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INSTALLATION AND USE OF A QUANTIMET 720 IMAGE ANALYZER FOR PARTICLE CHARACTERIZATION

K. J. JUDGE

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INTERNAL REPORT

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ABSTRACT

The size and shape of particles, in a dust, can affect the explosion hazards posed by the dust. Dust explosion work at the Canadian Explosive Atmospheres Laboratory (CEAL) now involves the use of an image analyzer. The analyzer is being used to characterize the shape and size of grains involved in explosion tests at this laboratory. It is hoped that this information will indicate the relationships between these parameters and that a more comprehensive prediction of dust explosion phenomena will result.

The system configuration, operating procedures and supporting hardware and software are detailed in this report.

Key words: Image analyzer; dust explosions, particle size distribution; procedures

* Research Technologist, Canadian Explosive Atmospheres Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Ontario.

INSTALLATION ET UTILISATION DE L'ANALYSEUR D'IMAGE QUANTIMET 720 POUR LA CARACTÉRISATION DES PARTICULES

par

K.J. Judge*

RÉSUMÉ

La dimension et la forme des particules de poussière peut influer sur les dangers d'explosion de cette dernière. Les Laboratoires canadiens de recherche sur les atmosphères explosives (LCRAE) se servent, à présent, d'un analyseur d'image dans leurs travaux sur les coups de poussière. L'analyseur est utilisé pour caractériser la forme et la taille des grains utilisés au laboratoire à des fins d'essai sur les matières explosives. On espère que l'information recueillie démontrera les liens entre ces paramètres et qu'il sera possible d'établir des prévisions plus complètes pour ce qui est des coups de poussière.

Dans le présent rapport, la configuration du système, le mode opératoire, de même que le matériel de soutien et les logiciels sont décrits de façon détaillée.

Mots clés : Analyseur d'image; coups de poussière; distribution granulométrique des particules; mode opératoire.

*Technologue de la recherche, Laboratoires canadiens de recherche sur les atmosphères explosives, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa (Ontario)

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INTRODUCTION

A Quantimet 720 optical image analyzer has recently been installed at the Canadian Explosive Atmospheres Laboratory (CEAL). This apparatus is intended to be used as a tool to further our knowledge of dust explosions and their relationship to grain shape and size. By making some basic measurements, we hope to quantitatively characterize the shape and size of dust particles in a given sample. This information will be correlated with various explosion tests in attempts to find relationships between grain shape and size and their effect on explosion hazards.

The 700 Series of analyzers, made by Imanco, is no longer in production and documentation is somewhat lacking. However, the resolution of the system is above average and the quality of the microscope stage and optics is quite good. This report is intended to detail the current system configuration, module functions, sample preparation techniques, operating procedures, and in-house software so as to provide a comprehensive and well organized source of information relevant to this laboratory's image analysis requirements. Since the development of software for this project will be an evolving process, the programs developed to date should be considered only as a first stage in this evolution.

SYSTEM CONFIGURATION

The system consists of three physically separate units:

1) Microscope, stage and associated modules
2) Analyzer function and display modules
3) Desk top computer and peripherals

Units 1 and 2 (Quantimet 720 image analyzer) are modular in design but, being of older design, do require interconnections to be made by the rear of the unit using twisted pair leads. These interconnections are detailed in Appendix X.

UNIT 1

Microscope

The microscope, made by Reichert, is of the type used in optical mineralogy and is fitted with X10, X25 and X40 objectives. A lever operated prism is used to transmit the image to either a scanning head or a binocular eyepiece. The binocular has two adjustments. The central knob adjusts for operator eye separation and the left monocle adjusts to account for differing eye strength (left to right). The microscope is currently set up for transmitted light but a reflected light arrangement can be realized by repositioning the light source to the upper mounting bracket. Between the microscope and the scanning head is a magnifier which has a three lens drum. This drum can be rotated (using the front mounted indicator knob) to select one of the three lenses (X0.8, X1.0 or X1.2) which, combined with the three objectives, provide a variety of final magnifications (see Table 1).

Stage x/y Control

The microscope stage can be controlled automatically, in the "X" (left to right) and "Y" (front to back) directions using stepper motors. This control is carried out via the **Stage X/Y Control** module and the resolution is equal to one step or 80 microns. A footswitch is provided for manual initiation of a step but normally the **Programmer** module in Unit 2 is used to generate step instructions. Fully manual movement of the stage is facilitated by setting the **AUTO/MANUAL** switch to **MANUAL** and turning the appropriate stage mounted knob by hand. The knob at the right rear controls the "Y" and the knob at the left front controls the "X" movement. Details of the operation of this module are included in Appendices I, IV and VII.

Auto Focus

The "Z" or vertical movement, used to focus the microscope, is controlled by the **Auto Focus** module and has a selectable resolution down to 0.11 microns. Generally, the stage horizontal motion is very planar and as a result the image usually stays in good focus when the stage is moved in the "X" and "Y" directions. However, on occasion, the slide/sample/cover glass combination may, on lengthy traverses, cause the image to go out of focus. Often, this module can be used to keep the image in good focus (for opaque grains) should such a combination occur. When attempting to refocus, the module detects the sharpness of grain boundaries and hunts up and down using a successive approximation method (better/worse) until the grain boundaries become sharpest. The procedure for using this module may be found in Appendix VI.

Panel controls for this module consist of **STEP SIZE** and **SKIP FIELDS** knobswitches; **MANUAL/AUTO/START, ALLOWED EMPTY FIELDS** and **POWER** ON toggle switches; and a **RESET** push button. The **STEP SIZE** knobswitch is used to select the distance (in microns) that the stage will travel up or down each time a stage move is initiated during a focusing operation.

The **SKIP FIELDS** control selects the number of fields of view that will be skipped between focusing operations. A flatter slide requires fewer refocus operations than a sharply tapered one and similarly so would a smaller horizontal step increment (for the same lens).

The three position toggle switch **ALLOWED EMPTY FIELDS** will allow the system to encounter 1, 8 or an infinite number of empty fields, avoid focusing and continue to the next field. If more fields are encountered than the switch setting allows, program control will halt. This might occur when the sample is concentrated in one spot and a square sampling traverse is followed giving empty fields around the edges. This situation is unlikely however, because the amount of noise in the system currently produces enough image information to fool the module into focusing on it. If the **ALLOWED EMPTY FIELDS** lamp is on, it can be reset by setting the switch to the infinite position or by turning the module off then back on (providing there is an image).

The **MANUAL/AUTO/START** toggle switch selects **MANUAL** or **AUTOMATIC** focusing modes and has a momentary **START** position which can be used to manually start the focusing sequence. This **START** parallels the rear panel START input which is used during program control for the specific case when an out of focus is sensed by the module but no focus command is issued (this is a module level fault).

The **LIMIT** lamp lights when the fine focus has travelled up or down to the end of its travel (**LIMIT**). The **RESET** push button is used to reset the module when a limit has been detected. However, the module will not **RESET** until the focus has been removed from the limit condition by the operator.

Stabilized Power Supply

The **Stabilized Power Supply** module is an adjustable regulated DC power supply which provides 6 to 13 volts to the microscope's lamp. The only panel controls are the **POWER ON** toggle switch (up is on/down is off) and the voltage adjust knob. The numbers 7 through 12 around the knob correspond, approximately, with lamp voltage.

Sensing Head

The sensing head may be either a **Vidicon Head** or a **Plumbicon Head**; the latter is currently being used at CEAL. In either case, the only control associated with the sensing head is an **IMAGE ROTATION** knob. This knob, when turned, actually rotates the scanning head inside the module thereby rotating the image received by the system and seen on the **Display** module. This feature in combination with the **Variable Frame & Scales** module allows precise length and width measurements on individual grains since their axes can be lined up with the grid. This module receives video raster signals from the **System Control** module, scans the optical image and produces an analog video output to the **System Control** module which in turn directs it to the **2D Auto Detector** for grey level detection and to the **Auto Focus** module for better/worse focus detection.

Unit 2

Unit 2 processes the Video signal received from **Unit 1**, displays it, makes data available to the computer and provides stage stepping and focusing instructions back to **Unit 1**. The following is a module by module functional description of **Unit 2**. The modules are presented in a function logical order.

System Control

This module generates all system timing signals required by the **Scanner** and **Display** modules and any other module requiring timing signals. In turn, it receives the analog signal from the scanner head, amplifies it, applies a shade correction and makes this signal available to the other modules. The shade correction is a detector (**see 2D Auto Detector**), with a block of memory and a summing amplifier which effectively tares out (removes) variation of shading inherent in the microscope and scanning head. This correction is made by scanning a blank slide and digitally storing this signal (pixel by pixel). Then, by subtracting this stored information from the incoming signal (from a sample slide), a shade corrected image is produced. Lastly, data received from other modules is accumulated and characters are generated for display and sent to the **Display** module.

The **SHADE CORRECTION - RANGE** knob adjusts the amount of correction applied. Full range would be used for large blank slide gray level variations (tare) but gives coarser resolution. Minimum range would be used for small variations and give finer resolution. Usually this knob is set to full range (full CW).

The **SET** push button is used to initiate the tare scan which takes about 13 seconds.

The **SENSITIVITY/WHITE LEVEL** toggle switch when set to **SENSITIVITY** gives an indication, on the analog meter, of the gain of the video amplifier. When this switch is set to **WHITE LEVEL** the meter indicates the strength of the incoming video signal.

The **ACCUMULATOR** section has a **RESET ALL** push button which resets all modules connected to it via the rear panel **RESET** interconnection. Also there is an **ACC** toggle switch which, in the up (on) position, sets the module to accumulate consecutive readings in its memory. When this memory is full the red **FULL** indicator lamp lights and can be reset by the **RESET** push button.

The **SYSTEM MODE** section consists of an **AVERAGE** switch which, when in the **AVERAGE** (up) position, averages the readings from sixteen scans before displaying the data or making it available to the **CFFI**. This mode takes approximately four times longer than a single operation but will reduce variations in consecutive readings. The **INTERCEPT/AREA** switch setting determines whether the detector will be used to detect transitions (grain boundaries) or areas (within boundaries). This switch is left in the **AREA** position. The **CONTINUOUS/SINGLE SCAN/AUTO** switch when set to **CONTINUOUS** will scan repeatedly while the **SINGLE SCAN/AUTO** setting will scan only when the **SINGLE SCAN** button is pressed or under program control from the **Programmer** module.

