check its directory: enter the FLEX Operation System (press Escape key if you are in GRM program, Variables Menu) and press F11 Function key. If you wish to retain current data, go to the Step 33 (page 33).

10 Press "Left Margin" key to enter the Variables value into the Variables field.

(The "Left Margin" key is located on the left top of the cursor direction key pad)

RESPONSE:

1 Cursor returns to the Variable selected during the Step 7 (by the cursor moving) and step 8 (by the "Right Margin" key) into the edit field.

2 The Variable value is entered or updated.

3 The status line reads: **inf : move cursor.**

11 Go to 7 through 10 repeatedly to complete or update the editing of Variables.

12 Press Mode Key to leave the EDITING MODE environment.

RESPONSE:

1 Cursor jumps below the status line.

2 The status line reads: **inf : enter command.**

EXPLANATION:

If all the editing tasks of the Variables are performed, any other Menu can be continued. If the Analysis is to be performed next, before leaving Variables, take a last look at:

File Name:	check its validity, it must not exist on the current diskette;
Temperature Difference:	it must be positive (zero or negative value would disable the Analysis);
Load Balance:	it must be between the values 0.010 and 0.500 Volt (other values disable the Analysis; if needed go to 0 Zero Balance); <i>→ geader!</i>
Amplifier Range:	it should be chosen according to the Sample Weight.

If any change is to be carried out, go to Editing Variables field, Steps 6 through 12 (page 18 - 22).

13 Introduce Sample into the Venetian Blind: can be carried out earlier but not before Step 3; the Step 2.3 must precede Step 13 each time.

13.1 Remove the cover lid of acrylic glass (hold it by its central handle) to open the sample introduction area: a free water surface, diameter 18 cm, will appear.

13.2 Close the Venetian Blind lamellae: turn the knob counter clockwise.

13.3 Spread the whole dry sample over the entire introduction area up to about 1 cm from its outer edge (circle diameter 16 cm); avoid crowding of fine particles. In order that the whole sample will deposit on the lamellae beneath the water surface, floating particles must be sprayed with distilled water (Step 13.4). If a wet sample is to be introduced, the wetting liquid must be distilled water (natural, particularly marine water, and/or dissolved chemicals such as tensides would change water viscosity and density, electrolytes may lead to corrosion, organics may support microorganisms, and soon the whole settling column would have to be thoroughly cleaned).

13.4 Spray the water surface with distilled water from the green glass jar; it should have a temperature a few degrees C° higher than the water surface (store the jar above the Venetian Blind).

13.5 Return carefully the cover lid to close the water surface; plug it gently having both hands leaned on the Venetian Blind, allow for escaping of all air bubbles through the central deaerating hole; abrupt action would squeeze the sample through the lamellae; do not press the cover lid yet.

13.6 Remove excessive water that has poured out from the gap around the cover lid and from its central hole with an injector supplied with the Macrogranometer's Accessories. Now, gently press the cover lid and repeat the water removal. Apply soft clean cloth to dry the surface. If necessary, refill water so that no bubbles remain in the Venetian Blind.

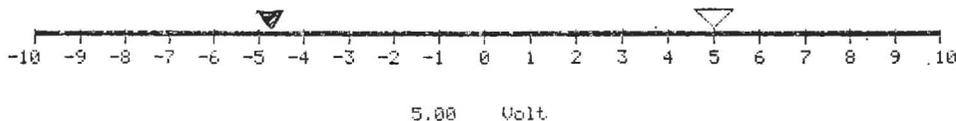
14 Type 0 (=Zero) to enter the ZERO Balance GRM Program Segment (any of the two zero keys on the key board, but not the letter O, may be used).

RESPONSE:

The ZERO BALANCE menu is displayed:

```

Macrogrometer          Stellenbosch          Granometry/RTE
-----
Zero Balance           Date 10.10.84
                       Time 11:22:33
  
```



Inf : Enter Space

Cmd : █

Figure 9

The screen content shows graphically a current load of the Underwater Balance released as the output voltage of the CFM Amplifier without any averaging. The displayed load, from -10 Volt to +10 Volt, is relative because it refers to the applied amplification (range).

On the horizontal voltage scale, values from -10.00 over 0.00 to +10.00 increase from left to right. A triangle arrow points to an instantaneous output voltage which is displayed numerically below to two decimal digits. The triangle arrow appears empty (in contours) for positive voltage values which are permitted for sedimentation; it appears full for negative voltage values which are prohibited for the sedimentation record.