Display

This module receives various display signals and character information, from other modules, and displays them on the screen as selected by the operator. These signals are:

1) Image - shade corrected video signal
2) Detected - selected by the **Auto Detector** module
3) Scales & Figs - scales as selected by the **Variable Frame and Scale module**
   - figures; left from detector; right from **Calculator Field/Feature Interface** module

4) Guard - the border around the selected frame (highlights the character display)
5) Computed & Amended - selected via the **Standard** and **Function Computer** modules

Each signal has its own on/off toggle switch and intensity knob to control its display, and there is a brightness and standby switch for the overall display.

Variable Frame & Scale

This module allows the user to adjust the size and shape of the field being examined by the other modules. These features allow manual grain size measurements or, possibly, exclusion of areas that may have shading variations that are too large for the shade corrector. Also, since the computers (**Standard** and **Function**) perform their operations on grains whose lowermost picture point is within the variable frame, the upper frame boundary can be lowered so that most grains thus observed will fall completely within the screen boundaries i.e., if the grains are generally less than 100 picture points in diameter the upper boundary can then be set to 100 and the whole grain will be analyzed even if only its bottom edge is within the frame selected.

FRAME POSITION is defined as the upper left corner of the **Variable Frame** and is set via the corresponding **HORIZONTAL** or **VERTICAL** thumbwheel switch with respect to the upper left corner of the display. **FRAME SIZE** defines the variable frame with respect to the frame position and is set by its corresponding switches. One other control on this module is the **VARIABLE/STANDARD** toggle switch and controls which display (**Variable** as set by **FRAME SIZE** and **FRAME POSITION** or **STANDARD**) is to be used by the display and the computers.

2D Auto Detector

This module is essentially an adjustable shading comparator.

The incoming analog video signal (shades of gray) is compared (lighter than/darker than) to a reference level which is set by the operator. A "true" comparison results in the picture point being **DETECTED.** Thus, in a transmitted light situation where a grain will appear darker than the background, the grain may be detected by selecting darker than (black down arrow) and adjusting the detection level (or selector) until the grains are detected. This information is used by other modules to calculate areas, lengths, boundaries etc.

The upper left knobswitch sets the detected function (or polarity) and has three settings; darker than (top position - black down arrows); slice (middle position - white horizontal line); and lighter than (bottom - white up arrows) and defines the relation of the detected area with respect to the detection level or levels. The knobswitch directly below this one selects the detection level to be used as a reference for the detected function. The **SELECTOR A** and **SELECTOR B** knobs are used to set detection levels within its 0 to 64 grey range. Seven segment displays to the left of the knobs indicate these levels. As an example of the detection logic, a darker than detected function and a detector selector setting of 3 would display a point darker than the level selected by **SELECTOR B.**

The **DISPLAY** switch, usually left in the on (up) position, acts as an enable sending the **DETECTED** information to the **Display** module. The **AUTO DELINEATOR,** when on (switch in up position), removes the transition region halo errors from the slice display and sharpens the grain boundaries. The **EMPHASIS** control selects the kind of image detail to be given accentuated contrast. This switch is normally left in the off position. The **ATTENUATION** control, normally left in the **DETAIL** position, reduces (attenuates) the contrast of certain features and details.

Standard Computer

This module normally (**INPUT** switch set to **NORMAL**) receives the detected signal mentioned above and, depending upon its function switch setting or program input, calculates various parameter values. However, input may be received from another module (**INPUT** switch set to **MODIFIED**). The **SIZER** may be used (switch up) so that only those grains that are larger or smaller (toggle switch) than the selected number (thumbwheel switch) of picture points. The sizer is not used here as the Peach computer is being used, instead, to sort grain size. Three keys may be used to further select or ignore features. These keys are also not used for our application. **AREA, PERIMETER, INTERCEPT** (also called **PROJECTION**) and number of grains (or **COUNT**) in a field are the parameters which may be derived using this module. Two **PROJECTIONS** (**HORIZONTAL** and **VERTICAL**) are available. A **PROJECTION** is the horizontal or vertical length (in picture points) of a grain plus the horizontal or vertical length (in picture points) of any convolutions of the grain. A setting exists for automatic control of this module via the **Programmer** module. One other function setting (**PATTERN RECOGNITION**) allows control to be passed to the **Function Computer** which is discussed below and is the normal setting. The **DISPLAY** enable switch position is unimportant since the **Function Computer** is providing the **COMPUTED** display for the system.

Function Computer

This module, with the function switch of the Standard Computer set to **PATTERN RECOGNITION**, can be used to determine **AREA, PERIMETER**, horizontal and vertical **PROJECTION** and **FERET** diameters. Like the **PROJECTION** two **FERET** diameters (**HORIZONTAL** and **VERTICAL**) are available. As with the **PROJECTION** and **FERET** measurements is the length of a grain except it does not include the length of convolutions and is, therefore, a true length. Similar to the **Standard Computer** the **Function Computer** has an **AUTO** setting. The information collected by the software programs includes these horizontal and vertical feret diameters and thus this computer is normally selected and set to **AUTO**. The **DISPLAY** enable is left on (up position) and the **INPUT** switch is set to

NORMAL.

Calculator Field/Feature Interface

Usually abbreviated **CFFI**, this module acts as the interface between the analyzer and the Peach computer. Seven digits, each in binary coded decimal (BCD) form, are simultaneously transmitted in parallel along with a data ready flag to the Peach computer. Six of these digits are data and one is a **SOFTWARE CODE** added by the **PROGRAMMER** module so the Peach computer can confirm which instruction is being executed by the analyzer. Commands are received, from the Peach computer, in the form of one four bit word. The commands are; initiate the next programmed instruction; initiate a focus; and initiate a reset.

When data has been loaded into its buffer the **CFFI** suspends systems operation via an **EXT BUSY TO PROG** rear connection to the **Programmer** module. The instruction execution command frees the **CFFI** removing its **BUSY** signal and the **Programmer** module continues. This command is a positive going edge to the execute pin (pin 31) on the interface connector. The **CFFI** returns a low level on the **FLAG** pin (pin 29) when data is ready.

The focus initiation command line has been added as a flying lead on the back of the **CFFI** connector. This line, coming from the Peach computer, bypasses the rear connector of the **CFFI** and is routed directly to the auto focus module **START** input. A positive going edge triggers the **START** of a focus by the **Auto Focus** module.

The 'reset' command line has also been added as a flying lead on the back of the **CFFI**. Bypassing the connector, this lead is routed to the **Function Computer** module so that it may be reset when an overflow situation occurs.

The data being transmitted to the Peach computer is also sent to the **System Control** module and eventually appears as the right numerical display on the screen of the **Display** module.

The **SOFTWARE CODE** switch, when set to **AUTO**, allows the **Programmer** to send an instruction number to the Peach computer, along with the data, so that synchronization can be maintained between the analyzer and the computer. An **OVERFLOW RESET** switch allows the module to be reset should an overflow occur. The upper **DISPLAY** switch, when in the on (top), position enables the character output. This information is displayed on the **RIGHT** character display of the **Display** module. The lower **DISPLAY** switch, when on, enables the current feature marker (oblong box) which appears on the **DISPLAY** module at the bottom right of the current feature. The **FIRST FEATURE/NEXT FEATURE** switch moves the current feature marker to the first feature (up) or next feature (down).

The 'data transfer selector' (bottom) knob selects whether **FIELD DATA** or **FEATURE DATA** is transferred to the Peach computer. **FEATURE DATA** is gathered and transferred grain by grain and instruction by instruction. **FEATURE DATA** includes **AREA**, **PERIMETER**, **PROJECTIONS** and **FERETS** as well as coordinate information. Two additional **FERET** diameters may be determined using this module and are selected by this switch. These **FERET** measurements are taken at 45 and 135 degrees with respect to those of the **Function Computer** and can give a better indication of the true elongation of a grain if the maximum and minimum of the set are used. At the moment there seems to be a timing problem with this function and it is not being used. The **Programmer** instruction set and the data gathering control program will have to be revised to incorporate this feature when it is repaired. This switch is left in the **AUTO** position.

Programmer

The programmer module controls the **High Level Programming** lines to the other modules. Up to sixteen instructions may be set on either or both of two instruction cards. The instructions on a board will be numbered according to which slot the card is inserted into. The left slot will number the instructions 0 - 15 while the right slot will number them 16 - 31. The instructions are set using dip switches on the newer boards and by pin insertions on the older boards. There are thirty-two control lines available which are labelled **A** through **Z** and **AA** through **KK**. Line **A** acts as an enable for the instruction. If **A** is off (not pinned) the instruction if present will be ignored. The switch settings and control line/module wiring for the current data acquisition system are outlined in Appendces II & X.

The top knobswitch selects which or both board(s) will be accessed for instructions. The lower knobswitch selects which instruction, in the **SET UP** (manual) mode, is accessed. The field counter digiswitch selects the number of fields of view (for **FIELD DATA**) or grains (for **FEATURE DATA**) that will be sampled before stopping. Pressing the button resets the counter to the preset value. This value may be set by pressing the button, holding it in and turning it 90 degrees then setting the value on the digiswitch and releasing the button. Since our programs count the number of grains and has rejection criteria this switch is left in the 'in and turned' position. The **RUN/STOP** switch, for programmed control, is left in the **RUN** (up) position. The **STEP** button is pressed to advance to the next instruction when in the manual mode.

UNIT 3

Peach Computer

The Peach computer ('executive' module) is an Apple II clone. Sales and service are handled through Peach Microsystems Inc., 110 O'Connor St., Ottawa, Ontario, Telephone 594-4721. Separate interface cards for the disk drives are not required as Peach has put these interfaces on the mother board. The computer itself has 64K of **Random Access Memory** on the mother board. A **Saturn 128K RAM Card** in one of the expansion slots provides additional memory. Other expansion slots contain cards which perform the following: serial communications, parallel communications, **CP/M** operating system, clock/calendar, and the **CFFI Interface Card.**

The serial communications card, a **Super Serial Card** clone, in slot 0, can be used to plot histograms on a plotter. Using a set of DIP switches on the card, communications protocol may be set to match the plotter being used. The necessary cabling and software for this task has not yet been undertaken.

The parallel communications card, a **Wizard Buffered Parallel Output Printer Interface Card (Wizard BPO)**, in slot 1, is used as the interface to the printer. The buffer allows the operator to continue other tasks while the printer is printing.