The ZERO BALANCE is used for the following purposes:

A) MECHANICAL ZEROING of the Underwater Balance by screwdriver.

The mechanical zeroing is a vertical centering of the inductive sensors between two soft-magnetic plates fixed on the Balance pan axis. The centering itself is accomplished mechanically with a screwdriver, and monitored on the "Zero Balance" screen; the central position is reached when the bridge of the CFM amplifier is symmetrically balanced, i.e., the coarse and fine bridge adjustments are centered (coarse: 0 mV/V, fine 5.00 mV/V).

The Mechanical Zeroing of the Underwater Balance can be approximately accomplished even without the balance immersed in water by an optional steel disk replacing the Underwater Balance pan. The air weight of the disk is equal to the weight of the original acrylic glass pan reduced by water buoyancy acting on both the acrylic glass pan and other moving parts attached to it.

WARNING:

The mechanical zeroing should never be used frequently. It is justified during the first installation by Granometry, and, exceptionally, after the original mechanical adjustment was accidentally altered (during instrument cleaning etc).

If really necessary, the mechanical zeroing can be accomplished in six steps described below. Needed tools: 2.5mm and 2.0mm hexagonal keys; strong screwdriver, tip 2mm by 5mm, shaft at least 6.5 cm long.

1 Make the Underwater Balance position horizontal if inclined: release the clamp which fixes the motor axis in the axis of the Underwater Balance rotational axis (release two DIN 912 inner hexagonal M3 screws by a 2.5mm hexagonal key), adjust the horizontal position by hand, and fix the clamp.

2 Release fixing of the eccentric rod: two DIN 912 inner hexagonal M3 screws on the bottom of the small aluminum clamp (this clamp is located 1.7 cm below the larger motor axis clamp); one DIN 913 inner hexagonal M4 screw from bottom, inside of the acrylic glass disk (use a 2mm hexagonal key).

3 Turn both the bridge adjustments to zero: the coarse bridge zero adjustment is the CFM Amplifier's knob 13 located bottom left, the fine bridge zero adjustment is the CFM Amplifier's knob 12 (a 10-cycle potentiometer located above the knob 13).

4 Select the lowest amplification (=broadest range): turn the Range Selection Switch S2 (=knob 10 of the CFM amplifier) to 50 mV/V.

5 Turn the eccentric rod in that direction, and so far, until the monitor displays a value as close to zero as possible: the eccentric rod can be turned by a screwdriver inserted into its slot (a screwdriver whose tip is 1mm wide and 5mm long); this action is to be repeated with an increasing amplification, such as 20 mV/V, 10 mV/V, 5 mV/V, 2 mV/V and perhaps 1 mV/V.

However, due to increasing vibration interference, stop when no effective improvement can be achieved; the remaining zeroing is usually so negligible that it can easily be completed electronically; the mechanical zeroing is sufficient if the Coarse Zero Bridge Adjustment switch (knob 13) is within ± 1 mV/V when Electronic Adjustment is performed.

6 Fix the eccentric rod by turning clockwise those screws which released it (Step 2 of Mechanical Zeroing above on this page).

7 Continue with the ELECTRONIC ZEROING.

B) ELECTRONIC ZEROING of the Underwater Balance by the CFM amplifier.

The electronic zeroing means an electronic compensation of a slight mechanical zero offset of the Underwater Balance. The compensation is accomplished by a resistance (and a following capacitance) adjustment of the CFM amplifier bridge.

The typical use is before the ANALYSIS program segment (a slightly positive voltage must be set +0.05 to +0.50 Volt).

The electronic zeroing is currently accomplished by five steps described below (no tools needed).

1 Select amplification - start with a low amplification (=broad range): Turn the Range Selection Switch S2 (knob 10) to such a low amplification at which the triangle voltage pointer appears between the minimum and maximum scale values. Using too a high amplification, the voltage may be out of range, i.e. either lower than -10 Volt or higher than +10 Volt; then, the pointer remains fixed at one of the scale margins. If the Underwater Balance was zeroed shortly before, then the amplification range may not differ from that range which was used for the previously analyzed sample; for example, the original range 0.5 mV/V used for analyzing a 0.923 g specimen will probably be suitable even for the following electronic zeroing of a 0.825 gram sample starting with this low amplification. If, however, the Underwater Balance pan changed its load due to removal of more or less deposit by the Balance Clear program segment, or if some instrument change slightly affected the original mechanical zero position, a low amplification must be selected in order to get the triangle pointer "moving" (between the minimum and maximum voltage).

2 Zero the voltage by an R (=resistance) adjustment: turn the bridge zero fine adjustment P1 (10-revolution potentiometer, knob 10) in such a direction that the triangle pointer moves to zero; if necessary, continue also by turning the bridge zero COARSE adjustment S4 - until the zero voltage is displayed both graphically and numerically.

3 Zero the phase by a C (=capacitance) adjustment: turn the C-Adjustment screw 6 (remove a grey plastic cap beforehand) in such a direction that the red bar of the Modulation Indicator 9 (top left instrument on the CFM amplifier front panel) moves left (=toward zero), and continue until the red bar moves leftmost; a further continuation returns the red bar to right; if this happens revert the screwdriver turning and stop exactly when the red bar is leftmost (almost hidden) which indicates a zero phase unbalance.

4 Increase amplification (decrease range) by turning the Range Selection Switch S2 clockwise by one or more steps.

5 Repeat steps 2, 3 and 4 in as many cycles as a sufficiently high amplification is reached (to: 20 - 10 - 5 - 2 - 1 - 0.5 - 0.2 - 0.1 - 0.05 mV/V). Be sure the step 2 does precede the step 3 and not inversely, otherwise the Electronic Zeroing cannot be accomplished. If the leftmost position of the red bar is seemingly reached under a very high amplification, repeat step 3 (turning of the C-Adjustment screw 6) during the push button 7 (sensitivity expander of the modulation indicator) located below is pressed. The "sufficiently high amplification" should be approximately 5-times higher (the range 5-times smaller) than the desired amplification needed for analysis (Step 6 of Electronic Zeroing below).

6 Select a desirable amplification according to the sample weight as entered into the Variables field (see the scheme on page 18).

C) OTHER USES of the ZERO BALANCE are listed in the *OPERATION PROGRAM MANUAL, 3rd Edition (10 November 1978), page 13*: note that the term "Zero Balance" supersedes the "Voltage Display" of the earlier than 1984 Macrogranometer versions.

The Zero Balance screen shows the dynamic behavior of the Underwater Balance usually due to environmental influence, particularly when a very high amplification is used:

- a) Fast oscillation due to environmental vibration (low frequencies, such as 10 Hz \pm 3 Hz);
- b) Irregular zero drift due to water streaming after sample removal by the Balance Clear (originally strong, it weakens progressively until it disappears within a maximum of about 5 minutes);
- c) Slow drift with a complex path due to environmental temperature change.

The status line of the Zero Balance reads:

Inf : Enter Space

Cmd : ■

15 Press Space Bar to enter and check Variables before Analysis.

RESPONSE:

Variables menu is displayed.

EXPLANATION:

The command Space (=Space Bar) causes an escape from any screen into the Variables menu (the same effect has typing of Y), which is the only escape allowed (typing of another command is not accepted): now the operator has the last chance to check (and correct if necessary) the Variables before the Analysis command is entered (page 17 - 21).

16 Type "A" to begin the ANALYSIS GRM Program Segment.

RESPONSE:

The Analysis frame (Fig. 10) for a PSI distribution plot appears on the screen. The status line reads:

Inf : Enter Space

Cmd : ■

Figure 10

CAUTION: Since now, the environment must be free of electrical and mechanical (vibration, shock etc.) interference during SEDIMENTATION introduced by the following Step 17.

SEDIMENTATION:

17 Press Space Bar to START SEDIMENTATION.

RESPONSE:

Immersed in water, the lamellae of the Venetian Blind open and vibrate around the open position for 2.5 or 3.0 second.

EXPLANATION:

Within the Analysis environment, the command Space (=Space Bar) causes the START OF SEDIMENTATION by opening of the Venetian Blind; this instant defines the commencement of the sedimentation time. The specification of the actual opening time and vibration pulses can be seen in Constants menu (page 33), line "Blind Intv . . . 2500, 60, 35"; the first number, for example "2500", is the opening time in milliseconds, the second number, "60", is the pulse period in milliseconds, and the third number, "35", is the pulse length in milliseconds. As for all Constants, their values were set by Granometry during installation and are currently not accessible for editing. They can be changed by editing and assembling of the Constants program file as described in the Appendix 1. Granometry will gladly accomplish this action, but bears no responsibility for software and hardware damages due to program changes by user.