Slot 2 contains a Z-80 co-processor unit which provides the flexibility of Digital Research's **CP/M** operating system and **Microsoft's BASIC** interpreter. This operating system is available when the computer is booted.

The clock card, a **Thunderclock Plus** clone, in slot 4, can be used to automatically time and date stamp each data file. This will involve some additional programming but will ensure that all files are properly and consistently stamped. Presently, the operator is prompted to enter this information through the keyboard.

Slot 5 contains the **CFFI Interface Card** and is discussed in detail later (see **CFFI Interface Card** p.14).

The Saturn **128K RAM Card**, located in slot 7, provides 128 kilobytes of random access memory. For our purposes, this memory is used as a **RAM** disk to provide fast data storage and retrieval. Information on up to 2900 grains may be acquired in this way and then transferred to diskettes for storage and evaluation. The driver for this card/disk is installed when the system is booted (turned on). Complete details may be found in its accompanying manual.

CFFI Interface Card

The **CFFI Interface Card**, located in slot five, was designed and constructed by Peach Microsystems and has since been modified in-house. A block diagram and schematic diagram are provided in Appendices XIV and XV. This interface employs a decoder (U5) designed to select 1 of 8 - 4 bit words (U1 - U4 tristate octal line drivers) being sent to/from the **CFFI** module. Seven of these words retrieve information from the **CFFI** (six of which are BCD data the other is a status word) and the eighth is a control word being sent to the **CFFI**. A 3-state octal transceiver with enable (U6) is used to buffer the input/output signals to the Peach data bus. Originally the data received from the **CFFI** was converted to ASCII by adding 48 (D4 & D5 tied high, D6 & D7 tied low) to the data from the drivers. As it seemed pointless to convert the data to ASCII then later back to character format this conversion was removed (D4 - D7 tied low).

The **CFFI Interface Card** may be accessed via **PEEK** and **POKE** instructions in **BASIC**. The base address is hexadecimal EOD8. Data from the **CFFI** is obtained by **PEEK**ing digits DO - D5 (&HEOD8 - &HEOD8 + 5), weighting each by its appropriate magnitude (DO * 100, DI * 101...., D5 * 105) and summing together, the result being the value of the instruction. The status word is made up of a **Data Ready Flag** and a three bit **Instruction Number Indicator**. The status word is obtained by **PEEK**ing location &HEODE. The first bit of the word is the **Data Ready Flag** and gives a positive logic i.e., busy lamp on - **CFFI** buffers loaded - logic level high - data ready. This value is found by **AND**ing the status word with one. The **Instruction Number Indicator** is found by stripping the leading bit **Data Ready Flag** (in binary, divide by two) from the status word and evaluating the quotient (3 bits as a BCD from 0 to 7).

The control word is an output to the **CFFI** and is set by **POKE**ing memory location &HEODF with an appropriate value. Values are determined by setting bits according to the function(s) desired. The three functions; instruction execution, focus initiation and function computer reset correspond to the first three bits of the hexadecimal memory address location EODF. Multiple instructions may set by adding individual instructions together. As an example, a focus and reset may be initiated by setting the second and third bits. The fourth bit is available should some other function become necessary and encoding could give a total of fifteen functions. A monostable (U7) is used to extend the reset pulse to allow the analyzer enough time to respond to the reset command before the signal is removed.

SAMPLE PREPARATION

If the material is not already well sorted, it may be sorted using sieves. The amount of sample being sieved should first be weighed. Sieving is best accomplished by placing a small amount of sample in the sieve at a time (enough to cover the bottom of the sieve), sieving it into a pan, and collecting each portion. Starting with the coarsest sieve (lowest mesh number), this step is repeated, with occasional sieve cleanings, until all the sample has been sieved. Using the portion collected in the pan, this procedure is repeated with the next finer sieve and so on until all fractions required have been separated. The standard set of sieves used at CEAL is: 20, 100, 200, 325 and 400 mesh.

Very small particles can be prone to significant electrostatic attraction which may cause clumping and thus hinder the sieving process. These particles may be removed from the sample through washing. However, before washing, the effects of this operation must be considered i.e., significantly loss of material, oxidation and further grain size reduction. If washing is to be carried out it may be done by stirring the sample in water, allowing a reasonable settling time and then decanting the water and suspended particles. The sample is then dried in the oven below 100°C. The weight is measured again, compared with the initial weight and any significant loss of material should be accounted for or its significance evaluated and discussed with the project leader.

After sieving, each fraction is weighed, its proportion determined and the total compared to the pre-sieving weight. Any significant loss of material should be accounted for and its significance evaluated as in the washing stage. After this separation, individual image analysis may be carried out and then combined using the proportions found above.

SLIDE PREPARATION

The best materials for analysis are those whose grains are well sorted and opaque. For this type of sample, a small amount is placed on the centre of a clean glass slide. A drop of immersion oil is dropped onto the sample and stirred with a piece of soft wire such as the end of a paper clip (more oil may be required for large grained materials). A clean slide cover is put over this mixture. Care should be taken to not entrain air bubbles which could give a false 'particle' during the analysis. This procedure may have to be repeated with less or more sample so that roughly 10% coverage is attained. The most important fact is that the grains should not be in contact with one another.

EXAMPLE ANALYSIS

A sample of pure pyrite was ground and then sieved into various fractions for a study of grain size versus minimum explosible concentration and maximum pressure rise. The standard set of sieves used was 20, 100, 200, 325 and 400 mesh. The sieving process proved difficult and clumping occurred. Examination under the microscope showed the large grains to be covered with very fine grains. The samples (except the -400 mesh) were washed in the sieves thus removing this very fine material. Then each fraction was dried and sieved again to improve the sorting of the remainder, which resulted in an additional -400 micron sample, now cleaned of the very fine material. This procedure differs from that described earlier in that no weighing was done and the samples were washed in individual sieves. This procedure was used as the sample was produced at CEAL, by grinding, and did not represent any particular mine dust so proportions were not of interest. Consideration of this procedure did result in development of the procedure described earlier.

Slides were prepared of each fraction (including the unwashed

-400 mesh sample) and data was collected using the acquisition program DUST.BAS. Histograms were produced from this data and are presented in Appendix XVI

CONCLUSIONS

The basic installation of the Quantimet 720 has been completed, including numerous repairs. While some troubleshooting and modifications remain to be carried out, in the areas of improved video clarity and parameter selection, image analysis may be performed under programmed control via the interface to the Peach computer.

The programs written to date allow basic parameter measurement, data storage/retrieval, generation of histograms and, data and calculations printouts.

Analysis, using the previously mentioned software, has been carried out on a number of different samples. As mentioned, well sorted opaque materials gives the best results.

Sieved fractions are relatively easy to make slides from and programmed control of the data acquisition process proceeds smoothly when samples with high contrast and good sorting are analyzed. Histograms of these fractions show that reasonable separation is attained using the wet sieving process.

Since the explosibility of dusts is very dependant on the particle size, it is imperative to know the particle size distribution for any particular sample in order to provide meaningful data. The method using the image analysis system, in this report, provides a reasonably easy method of generating a particle size distribution, as well as providing some information about the distribution of shapes.

Table 1. Lens combinations vs. system specifications

	Magnification		Screen	Step Size	X Steps
Objective	Magnifier	Overall	Resolution*	(mm)	(per field)
10	0.8	8.0	2.2	2.5	5
	1.0	10	1.8	1.2	10
	1.2	12	1.5	1.2	10
25	0.8	20	0.77	.62	20
	1.0	25	0.61	.62	20
	1.2	30	0.51	.62	20
40	0.8	32	0.52	.62	20
	1.0	40	0.42	.31	40
	1.2	48	0.35	.31	40

*Screen resolution: actual overall; measured using graduated slide and screen scales; given in um/pixel

Table 2. Sieve mesh vs. opening size

Mesh	Opening Size	
(Tyler Standard Equiv.)	(um)	(in.)
20	850	0.033
28	600	0.0234
35	425	0.0165
48	300	0.0117
60	250	0.0098
80	180	0.0070
100	150	0.0059
115	125	0.0049
150	106	0.0041
170	90	0.0035
200	75	0.0029
250	63	0.0025
270	53	0.0021
325	45	0.0017
400	38	0.0015

APPENDIX I

Operating procedure "Cold Boot"

1. Verify programmer card instruction set (see **Appendix II**)

2. Turn on the three power switches on the microscope modules (**Stabilized Power 100, Auto Focus, Stage X/Y Control**)

3. Turn on the two power switches on the analyzer chassis

4. Put the diskette labelled **ANALYZER SYSTEM AND PROGRAMS** in **DRIVE A** (bottom drive) of the computer and close the door

5. Put a blank formatted data disk in **DRIVE B** (top drive) of the computer and close the door. note: if disk needs to be formatted see **Appendix III** starting with step 2

6. Turn on the power bar for the desk top computer and peripherals. The printer carriage should move to the right and the **ON LINE** light should be lit. The computer should beep, the **A DRIVE** lamp should light momentarily as the disk is accessed and the monitor should display the system level prompt (**A>**)

7. Verify **Start-up Switch Settings** (see **Appendix IV**)

8. Place the sample slide (see **Appendix V**) on the stage

9. Slide the **SCANNER/BINOCULAR** pin in (left side of microscope above the objectives)

10. Select an appropriate lens and focus on the sample slide

11. Replace the sample slide with a clean blank slide

12. Slide the **SCANNER/BINOCULAR** pin out

13. Adjust the **LIGHT SENSITIVITY** knob on the **System Control** module to give a reading, on the meter above it, of 0.3

14. Set the **SENSITIVITY/WHITE LEVEL** switch on the **System Control** module to **WHITE LEVEL**

15. Adjust the knob on the **Stabilized Power 100** module to give a meter reading of **1** on the **System Control** module. Try to keep the setting of the knob below **10** to prolong the life of the lamp. If necessary, adjust the iris under the stage or raise or lower it to attain the **1** reading. Closing the iris will cut the amount of light passing it and will increase the depth of focus

16. Press the **SHADE CORRECTION - SET** switch on the **System Control** module. The corrector will perform a tare of this "null image" pixel by pixel in about 13 sec. and a mosaic will flash on the screen for a moment

17. Repeat steps 15 to 16 until the meter reading remains at **1** after the correction

18. Turn on (switch up) the **DETECTED** display on the **Display** module and check the shade correction by adjusting the **SELECTOR B** knob on the **2D Auto Detector** module. The detection should occur across the whole screen around 50 or more

19. Turn off the **DETECTED** display

20. Replace the blank slide with the sample slide

21. Push in the **SCANNER/BINOCULAR** pin

22. Move the stage, using the left to right (front knob) and front to back (right rear) knobs, to the front left 1/3 portion of the slide and adjust the focus

23. Check the focus across the slide (if necessary use the auto focus procedure, see **Appendix VI**) and return to the front left 1/3 position.