In the water below the Venetian Blind, the sample begins to distribute along the sedimentation length according to the settling rate of each grain. The sediment load of the Underwater Balance starts to be recorded first at 5.625 second of sedimentation time when the fastest grains with settling rate of 32.000 cm/sec (=5.00 PSI) pass the sedimentation length of 180 cm. Since this moment, a distribution curve is being plotted from left to right at sedimentation time instants which correspond to 0.02 PSI step, starting with -5.00 PSI: -4.98 PSI, -4.96 PSI etc. The 0.02 PSI bars proceed to form with a decreasing rate; 13 bar/second at -5.00 PSI, 5 bar/second at -4.2 PSI, 3 bar/second at -3.2 PSI, 2 bar/second at -2.6 PSI, 1 bar/second at -1.6 PSI; they double their time each successive PSI: 2 second/bar at -.6 PSI, 4 second/bar at 0.4 PSI, 8 second/bar at 1.4 PSI and 16 second/bar at 2.4 PSI.

As long as no grains fall onto the balance pan, the PSI distribution plot starting from the lower left corner of the Analysis frame is an almost straight horizontal line. At the beginning, a slight undulation around the straight line may occur due to initial vibration from the opening of the Venetian Blind. Starting with -5.00 PSI at 0.02 PSI steps, the numeric values of the Underwater Balance load are recorded for a floppy disk file. The maximum value $2^{15}-1 = 32767$ is for 10.00 Volt. The recorded data influenced by vibration before the deposition beginning can be, however, neglected during a later data processing, if a separation mark PSI - Beginning is entered. For this purpose, a deposition (PSI) beginning will be determined (see Step 18).

WATCH the SEDIMENT FRONT APPROACHING the BALANCE PAN and carry out the next action (Step 18) shortly before the first few grains will reach the balance pan:

18 Type "B" to record the DEPOSITION (PSI) BEGINNING (an optional but recommended action).

RESPONSE:

1 The PSI beginning value is marked by a little vertical bar below the currently forming PSI distribution plot beneath the bottom of the Analysis frame.

2 Shortly after this moment, the vertical bars of the PSI distribution plot will rise due to deposition progress on the Underwater Balance pan. The height of each bar corresponds to positive voltage of the \emptyset Zero Balance horizontal plot multiplied by ten (it equals a per centage of the 10.00 Volt); the current numeric value is displayed along the outer side of the right margin.

EXPLANATION:

"B" stands for BEGINNING of the deposition record. The deposition beginning is recorded in terms of a PSI value pertaining to that sedimentation time instant at which "B" was typed; this PSI value overwrites the PSI - Beginning value in the Variables field (the PSI - Beginning default value is -5.00; see page 17 and 20) and will become part of the file header (line 4, 3rd value from left). Step 18 is optional, because a definitive PSI - Beginning value can be determined later when the stored file is loaded into the FORTRAN processing program. But the record of the directly observed deposition beginning helps locate the beginning value of the PSI distribution. The PSI - Beginning is necessary for further data processing.

The deposition record at 0.02 PSI steps proceeds up to a PSI - End value which was entered into the Variables field (page 17 and 20), or was left there as a default (=+3.00 PSI) However, the deposition record end can, similarly to the PSI - Beginning, be activated *earlier* by typing "E" (see Step 19).

WATCH the SEDIMENTATION PROGRESS: when no suspended grains are visible above the Underwater Balance pan (a strong cool light should illuminate the pan) and, if no percentage increase of the PSI distribution is observed, carry out the next action (Step 19):

19 Type "E" to terminate the DEPOSITION RECORD before the PSI - End value stored in the Variables field will be active (an optional but very recommended action).

RESPONSE:

1 The PSI - End value is marked by a little vertical bar above the currently forming PSI distribution plot on the top margin of the Analysis frame.

2 Shortly after "E" was typed (between a fraction of second and about 1 minute), the PSI distribution plot is completed and the differences between a 0.02 PSI step and the previous one are plotted on a magnified scale (in order that the maximum difference aligns itself with the 100 % line): Fig. 11.