24. Pull out the **SCANNER/BINOCULAR** pin

25. Select an appropriate magnifier lens using the knob above the microscope

26. Select the appropriate **X** and **Y STEP SIZE** (obtained from **Table 1**) on the **Stage X/Y Control** module

27. Select an appropriate number of **X STEPS**, also on the **Stage X/Y Control** module (**Table 1** gives a reasonable maximum value)

28. Select **AUTO** with the two position toggle switch on the **Stage X/Y Control** module

29. Press **ORIGIN** on the **Stage X/Y Control** module

30. Turn on (switch up) the **DETECTED** display (on the **Display** module)

31. Adjust the **SELECTOR B** knob on the **2D Auto Detector** module until the areas within the grains are detected and little or none of the background is detected (compare with the normal **IMAGE** by turning the **DETECTED** switch on and off)

32. Select **VARIABLE** (switch up) on the **Variable Frame and Scale** module. This should mask any wavy noise on the edges of the screen

33. Turn off (switch down) the **IMAGE** display (on the **Display** module)

34. Turn off (switch down) the **DETECTED** display and turn on (switch up) the **COMPUTED & AMENDED** switch (both on the **Display** module). This is the **AREA** display derived from the **Function Computer** module and should be the same as the **DETECTED** display

35. Select **19-3** with the **SET UP** switch on the **Programmer** module. This is the **PERIMETER** display derived from the **Function Computer** module and should form an outline of the detected grains

36. Select **20-4** as above and the **HORIZONTAL FERET** (derived from the **Function Computer** module) should be displayed. This display appears as an outline of the top of each detected grain

37. Select **21-5** as above and the **VERTICAL FERET** derived from the **Function Computer** module should be displayed and appears to be an outline of the left side of each detected grain

38. Select **18-2** and the **AREA** display should return

39. Proceed to **Data Collection** operating procedure **Appendix VII** step 2

APPENDIX II

PROGRAMMER CARD INSTRUCTION SET

Instruction #	Control Line	Switch Position	Controlled Function
0, 1, 6-15	A	off	instruction: disable
2	A	on	instruction: enable
	B	off	**Function Computer: AREA**
	C	off	
	D	on	
	E	off	
	AA	on	**SOFTWARE CODE: 2**
	BB	off	
	CC	on	
	DD	off	
	FF	off	**CIFFI** function: **FEATURE DATA**
	GG	off	
	HH	on	
	JJ	off	
	others	off	
3	A	on	instruction: enable
	B	off	**Function Computer: PERIMETER**
	C	off	
	D	on	
	E	on	
	AA	on	**SOFTWARE CODE: 3**
	BB	off	
	CC	on	
	DD	on	
	FF	off	**CIFFI** function: **FEATURE DATA**
	GG	off	
	HH	on	
	JJ	off	
	others	off	

4	A	on	instruction: enable
	B	off	**Function Computer:**
	C	on	**HORIZONTAL**
	D	on	**FERET**
	E	off	
	AA	on	**SOFTWARE CODE: 4**
	BB	on	
	CC	off	
	DD	off	
	FF	off	**CIFFI** Function:
	GG	off	**FEATURE DATA**
	HH	on	
	JJ	off	
	others	off	
5	A	on	instruction: enabled
	B	off	**Function Computer:**
	C	on	**VERTICAL**
	D	on	**FERET**
	E	on	
	AA	on	**SOFTWARE CODE: 5**
	BB	on	
	CC	off	
	DD	on	
	FF	off	**CIFFI** function:
	GG	off	**FEATURE DATA**
	HH	on	
	JJ	off	
	others	off	

APPENDIX III

Operating procedure "Disk Formatting"

1. Put the diskette labelled **ANALYZER SYSTEM AND PROGRAMS** in **DRIVE A** (bottom drive) of the computer and close the door

2. Put the disk to be formatted in **DRIVE B** (top drive) of the computer and close the door.

3. Turn on the power bar for the desk top computer and peripherals.

4. Type **COPY B:/F** then press **RETURN**
   the computer will respond with:
   Insert disk to be formatted in drive B:
   Press RETURN to begin

5. Press **RETURN**
   the computer will format the disk then respond with:
   Operation complete

   Do you want to want to repeat this operation?

6. Type **N** the computer will return to the system level prompt **A>**; the **Cold Boot** operating procedure of **Appendix I** may be resumed from step 7.

APPENDIX IV

START UP SWITCH SETTINGS

MODULE: **Display**

IMAGE	- knob: 5 o-clock position - switch: on (middle)
UNDETECTED	- knob: 5 o-clock
DETECTED	- knob: 8 o-clock - switch: off (down)
BRIGHTNESS	- knob: 4 o-clock
STAND BY	- switch: display on (up)
SCALE & FIGS	- knob: 8 o-clock - switch: both on (top)
GUARD	- knob: 7 o-clock - switch: on (up)
COMPUTED & AMENDED	- knob: 8 o-clock - switch: off (down)

MODULE: **System Control**

SHADE CORRECTION

RANGE	- knob: full CW

SCANNER LIGHT SENSITIVITY

SENSITIVITY/ WHITE LEVEL	- switch: **SENSITIVITY**
PLUMBICON LIGHT INTEGRATION	- switch: **X 1**
MAN/AUTO	- switch: **MAN**
LIGHT SENSITIVITY	- knob: 10 o-clock

ACCUMULATOR

ACC	- switch: off (down)

MODULE: **System Control** con't

SYSTEM MODE

AVERAGE - switch: off (down)

INTERCEPT/AREA - switch: **AREA**

CONTINUOUS/
SINGLE SCAN/AUTO - switch: **SINGLE SCAN/AUTO**

MODULE: **Variable Frame and Scale**

FRAME POSITION

HORIZONTAL - thumbwheel switch: **100**

VERTICAL - thumbwheel switch: **100**

FRAME SIZE

HORIZONTAL - thumbwheel switch: **700**

VERTICAL - thumbwheel switch: **500**

FRAME OUTPUT

VARIABLE/
STANDARD - switch: **STANDARD**

SCALE DISPLAY

HORIZONTAL - switch: off (down)

VERTICAL - switch: off (down)

MODULE: **Calculator Field/Feature Interface**

SOFTWARE CODE - knobswitch: **AUTO**

DISPLAY - switch: on (up)

Field/Feature - knobswitch: **AUTO**

DISPLAY - switch: on (up)

MODULE: **Programmer**

AUTO/SET UP	- top knobswitch: **0-15** (blue) - bottom knobswitch: **18-2**
RUN/STOP	- switch: **RUN**

MODULE: **Standard Computer**

INPUT	- switch: **NORMAL**
SIZER	- switch: off (down)
Function Switch	- knobswitch: **PATTERN RECOGNITION**

MODULE: **Auto Detector**

Detected Function	- top left knobswitch: darker than (black down arrows)
Detected Selector	- knobswitch (below above switch): **3**
SELECTOR A	- knob: **64** (LED indication)
SELECTOR B	- knob: **30**
DISPLAY	- switch: on (up)
AUTO DELINEATOR	- switch: on (up)
EMPHASIS	- knobswitch: off
ATTENUATION	- knobswitch: **DETAIL**

MODULE: **Function Computer**

INPUT	- switch: **NORMAL**
FUNCTION	- knobswitch: **AUTO**

MODULE: **Stabilized Power 100**

POWER ON	- switch: **POWER ON**
Level	- knob: **8**

MODULE: **Auto Focus**

STEP SIZE - knobswitch: **0.8**

SKIP FIELDS - knobswitch: **0**

MANUAL/AUTO/START- switch: **MANUAL**

ALLOWED EMPTY FIELDS - switch: **8**

POWER ON - switch: **POWER ON**

MODULE: **Stage X/Y Control**

MANUAL/AUTO - switch: **MANUAL**

POWER ON - switch: **POWER ON**

APPENDIX V

Operating procedure "Slide Preparation"

1. Take a glass slide from the bottom drawer of the image analyser cabinet and ensure that it is clean

2. Using a small spatula place some sample in the middle of the slide

3. Drop a drop of immersion oil on the slide next to the sample

4. Stir the sample into the oil with a piece of soft metal (such as the end of an opened paper clip)

5. Trying to remove any air bubbles spread the oil and sample over an area about half the size of a cover slide (stir in different directions to make a more homogeneous mix)

6. Place a cover glass over the mix in such a way so as not to entrain air bubbles. This is best done by placing one edge on the slide then slowly lowering the other edge

7. Place the slide on the microscope stage and push in the **SCANNER/BINOCULAR** pin

8. Ideally the grains should not be touching each other but at least there should be very few if any clumps. It may be necessary to repeat the procedure with less sample or more stirring.

note: If the material is affected by the oil some other media which does not affect the sample, possibly water, may be used to suspend the grains and relieve surface attractions

APPENDIX VI

Operating procedure "Auto Focus"

1. If the **LIMIT** lamp on the **Auto Focus** module is on turn the manual ring on the stepper motor (left side of motor at the rear left of the microscope stage) in the allowed direction about ten turns. This will move it to the middle of its range

2. Focus on a grain using the manual/coarse focus drum (at rear and slightly below the microscope stage). If sorting is poor focusing on a midsized grain will the give best overall results

3. Slide the microscope **SCANNER/BINOCULAR** pin out

4. Slide the manual-coarse focus drum (at rear and slightly below the microscope stage) to the left to disengage it

5. Select **START** with the **AUTO/MANUAL/START** switch on the **Auto Focus** module then release (this is a momentary position and the switch will return to **AUTO**)

6. The manual ring on the stepper motor should move slightly then stop if it does not stop but hunts back and forth the **STEP SIZE** on the **Auto Focus** module must be reduced. Ideally the ring should move back and fourth a couple of times then stop. If little or no movement occurs increase the **STEP SIZE**

7. Repeat 5 and 6 until a suitable setting is found

8. Check the set up on another field of view by pressing the stage step footswitch (connected to the rear of the **Stage X/Y Control** module)

APPENDIX VII

Operating procedure "Data Collection"

1. Perform the **Cold Boot** operating procedure or similarly prepare analyzer for acquisition

2. Type **MBASIC DUST** then press **RETURN** the computer responds by loading the Basic programming file then loading and running the Basic program called **DUST.BAS** which gathers data from and issues instructions to the image analyzer

3. The computer will display any files that are on the data disk (data files will have a **.DAT** ending called and extension) and prompt with **ENTER FILENAME TO BE CREATED ON DRIVE C:.** type in a filename of up to eight characters and numbers (do not specify a drive or include an extension as it will be added by the computer) then press **RETURN**

4. The computer responds with **ENTER COMMENTS: (date, time etc.)** type any comments as suggested up to 45 characters then press **RETURN**

5. The computer responds with **ENTER RESOLUTION OF SCREEN (um/pixel):** type the value obtained from **Table 1** for the objective and multiplier used then press **RETURN**

6. The computer responds with **HOW MANY GRAINS? (MAX = 2900)** type in the number of grains to include in the sample then press **RETURN**

7. Set the **AUTO/SET UP** switch (on the **Programmer** module) to **Auto 0-15** (white letters)

8. The analyzer should commence programmed parameter measurements. The **BUSY** lamp on the **CFFI** module should flash on and off as data is passed to the **PEACH** computer; the green binary instruction number lamps on the **Programmer** module should consecutively display the four programmed instructions (two through five) and; the display module should display each parameter and, the marker should move from grain to grain (left to right and top to bottom)

   Notes: if nothing happens press **STEP** on the **Programmer** module to initiate the first instruction if the **Auto Focus** module is not being used (i.e. manual operation) and the **EXT** lamp on the **Programmer** module is lit, the **Auto Focus** module may be generating a busy signal. This can be cleared by selecting **START** on the **Auto Focus** module then resetting to manual

if the **Auto Focus** module is not being used (i.e. manual operation) it must still be turned on or else the **BUSY** signal from the **Stage X/Y Control** module will not be passed to the **Programmer** module

9. For lengthy sampling procedures the **STAND BY** switch on the **Display** module may be turned off (down position) to save the display from being burned into the screen

   Notes: the **Auto Focus** module (when in the **AUTO** mode) will from time to time generate a busy signal to the **EXT** busy on the **Programmer** module but does not initiate a refocus. This results in operation being halted and thus the **CFFI** module does not receive any new data. The computer has a time out sequence for receiving data from the **CFFI** module and generates a refocus command for the **Auto Focus** module if data is not received within that period. No action is required by the operator.

   Similarly the **OVERFLOW** lamp on the **Function Computer** indicates an external busy **EXT** to the **Programmer** module. This will also be reset by the time out sequence from the computer

10. Once sampling is complete the computer will provide some information regarding rejected grains and explain how to save the data to floppy disk

11. Leave **MBASIC** and go to the system level by typing **SYSTEM** then pressing **RETURN**
    the computer will respond with the **A>** prompt

12. Check the name of the file you have just created on the pseudo disk using the directory. Type **CAT C:** then press **RETURN** the computer will respond with a list of the files. Those that are data files will have the **.DAT** extension

13. Transfer this file to a data disk **DRIVE B:** by typing **PIP B:=C:FILENAME.DAT** (substitute, for **FILENAME**, the name given to the file created by **DUST.BAS**) and then pressing **RETURN**
    the light on **DRIVE B:** will light as the file is

transferred and then the computer will give the **A>** prompt

14. To check that the file has been transferred to the data disk type **CAT B:** then press **RETURN**
the computer will respond by listing any files on **DRIVE B:**

APPENDIX VIII

Operating procedure "Data Printout"

1. Ensure that the **ANALYZER SYSTEM AND PROGRAMS** disk is in **DRIVE A** and close the door

2. Ensure that the data disk containing the data file to be printed is in **DRIVE B** and close the door

3. Turn on computer and peripherals via power bar if not already on

4. If in **MBASIC** enter the system mode by typing **SYSTEM** and pressing **RETURN**)
   The computer should display the system prompt (**A>**)

5. Type **CTRL-C** (press and hold **CTRL** key while typing **C**)
   The computer will initiallize all disks and return with the **A>** prompt

6. Type **MBASIC PRTDATA** then press **RETURN**
   The computer will load the Basic operating and language file (**MBASIC**): the printout program **PRTDATA.BAS** is then loaded, commences execution and lists any files that are on the data disk

7. The computer then prompts for the name of the file to be printed with **ENTER FILENAME TO OUTPUT:**
   Type the filename (8 characters or less with no extension) then press **RETURN**

8. The computer responds with **SET PRINTER TO TOP OF PAGE THEN HIT ANY KEY.**
   If the printer is not set rotate the drum until the printer head is set to print at the top of the page then turn the printer off then back on again. The printer will then initiallize and the **ON LINE** lamp will light. Press **RETURN**

9. The computer will print the file information and comments and then the headings and data in columnar form with 60 grains per page. When finished printing the data the rejection data is printed, the program ends and the computer prompts with **OK**

10. The system may be turned off via the button on the power bar

APPENDIX IX

Operating procedure "Plot Histograms"

1. Ensure that the **ANALYZER SYSTEM AND PROGRAMS** disk is in **DRIVE A** and close the door

2. Ensure that the data disk containing the data file to be printed is in **DRIVE B** and close the door

3. If in **MBASIC** enter system mode by typing **SYSTEM** then pressing **RETURN**
   The computer should display the system prompt (**A>**)

4. Ensure that the pseudo disk (**DRIVE C**) has enough space available for the working files (i.e. erase all files)
   Type **ERA C:*.*** then press **RETURN**
   The computer prompts to double check this operation **All (y/n)?**
   Type **Y** then press **RETURN**
   The computer will erase the directory for **DRIVE C** then prompt with **A>**

5. Type **CTRL-C** (press and hold **CTRL** key while typing **C**
   The computer will initiallize all disk drives and then prompt with **A>**

6. Type **MBASIC HSTOGRAM** then press **RETURN**
   The computer will load the Basic operating and language file then load the histogram program, commence execution and list any files that are on the data disk

7. The computer then prompts for the name of the file to be plotted with **ENTER THE FILENAME TO PLOT:**
   Type in the filename of the file to be plotted (8 characters or less with no extension) then press **RETURN**

8. The computer then prompts for the printer to be set to the top of a page. Rotate the printer drum to the top of a page, turn the printer off then on again then press **RETURN**

9. Next the computer prompts with **ARE YOU ZOOMING? (y/n):** to find out wether or not a zoom or expanded window of any parameter is required (usually this is done after a no zoom set of histograms has been generated)
   Type **Y** for yes if zooming is required or **N** for no

if it is not then press **RETURN**

10. If zooms are not requested a full set of plots is generated and then the zoom menu is displayed

11. If zooms are requested each parameter and window is specified (up to 10) from a menu using the number keys then pressing **RETURN**
execution commences with the selection of the **RUN** option (**#8**)

12. Once the histograms have been generated the program returns to the zoom menu for further windowing or termination

APPENDIX X

REAR PANEL INTERCONNECTIONS

MODULE: Display

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
LIVE FRAME IN	2-S	LIVE FRAME IN	2-P	STD. COMP.
BLANK FRAME IN	2-S	BIG FRAME OUT	2-P	VAR. F. & S.
FRAME BRIGHT UP 1	2-S	FRAME BRIGHT UP 2	2-P	DISPLAY
2	2-P	1	2-S	DISPLAY
3	2-S	4	2-P	DISPLAY
4	2-P	3	2-S	DISPLAY
DETECTED DISPLAY	2-S	DETECTED DISPLAY	2-P	2D AUTO DET.
COMPUTED/AMENDED DISPLAY	2-S	ANALYSER DISPLAY	2-P	CFFI
NUMERAL DISPLAY	2-S	NUMERAL DISPLAY	2-P	SYS. CTRL.
SCALE 1 DISPLAY	2-S	SCALE DISPLAY	2-P	VAR. F. & S.
DISPLAY VIDEO	BNC	DISPLAY VIDEO	BNC	2D AUTO DET.
BLANK +10	2-S	BLANK +10	2-P	SYNCHRONIZATION 2D AUTO DET.
SYNC +16	2-S	SYNC +16	2-P	SYNCHRONIZATION 2D AUTO DET.
ERASE	2-S	ERASE	2-P	SYS. CTRL.
DISPLAY POWER SUPPLIES	32-P	plinth power rails		
2A & 110V	3-P	plinth AC rails		

NOTE 1: connector given as number of contacts and plug (P) or socket (S)
2: terminated - 150ohms

MODULE: System Control (SYS. CTRL.)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
DATA IN	2-S 2-P	FIELD DATA IN terminated	2-P	CFFI
STANDARD BIG FRAME OUT	2-P	BIG FRAME	2-S	SYS. CTRL. SIDE 2D AUTO DET.
STANDARD SMALL FRAME OUT	2-P	SMALL FRAME	2-S	SYS. CTRL. SIDE 2D AUTO DET.
READ	2-S	flying lead (rd/grn)		
INT	2-S	flying lead (yel/grn)		
RIGHT	2-P	RIGHT	2-S	CFFI
OFLO (right)	2-S	OFLO (right)	2-P	CFFI
INPUT BUSY	2-S	BUSY	2-P	STAGE X/Y CTRL.
EXT BUSY	2-P	EXT FROM SYS CONT	2-P	AUTO FOCUS
NUMERAL DISPLAY	2-P	NUMERAL DISPLAY	2-S	DISPLAY
SELECT ACC	2-S	flying lead (2 X yel/grn)		
FOOTSWITCH	2-S	terminated		
RESET	2-P	RESET	2-S	CFFI
HOLD	2-P	HOLD	2-S	CFFI
-16	2-P	-16	2-S	STD. COMP.
PAUSE	2-P	PAUSE	2-S	PROGRAMMER
AUTO	2-S	AUTO	2-P	PROGRAMMER
INTAR	2-S	INTAR	2-P	2D AUTO DET.
UNSYNC	2-P	UNSYNC	2-S	SYS. CTRL. SIDE 2D AUTO DET.
BV FRAME	2-P	BV FRAME	2-S	2D AUTO DET.
SLOW CLOCK	2-P	SLOW CLOCK	2-S	PROGRAMMER
H TRIG	2-P	H TRIG	2-S	SYS. CTRL. SIDE 2D AUTO DET.