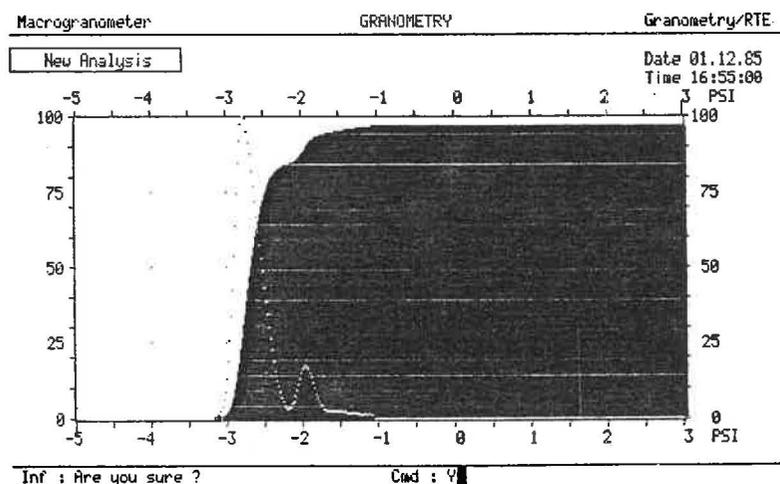


Figure 11

EXPLANATION:

"E" stands for END of the deposition record, PSI - End. Similarly as with the PSI - Beginning, the END of deposition is recorded in terms of the PSI value pertaining to that sedimentation time instant at which "E" was typed; this PSI value overwrites a greater PSI - End value in the Variables field (the maximum PSI - End value is its default value +3.00; see page 17 and 20) and, as such, it will become part of the file header (line 4, 4th value from left).

Contrary to the PSI - Beginning, the typing of "E" stops the real time clock operation and therefore *definitively* terminates the deposition record within a *known* sedimentation time.

20 Type "L" to record the LAST VOLTAGE before BALANCE CLEAR.

RESPONSE:

An additional vertical bar of the PSI distribution will appear behind the right hand margin of the Analysis frame. Its height may, but does not need to, be higher than the main PSI distribution.

EXPLANATION:

"L" stands for LAST VOLTAGE. Any time after PSI - End was effective but before the BALANCE CLEAR command is applied, the deposit load on the Underwater Balance can be recorded *without a known sedimentation time* by the command L, LAST VOLTAGE. This information is useful for the following purposes:

- 1 To check whether the PSI - End was not applied too early;
- 2 To record an eventually *decreasing* Underwater Balance load in order to evaluate analysis quality; a decreased load indicates a rebound effect from too a large sample, or from uneven sample spreading on the Venetian Blind;
- 3 To record the portion of the unspecified deposit which escaped the operator's attention and sedimented later, after PSI - End was applied; this record helps extend correctly the truncated PSI distribution.

21 Enter Space Bar or type "V" to enter Variables menu in order to continue with other commands and check the Variables fields, particularly FileName (page 21).

RESPONSE:

Variables menu is displayed.

EXPLANATION:

The command Space (=Space Bar) has the same effect as typing of V: (page 25): it causes an escape from any screen into the Variables menu. Now the operator has the last chance to check (and correct if necessary) the Variables *before the analysis data will be written into a file*. The FileName must not exist on the used diskette (look into your working note book, page 21, and compare with the Directory of the current Data Diskette by typing "F" and "CAT" [Step 33 and Step 34]).

22 Type "W" to write the analysis data stored in the computer memory as a file onto the Data Diskette.

RESPONSE:

- 1 A red light appears on the drive 1 during this operation, and a typical noise can be heard.
- 2a If the writing cannot be accomplished due to File Name already existing on the Data Diskette, the status line displays a message "FILE OPEN ERROR".
- 2b If the writing is possible, it is carried out: the status line shows a message: "FILE WRITE";
- 3 When writing is accomplished, status line shows a confirmation message: "FILE WRITE OK";

EXPLANATION:

"W" stands for Write a File. The data currently stored in computer memory is copied onto the Data Diskette inserted in the drive 1. If the FileName does already exist on the Diskette, a message "FILE OPEN ERROR" appears in the status line: go to Step 6 to correct File Name in the Variables field, and try Step 22 again. If you wish to see a list of Files on the Data Diskette, go to Step 33 (FLEX operating system entrance without data loss) and Step 34 (Catalog of Files).

23 Type "S" to include the analysis data currently stored in the computer memory into cumulating analyses (=SPLITS) which will be later averaged into a MEAN ANALYSIS (Step 24).

RESPONSE:

In the Variables field, the value of Split # will increase by 1 every time "S" is typed.

EXPLANATION:

"S" stands for SPLIT CUMULATION. This program segment enables one to cumulate analyses data for a later calculation of an average analysis by the MEAN ANALYSIS program segment. A large sample can, in this way, be divided into subsamples (=SPLITS), each of them analyzed separately and finally averaged. This method presents a solution to analyze a very coarse material which would have to be represented by a too large sample whose sedimentation would cause streaming and particle interaction and therefore poor analysis quality. Fortunately, repeating split analyses does not take too much time because coarse material sediments rapidly.

Sedimentation data obtained from Analysis, from Read the File (page 30) and even from Mean Analysis (next Step) program segments can be merged by Split Cumulation; repeating of the same sedimentation data, each as a separate split, is possible as well, whenever the "S" key is typed, but this should only be done if really wanted: it causes multiplication of the Sample Weight by the number of repeated Split actions.

The sedimentation data is cumulated in proportion to the Sample Weight of the Variables field. In other words, each subsample (split) is cumulated in proportion to its abundance in the total sample.

24 Type "M" to terminate the Split Cumulation and average the Split Cumulation data.

RESPONSE:

In the Variables field, the value of the Split # is reset to zero, and appears under the Mean #.

EXPLANATION:

"M" stands for Mean Analysis. This program segment is typically used after all subsamples have been analyzed and cumulated in the computer memory by multiple use of the Split Cumulation program segment.

25 Type "B"

RESPONSE 1 (after analysis is accomplished):

The immersed part of the Underwater Balance starts rotating slowly; it stops within about 17 seconds when the tilting angle reached is about 70° to 80°; after some waiting time, it starts rotating slowly in the opposite direction until it reaches the original horizontal position.

EXPLANATION 1:

"B" stands for Balance Clear. The motor on the large acrylic glass disk of the Underwater Balance flange starts driving the Underwater Balance cylindrical shaft (acrylic glass tube) carrying the main balance body (immersed parts). The rotation speed is about 1 revolution/minute in order not to disturb the surrounding water during the sliding down of the sample from the balance pan. The rotation stops after about 17 seconds (this time is given under Constants, line 'Motor Time'); then it remains in the tilted position during a variable waiting time, and finally it rotates slowly backwards until it reaches the original horizontal position.

The operator can shorten the Balance Clear actions by typing "E" during the following stages:

- a Rotation forwards: the rotation stops, the waiting time begins; two additional typings of "E" are possible;
- b Waiting time: the waiting time stops, rotation backwards begins; one additional typing of "E" is possible;
- c Backwards rotation: the balance rotation stops at current position before reaching the final (horizontal) position.

The length of the waiting time equals approximately the maximum sedimentation time per centimeter of the sample deposited on the balance pan multiplied by the Underwater Balance pan diameter (=26 cm):

$$\text{waiting time in seconds} = \text{approx. } 26 \times 2^{+\text{PSI} - \text{End}}$$

RESPONSE 2 (if no analysis was made since a previous Balance Clear or since the Electronic Module was switched on):

Status line shows a message: "Enter Time".

EXPLANATION 2:

Because the PSI - End value is not available in computer memory, the waiting time must be entered by operator. The length of the waiting time in this case depends on the purpose.

26 Type "R" to read a file (defined in Variables field by File Name) from the Data Diskette into the computer memory).

RESPONSE:

- 1 A red light appears on the drive 1 during this operation, and a typical noise can be heard.
- 2a If the reading cannot be accomplished because the File Name is nonexistent on the Data Diskette, the status line displays a message "FILE OPEN ERROR".
- 2b If the reading is on the way, the status line shows a message: "FILE READ/WRITE";
- 3 Accomplished reading is confirmed in the status line by "FILE READ OK".

EXPLANATION:

"R" stands for Read a File. The requested file is read from the Data Diskette inserted in the Drive 1. If the File Name is not available on the Data Diskette, a message "FILE OPEN ERROR" appears in the status line; go to Step 33 and 34 to check the File directory (Catalog).

27 Type "H" to invert the PSI distribution display and to emphasize HISTOGRAM.**RESPONSE:**

The Analysis frame is filled by picture of the PSI distribution known from the Analysis Display after analysis completion with inverted emphasis: the differences of the PSI distribution are plotted as vertical bars, whereas the PSI distribution itself is shown by dots only: Fig. 12.