MODULE: System Control (con't)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
V TRIG	2-P	V TRIG	2-S	SYS. CTRL. SIDE 2D AUTO DET.
CLOCK (left)	2-P	CLOCK	2-S	2D AUTO DET.
(center)	2-p	CLOCK	2-S	CFFI
(right)	2-p	CLOCK	2-S	PROGRAMMER
SCANNER (left)	BNC	SCANNER VIDEO	BNC	2D AUTO DET.
VIDEO (right)	BNC	VIDEO IN	BNC	AUTO FOCUS
SCANNER	32-P	7-coax cable from plinth to camera		
MULTIPLE ACCUMULATORS	32-P	DATA TO SYS. CTRL.	32-P	CFFI

MODULE: Variable Frame & Scale (VAR. F. & S.)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
BIG FRAME OUT	2-P	BLANK FRAME IN	2-S	DISPLAY
VARIABLE FRAME OUT	2-P	LIVE FRAME IN	2-S	STD. COMP.
STANDARD FRAME IN	2-S	STANDARD SMALL FRAME IN	2-P	VAR. F. & S.
	2-P	MASK	2-S	AUTO FOCUS
STANDARD BIG FRAME IN	2-S	SMALL FRAME	2-P	2D AUTO DET.
	2-P	terminated		
STANDARD SMALL FRAME IN	2-S	SMALL FRAME	2-P	SYNCHRONIZATION 2D AUTO DET.
	2-P	STANDARD SMALL FRAME IN	2-S	VAR. F. & S.
BV FRAME	2-S	BV FRAME	2-P	2D AUTO DET.
	2-P	terminated		
V TRIG	2-S	V TRIG	2-P	SYNCHRONIZATION 2D AUTO DET.
	2-P	V TRIG	2-S	CFFI
CLOCK	2-S	CLOCK	2-P	CFFI
	2-P	terminated		
SYNC	2-S	SYNC	2-P	SYNCHRONIZATION 2D AUTO DET.
	2-P	terminated		
SCALE DISPLAY	2-P	SCALE 1 DISPLAY	2-S	DISPLAY

MODULE: Calculator Field/Feature Interface (CFFI)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
FIELD DATA IN	2-S	SELECTED	2-P	STD. COMP.
	2-P	DATA IN	2-S	SYS. CTRL.
CALC 1	2-S	END OF X	2-P	AUTO FOCUS
	2-P	terminated		
FUNCTION 1 IN	20-P	FUNCTION OUT	20-S	FUNCTION COMP.
	20-S	jumper A to N		
MS3 COINC. OUT	2-P	COINC. 1 IN	2-S.	STD. COMP.
MS3 COINC. IN	2-S	DETECTED VIDEO OUT SELECTED	2-P	2D AUTO DET.
	2-P	terminated		
OFLO (right)	2-p	OFLO (right)	2-S	SYS. CTRL.
RIGHT	2-S	RIGHT	2-P	SYS. CTRL.
FUNCTION CONTROL	20-P	FUNCTION CONTROL	20-S	FUNCTION COMP.
SOFTWARE CODES	6-S	AA-DD (white)	6-S	PROGRAMMER
PROGRAMMER CONTROLS	6-S	FF-JJ (black)	2-P	PROGRAMMER
EXT. DRIVE	20-S	EXTERNAL DRIVE	20-P	FUNCTION COMP.
FINISH	2-S	flying lead (blk/grn)		
	2-P	FINISH	2-S	STD. COMP.
FAIL	2-P	FAIL	2-S	STD. COMP.
	2-P	terminated		
V TRIG	2-S	V TRIG	2-P	VAR. F. & S.
	2-P	VERT TRIG	2-S	STD. COMP.
HOLD	2-S	HOLD	2-P	SYS. CTRL.
RESET	2-S	RESET	2-P	SYS. CTRL.
	2-P	RESET	2-S	PROGRAMMER
STORE	2-S	STORE	2-P	STD. COMP.
CLOCK	2-S	CLOCK (center)	2-P	SYS. CTRL.
	2-P	CLOCK	2-S	VAR. F. & S.

MODULE: Calculator Field/Feature Interface (con't)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
DATA TO SYSTEM CONTROL	32-P	MULTIPLE ACCUMULATORS	32-P	SYS. CTRL.
TO CALCULATOR	32-P	centronics connector on Peach computer		
flying leads on back of above connector				
rd/grn	2-P	START	2-S	AUTO FOCUS
org/grn	2-P	RESET (below EXT BUSY)	2-S	FUNCTION COMP.
EXT BUSY TO PROG	2-S	EXT BUSY	2-P	FUNCTION COMP.
	2-P	EXT BUSY (left)	2-S	PROGRAMMER
STEP IN	2-S	STEP	2-P	PROGRAMMER
STEP OUT	2-P	STEP STAGE	2-S	STAGE X/Y CTRL.
ANALYSER DISPLAY	2-S	COMPUTER DISPLAY	2-P	STD. COMP.
	2-P	COMPUTED/AMENDED DISPLAY	2-S	DISPLAY

MODULE: Programmer

Origin		Destination		
Name	Connector	Name	Connector	Module
B-E	6-S	PROGRAMMER CONTROL	6-S	FUNCTION COMP.
G-K	6-S	PROGRAMMER CONTROL	6-S	STD. COMP.
FF-JJ (black)	6-S	PROGRAMMER CONTROL	6-S	CFFI
AA-DD (white)	6-S	SOFTWARE CODES	6-S	CFFI
H TRIG	2-S 2-P	H TRIG terminated	2-P	2D AUTO DET.
SLOW CLOCK	2-S	SLOW CLOCK	2-P	SYS. CTRL.
AUTO	2-S	AUTO	2-P	SYS. CTRL.
FOOTSW	3-S	FOOTSWITCH	3-P	PLINTH
PAUSE	2-S	PAUSE	2-P	SYS. CTRL.
RESET	2-S	RESET	2-P	CFFI
EXT BUSY (center)	2-S	EXT BUSY TO PROG	2-P	CFFI
STEP	2-P	STEP IN	2-S	CFFI
EXT BUSY (right)	2-S	BUSY TO PROG	2-P	AUTO FOCUS

MODULE: Standard Computer (STD. COMP.)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
COINC 1 IN	2-S	MS3 COINC OUT	2-P	CFFI
	2-P	SIZING IN NORMAL	2-S	STD. COMP.
SIZING IN NORMAL	2-S	COINC 1 IN	2-P	STD. COMP.
	2-P	INPUT NORMAL	2-S	FUNCTION COMP.
KEYS OUT	2-P	KEYS 1 IN	2-S	STD. COMP.
KEYS 1 IN	2-S	KEYS OUT	2-P	STRD. COMP.
COINC 2 IN	2-P	terminated		
MODIFIED +17	2-S	MODIFIED VIDEO OUT V+P	2-P	STD.COMP.
	2-P	MODIFIED +17	2-S	FUNCTION COMP.
DATA IN	2-S	SELECTED	2-P	2D AUTO DET.
SELECTED	2-P	FIELD DATA IN	2-S	CFFI
LIVE FRAME IN	2-S	VARIABLE FRAME OUT	2-P	VAR. F. & S.
	2-P	LIVE FRAME IN	2-S	DISPLAY
MODIFIED VIDEO OUT V+P	2-P	MODIFIED +17	2-S	STD. COMP.
VERT TRIG	2-S	VERT TRIG	2-P	CFFI
CLOCK	2-S	CLOCK	2-P	FUNCTION COMP.
	2-P	terminated		
PROGRAMMER CONTROL	6-S	G-K	6-S	PROGRAMMER
FUNCTION CONTROL	20-S	FUNCTION CONTROL	2-P	FUNCTION COMP.
STORE	2-S	STORE	2-P	SYNCHRONIZATION 2D AUTO DET.
	2-P	STORE	2-S	CFFI
-16	2-S	-16	2-P	SYS. CTRL.
	2-P	terminated		
UNSYNC	2-S	UNSYNC	2-P	SYNCHRONIZATION 2D AUTO DET.
FINISH	2-S	FINISH	2-P	CFFI
FAIL	2-P	FAIL	2-S	CFFI

MODULE: Standard Computer (con't)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
COMPUTER DISPLAY	2-S	COMPUTER DISPLAY	2-P	FUNCTION COMP.
	2-P	ANALYSER DISPLAY	2-S	CFFI

MODULE: 2D Auto Detector (2D AUTO DET.)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
DETECTED VIDEO OUT SELECTED	2-P	MS3 COINC IN	2-S	CFFI
DATA OUT SELECTED	2-P	DATA IN	2-S	STD. COMP.
BLANK FRAME	2-S	BIG FRAME	2-P	2D AUTO DET.
	2-P	STANDARD BIG FRAME IN	2-S	VAR. F. & S.
REFERENCE PHASE ALL	2-S	flying lead (blk/grn)		
INTAR	2-S	INTAR	2-P	SYS. CTRL.
CLOCK	2-S	CLOCK (left)	2-P	SYS. CTRL.
	2-P	terminated		
BV FRAME	2-S	BV FRAME	2-P	SYS. CTRL.
	2-P	BV FRAME	2-S	VAR. F. & S.
PK WHITE	2-S	flying lead (brn/blk)		
UNDETECTED	2-S	terminated		
DETECTED DISPLAY	2-P	DETECTED DISPLAY	2-S	DISPLAY
SCANNER VIDEO	BNC	SCANNER VIDEO (left)	BNC	SYS. CTRL.
DISPLAY VIDEO	BNC	DISPLAY VIDEO	BNC	DISPLAY
TIMING: System Control Side				
SMALL FRAME	2-S	STANDARD SMALL FRAME OUT	2-P	SYS. CTRL.
BIG FRAME	2-S	STANDARD BIG FRAME OUT	2-P	SYS. CTRL.
UNSYNC	2-S	UNSYNC	2-P	SYS. CTRL.
V TRIG	2-S	V TRIG	2-P	SYS. CTRL.
SYNC	2-S	SYNC	2-P	SYS. CTRL.
SYNC +16	2-S	SYNC +16	2-P	SYS. CTRL.
STORE	2-S	STORE	2-P	SYS. CTRL.

MODULE: 2D Auto Detector (system control side con't)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
BLANK +10	2-S	BLANK +10	2-P	SYS. CTRL.
H TRIG	2-S	H TRIG	2-P	SYS. CTRL.

TIMING: Synchronization Side

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
SMALL FRAME	2-P	STANDARD SMALL FRAME IN	2-S	VAR. F. & S.
BIG FRAME	2-P	BLANK FRAME	2-S	2D AUTO DET.
UNSYNC	2-P	UNSYNC	2-S	STD. COMP.
V TRIG	2-P	V TRIG	2-S	VAR. F. & S.
SYNC	2-P	SYNC	2-S	VAR. F. & S.
SYNC +16	2-P	SYNC +16	2-S	DISPLAY
STORE	2-P	STORE	2-S	STD. COMP.
BLANK +10	2-P	BLANK +10	2-S	DISPLAY
H TRIG	2-P	H TRIG	2-S	PROGRAMMER

MODULE: Function Computer (Function Comp.)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
INPUT NORMAL	2-S	SIZING IN NORMAL	2-P	STD. COMP.
	2-P	terminated		
MODIFIED +17	2-S	MODIFIED +17	2-P	STD. COMP.
	2-P	terminated		
FUNCTION OUT	20-S	FUNCTION IN 1	20-P	CFFI
EXTERNAL DRIVE	20-P	EXT DRIVE	20-S	CFFI
FUNCTION CONTROL	20-S	FUNCTION CONTROL	20-P	CFFI
	20-P	FUNCTION CONTROL	20-S	STD. COMP.
PROGRAMMER CONTROL	6-S	B-E	6-S	STD. COMP.
CLOCK	2-S	CLOCK (right)	2-P	SYS. CTRL.
	2-P	CLOCK	2-S	STD. COMP.
COMPUTER DISPLAY	2-P	COMPUTER DISPLAY	2-S	STD. COMP.
EXT BUSY	2-P	EXT BUSY TO PROG	2-S	CFFI
RESET	2-S	flying lead (org/grn)	2-P	CFFI interface cable

MODULE: Stabilized Power 100 (Power 100)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
POWER INPUT	3-S	AC to plinth from cabinet		
LAMP	6-S	to microscope lamp		

MODULE: Auto Focus

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
START	2-S	flying lead (rd/grn)	2-P	CFFI interface cable
MASK	2-S	MASK	2-P	VAR. F. & S.
	2-P	SMALL FRAME	2-S	AUTO FOCUS
SMALL FRAME	2-S	MASK	2-P	AUTO FOCUS
	2-P	terminated		
END OF X	2-S	END OF X	2-P	STAGE X/Y CTRL.
	2-P	CALC 1	2-S	CFFI
EXT FROM SYST. CONT.	2-S	EXT BUSY	2-P	SYS. CTRL.
BUSY TO PROG	2-P	EXT BUSY (right)	2-S	PROGRAMMER
POWER INPUT	3-S	AC to plinth from cabinet		
MOTOR DRIVE	10-S	Amphenol cable to stepper stage		
VIEDEO IN	BNC	SCANNER VIDEO	BNC	SYS. CTRL.

MODULE: Stage X/Y Control (STAGE X/Y CTRL.)

Origin Name	Origin Connector	Destination Name	Destination Connector	Destination Module
POWER INPUT	3-S	AC to plinth from cabinet		
STAGE DRIVE	14-S	Amphenol cable to stepper stage		
BUSY	2-P	INPUT BUSY	2-S	SYS. CTRL.
END OF X	2-P	END OF X	2-S	AUTO FOCUS
STEP STAGE	2-S	STEP OUT	2-P	CFFI
FOOTSWITCH	5-S	cable to footswitch		

APPENDIX XI

```
1000 REM                ANALYSER DATA COLLECTION ROUTINE
1010 REM                          DUST.BAS
1020 REM                                                   REV. 1.6 MAY 3/89
1030 REM
1035 REM    **THIS IS A PRINTOUT LISTING OF DUST.DOC
1036 REM    **DUST.BAS HAS MOST OF THE COMMENTS REMOVED
1040 REM AREA - REAL, PERIMETER, MAX & MIN PROJECTIONS AS INT (VAL * 10)
1050 REM COMMENTS, SCALE, NUMBER OF GRAINS, DATA, REJECTION INFO
1060 REM NO CALCS. DURING AQUISITION
1070 CLS$ = CHR$ (27) + CHR$ (12)
1080 REM
1090 REM   SET INTERFACE ADDRESSES
1100 REM
1110 BASE = &HE0D8
1120 D0 = BASE
1130 D1 = BASE + 1
1140 D2 = BASE + 2
1150 D3 = BASE + 3
1160 D4 = BASE + 4
1170 D5 = BASE + 5
1180 FLAG = BASE + 6
1190 CTRL = BASE + 7
1200 REM
1210 REM   MISCELLANEOUS HOUSEKEEPING
1220 REM
1230 POKE CTRL, 0: REM          FOCUS CAMERA
1235 REM    HANDLE POSSIBLE EMPTY DISK SITUATION VIA ERROR CODE
1240 ON ERROR GOTO 2150
1250 PRINT CLS$: FILES "B:*.DAT"
1255 REM    RE-ENABLE NORMAL ERROR HANDLING
1260 ON ERROR GOTO 0
1270 PRINT: PRINT: PRINT
1275 REM    PROMPT THEN SET UP OUTPUT FILE ON DRIVE C:
1280 INPUT "ENTER FILENAME TO BE CREATED ON DIVE C:  ", F$
1290 F$ = "C:" + F$ + ".DAT"
1300 OPEN "O", #1, F$
1305 REM    PROMPT THEN SAVE COMMENTS
1310 INPUT "ENTER COMMENTS: (date, time etc.)  ", C$
1320 PRINT #1, CHR$ (34); C$; CHR$ (34);
1325 REM    PROMPT THEN SAVE SCREEN RESOLUTION AND NUMBER OF GRAINS
1330 INPUT "ENTER RESOLUTION OF SCREEN (um/pixel):  ", SCALE
1340 INPUT "HOW MANY GRAINS? (MAX = 3000) ", GRAINS%
1350 PRINT #1, SCALE; GRAINS%;
```

```
1360 REM
1370 REM    AQUISITION LOOP
1380 REM
1385 REM    FOR EACH GRAIN
1390 FOR GRAIN = 1 TO GRAINS%
1395   REM    FOR EACH PARAMETER (AREA, PERIMETER AND TWO PROJECTIONS)
1400   FOR PARAM = 1 TO 4
1410     IF PARAM = 1 THEN PRINT: PRINT USING "#### "; GRAIN;
1415     REM    INITIALLIZE TIME-OUT VARIABLE AND REQUEST DATA FROM CFFI MODULE
1420     COUNT = 1: POKE CTRL, 2
1425     REM    WAIT THEN READ FLAG WORD FROM CFFI
1430     FOR N = 1 TO 15
1440     NEXT
1450     TEST = PEEK (FLAG)
1455     REM    INCREMENT AND CHECK TIME-OUT VARIABLE (MAY NEED TO RE-FOCUS)
1460     COUNT = COUNT + 1: IF COUNT = 500 THEN POKE CTRL, 1: GOTO 1420
1465     REM    STRIP AND CHECK DATA READY BIT FROM FLAG WORD
1470     BITTEST = TEST AND 1: IF BITTEST = 1 THEN 1450
1475     REM    STRIP SOFTWARE CODE FROM FLAG WORD AND SET EXPECTED SOFTCODE
1480     CODE = TEST / 2: ZCODE = PARAM + 1
1485     REM    COMPARE SOFTCODE AND EXPECTED CODE FOR AGREEMENT
1490     IF CODE <> ZCODE THEN PARAM = 1: GOTO 1410
1500     REM
1510     REM    GET CURRENT VALUE
1520     REM
1525     REM    READ DIGITS FROM CFFI
1530     T(1) = PEEK (D0): T(2) = PEEK (D1): T(3) = PEEK (D2): T(4) = PEEK (D3)
1540     T(5) = PEEK (D4): T(6) = PEEK (D5)
1545     REM    WEIGHT AND SUM DIGITS FROM CFFI
1550     FOR DIGIT = 1 TO 6
1560       MAG = DIGIT - 1
1570       VALUE = VALUE + (T(DIGIT) * 10 ^ MAG)
1580     NEXT
1590     REM
1600     REM    GRAIN SIZE DISCRIMINATOR
1610     REM
1615     REM    CHECK FOR ZERO VALUE, INCREMENT COUNTER IF NECESSARY AND RESTART
1620     IF VALUE = 0 THEN ZEROVAL = ZEROVAL + 1: PARAM = 1: GOTO 1410
1625     REM    CHECK FOR MINIMUM AREA, INCREMENT COUNTER IF NEC. AND RESTART
1630     IF PARAM = 1 AND VALUE < 3 THEN SMALL = SMALL + 1: PARAM = 1: GOTO 1410
1640     REM
1650     REM    TRANSFER DATA TO GRAIN PARAMETER
1660     REM
1665     REM    SCALE DATA IN REQUIRED DIMENSIONS
1670     VALUE = VALUE * SCALE
1675     REM    FOR SINGLE DIMENSION PARAMETERS SHIFT DEC POINT TO CARRY 1 SIG. FIG.
1680     IF PARAM = 1 THEN AREA = VALUE * SCALE: PRVALUE = AREA: GOTO 1740
1690     VALUE = INT (VALUE * 10)
1695     REM    ALLOCATE TO APPROPRIATE PARAMETER VARIABLE
1700     IF PARAM = 2 THEN PERIM = VALUE: GOTO 1730
1710     IF PARAM = 3 THEN VP = VALUE: GOTO 1730
1720     IF PARAM = 4 THEN HP = VALUE
1725     REM    PRINT VALUE TO SCREEN
1730     PRVALUE = VALUE / 10
```

```
1740     PRINT USING "######.# "; PRVALUE;
1750     VALUE = 0
1760   NEXT
1770   REM
1780   REM     SORT PROJECTIONS
1790   REM
1800   IF VP > HP THEN PMAX = VP: PMIN = HP: GOTO 1830
1810   IF HP > VP THEN PMAX = HP: PMIN = VP: GOTO 1830
1820   IF VP = HP THEN PMAX = HP: PMIN = HP
1825     REM    CHECK FOR IMPOSSIBLE PROJECTION
1830   IF PMAX > PERIM / 2 THEN BADPROJ = BADPROJ + 1: PRINT: GOTO 1400
1835     REM    CHECK FOR UNLIKELY ELONGATION
1840   IF PMAX > 20 * PMIN THEN TOOLONG = TOOLONG + 1: PRINT: GOTO 1400
1850   REM
1860   REM    UPDATE MAXIMUM VARIABLES
1870   REM
1880   IF AREA > AMAX THEN AMAX = AREA
1890   IF PERIM > PERMAX THEN PERMAX = PERIM
1900   IF PMAX > PMAXMAX THEN PMAXMAX = PMAX
1910   IF PMIN > PMINMAX THEN PMINMAX = PMIN
1920   REM
1930   REM    OUTPUT DATA TO DISK
1940   REM
1950   PRINT #1, AREA; INT (PERIM); INT (PMAX); INT (PMIN);
1960 NEXT
1970 REM
1980 REM   OUTPUT MAXIMUM VARIABLES TO DISK
1990 REM
2000 PRINT #1, AMAX; INT (PERMAX); INT (PMAXMAX); INT (PMINMAX);
2010 PRINT
2015 REM    PRINT AND OUTPUT REJECTION DATA AND PRINT INFO TO SAVE DATA FILE
2020 BADVAL = ZEROVAL + SMALL + BADPROJ + TOOLONG
2030 PRINT "ZERO READINGS = "; TAB(20); ZEROVAL
2040 PRINT "SMALL GRAINS = "; TAB(20); SMALL
2050 PRINT "BAD PROJECTIONS = "; TAB(20); BADPROJ
2060 PRINT "TOO ELONGATED = "; TAB(20); TOOLONG
2070 PRINT "TOTAL REJECTIONS = "; TAB(20); BADVAL;
2080 PRINT TAB(35); "= "; (BADVAL / GRAINS%) * 100
2090 PRINT
2100 PRINT F$; " IS ON DRIVE 'C':  ENTER SYSTEM LEVEL TO SAVE TO DISK"
2110 PRINT "                              i.e. PIP B:= "; F$
2120 PRINT #1, ZEROVAL; SMALL; BADPROJ; TOOLONG; BADVAL; (BADVAL/GRAINS%) * 100;
2130 CLOSE #1
2140 END
2150 A = ERR
2160 IF A = 53 THEN PRINT "NO FILES ON DATA DISK": RESUME NEXT
2170 ON ERROR GOTO 0
```