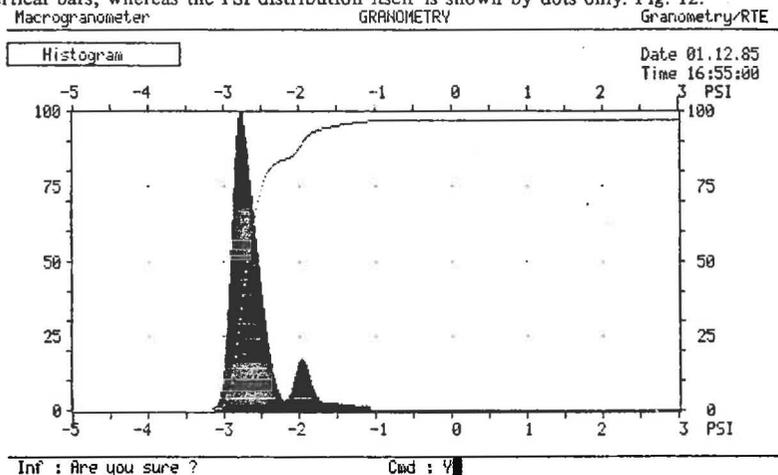


Figure 12

EXPLANATION:

"H" stands for HISTOGRAM. This type of display emphasizes the PSI distribution differences stretched vertically in proportion to a stretching of the maximum PSI distribution difference up to the top of the Analysis frame. This enlarges the differences in comparison with the scale of the PSI distribution bars.

28 Type "N" to see the PSI distribution emphasized (the Analysis Display).**RESPONSE:**

The Analysis frame is filled by the PSI distribution plotted with vertical bars, the differences of the PSI distribution are shown in dots, as it is after an analysis was accomplished.

EXPLANATION:

"N" stands for New Display. This command enables one:

- To see the Analysis display again when superseded by another display, such as Variables, 0 Zero Balance, Histogram etc.;
- To see the PSI distribution after Read a File command (see page 30) was applied.

29 Type "P" to transmit a screen content per serial line to a device (printer or a host computer).**RESPONSE:**

The currently displayed screen content is transmitted, the target device receives the currently displayed screen content:

- A printer is printing (in this case only a receipt confirmation may be displayed on the host computer video terminal);
- A host computer response (for example, receipt confirmation or data display); size is 33290 bytes/file.

EXPLANATION:

"P" stands for Print a Screen. The scanned screen data is transmitted bit by bit, 512 dots per line, 256 lines per screen, to the target device hooked on the serial line.

30 Type "T" to set clock at a new date and day time.**RESPONSE:**

The cursor jumps into the upper right corner of the Variables field, onto the first digit of the Date.

EXPLANATION:

"T" stands for Time Change. You may overwrite the old date as follows:

DD.MM.YY

D stands for day of the month (maximum value is 31),
M stands for month number (maximum value is 12),
Y stands for the last two digits of a year.

After the entering of date was accomplished, you may overwrite the day time as follows:

HH.MM.SS

H stands for the hour (maximum value is 24),
M stands for the minute (maximum value is 59),
S stands for the second (maximum value is 59).

With the entering of the last digit of Time, the time is set to the entered value and the clock is running.

31 Type "D" to update Date and Time only after Read a File changed and blocked it.**RESPONSE:**

Date and day time are displayed upgraded to the instant whenever D is typed in the upper right corner of the Variables.

EXPLANATION:

"D" stands for Date and Time Display. The clock is running unchanged.

21 September, 1986, 11:14

32 Type "C" to display the Constants menu (Fig. 13):

Macrogranometer	GRANOMETRY	Granometry/RTE
Constants		Date 01.12.85 Time 16:55:00
Name	GRANOMETRY	
Length (cal) . . .	185.0	
Grav. (N1) . . .	980.962	
Model	MC84-1.1	
Program	E2-1.1	
Blindintv.	2500,75,40	
.		
.		
.		
.		
Inf : Are you sure ?	Cmd : V	

Figure 13

The Constants display lists data about the Macrogranometer system installed, such as: user's name, sedimentation length, gravity acceleration of the Macrogranometer's site, Macrogranometer's model number, GRM program version number, opening constants of the Venetian Blind (page 26), calibration data of temperature sensors (offset and slope of the sensors both in the Venetian Blind and above the Underwater Balance), and waiting time of the Underwater Balance motor rotation (page 30).