APPENDIX XII

```
1000 REM              ANALYZER DATA PRINTOUT ROUTINE
1010 REM                      PRTDATA.DOC
1020 REM
1030 REM                                                 REV. 1.4 MAY 3/89
1040 REM    DATA FROM DUST.BAS: PERIMETER AND PROJECTIONS TO 1 DECIMAL PLACE
1045 REM    **THIS IS A DOCUMENTED LISTING OF PRTDATA.DOC
1046 REM    **PRTDATA.BAS HAS MOST OF THE COMMENTS REMOVED
1050 REM
1055 REM    SET UP CHARACTER TO CLEAR SCREEN AND FORM FEED PRINTER
1060 CLS$ = CHR$(27) + CHR$(12): FFEED$ = CHR$(12)
1065 REM    DISPLAY DISK FILES AND PROMPT A SELECTION
1070 PRINT CLS$: FILES "B:*.DAT": PRINT: PRINT: PRINT
1080 INPUT "ENTER FILENAME TO OUTPUT: ", F$
1090 F$ = "B:" + F$ + ".DAT"
1100 PRINT "SET PRINTER TO TO OF PAGE THEN HIT ANY KEY"
1110 H$ = INKEY$: IF LEN (H$) = 0 THEN 1110
1115 REM    PRINT FILE SELECTION AND PARTICULARS ON TO OF PAGE
1120 LPRINT F$;
1130 OPEN "I", #1, F$
1140 COUNT = 1
1150 INPUT #1, COMMENT$, RES, GRAINS%
1160 LPRINT "  resolution = ";
1170 LPRINT USING "#.###"; RES;
1180 LPRINT " uM / pixel";
1190 LPRINT "   "; COMMENT$
1200 LPRINT CHR$ (15);
1210 PIE = 3.14159
1220 CONST = (4 * 3.14159) / (3 * 2 ^ 3)
1230 FOR GRAIN = 1 TO GRAINS% + 1
1240   INPUT #1, AREA, PERIM, PROJMAX, PROJMIN
1250   PERIM = PERIM / 10: PROJMAX = PROJMAX / 10: PROJMIN = PROJMIN / 10
1255   REM    IF FIRST GRAIN ON A PAGE PRINT HEADINGS
1260   IF COUNT <> 1 THEN 1300
1270   LPRINT "GRAIN      AREA       PERIM   PROJMAX  PROJMIN   RATIO    MAJOR";
1280   LPRINT "   MINOR    DIAM 1       VOL 1        VOL 2      ROUNDNESS"
1290   LPRINT
1295   REM    CALCULATE RATIO, DIAMETERS, VOLUMES AND ROUNDNESS
1300   RATIO = PROJMAX / PROJMIN
1310   MAJOR = 2 * ((AREA * PROJMAX) / (PIE * PROJMIN)) ^ .5
1320   MINOR = 2 * ((AREA / PROJMIN) / (PIE * PROJMAX)) ^ .5
1330   DIA1 = 2 * (AREA / PIE) ^ .5
1340   VOL1 = CONST * DIA1 ^ 3
1350   VOL2 = CONST * MAJOR * MINOR ^ 2
1360   ROUND = PERIM ^ 2 / (4 * PIE * AREA)
1365   REM    IF NOT 'MAXIMUMS GRAIN' THEN PRINT INFO
1370   IF GRAIN = GRAINS% + 1 THEN 1550
1380   LPRINT USING "####     "; GRAIN;
1390   LPRINT USING "#####.#    "; AREA; PERIM;
1400   LPRINT USING "###.#    "; PROJMAX; PROJMIN;
1410   LPRINT USING "##.#     "; RATIO;
1420   LPRINT USING "###.#    "; MAJOR; MINOR; DIA1;
1430   LPRINT USING "##.##^^^^     "; VOL1; VOL2;
1440   LPRINT USING "##.##"; ROUND
```

```
1445   REM    UPDATE CALCULATED MAXIMUMS
1450   IF RATIO > RATMAX THEN RATMAX = RATIO
1460   IF MAJOR > MAJRMAX THEN MAJRMAX = MAJOR
1470   IF MINOR > MINRMAX THEN MINRMAX = MINOR
1480   IF DIA1 > D1MAX THEN D1MAX = DIA1
1490   IF VOL1 > V1MAX THEN V1MAX = VOL1
1500   IF VOL2 > V2MAX THEN V2MAX = VOL2
1510   IF ROUND > RNDMAX THEN RNDMAX = ROUND
1515   REM    CHECK FOR END OF PAGE
1520   IF COUNT <> 60 THEN 1540
1530   LPRINT FFEED$: COUNT = 0
1535 REM    INPUT AND PRINT REJECTION DATA
1540   COUNT = COUNT + 1
1550 NEXT
1555 REM    PRINT MAXIMUMS
1560 LPRINT USING "####     "; GRAIN - 1;
1570 LPRINT USING "#####.#    "; AREA; PERIM;
1580 LPRINT USING "###.#    "; PROJMAX; PROJMIN;
1590 LPRINT USING "##.#     "; RATMAX;
1600 LPRINT USING "###.#    "; MAJRMAX; MINRMAX; D1MAX;
1610 LPRINT USING "##.##^^^^     "; V1MAX; V2MAX;
1620 LPRINT USING "##.##"; RNDMAX
1630 LPRINT
1640 INPUT #1, ZEROVAL, SMALL, BADPROJ, TOOLONG, BADVAL, PCT
1650 LPRINT "ZERO READINGS = "; TAB(20); ZEROVAL
1660 LPRINT "SMALL GRAINS = "; TAB(20); SMALL
1670 LPRINT "BAD PROJECTIONS = "; TAB(20); BADPROJ
1680 LPRINT "TOO ELONGATED = "; TAB(20); TOOLONG
1690 LPRINT "TOTAL REJECTIONS = "; TAB(20); BADVAL; " = "; PCT; "%"
1700 CLOSE #1
1710 END
```

APPENDIX XIII

```
1000 REM                    HSTOGRAM.BAS
1010 REM                                       REV. 2.1 JUNE 14/89
1020 REM
1030 REM USE OF RAM DISK AND MULTI ZOOM OPTIONS
1035 REM    ** THIS IS A PRINTOUT LISTING OF WORKING.BAS
1036 REM    ** HSTOGRAM.BAS HAS MOST OF THE COMMENTS REMOVED
1040 REM
1050 REM     FILES/HOUSE KEEPING
1060 REM
1065 REM     DEFINE MOST USED VARIABLES AND CONSTANTS (1st IN LIST FOR SPEED)
1070 TEMP = 0: TEMP% = 0: GRAIN = 0: GRAINS% = 0
1080 PIE = 3.1415: RNDCNST = 12.57: VOLCNST = .5236
1090 DIM ZOOM (7, 10, 2)
1095 REM     CLEAR SCREEN AND FORM FEED CHARACTERS
1100 CLS$ = CHR$ (27) + CHR$ (12)
1110 FFEED$ = CHR$ (12)
1115 REM     HANDLE POSSIBLE EMPTY DISK SITUATION VIA ERROR CODE
1120 ON ERROR GOTO 5500
1130 PRINT CLS$: FILES "B:*.DAT"
1140 ON ERROR GOTO 0
1145 REM     RE-ENABLE ERROR HANDLING
1150 OPTN$ (1) = "AREA"
1155 REM     OPTION MENU VARIABLE
1160 OPTN$ (2) = "PERIMETER"
1170 OPTN$ (3) = "DIAMETER 1"
1180 OPTN$ (4) = "ELONGATION"
1190 OPTN$ (5) = "ROUNDNESS"
1200 OPTN$ (6) = "VOLUMES vs. DIAMETER 1"
1210 OPTN$ (7) = "AREA vs. DIAMETER 1"
1220 OPTN$ (8) = "RUN"
1230 OPTN$ (9) = "QUIT"
1240 PRINT: PRINT: PRINT
1250 INPUT "ENTER FILENAME TO PLOT: ", F$
1260 F$ = "B:" + F$ + ".DAT"
1270 PRINT "SET PRINTER TO TOP OF PAGE THEN HIT ANY KEY"
1280 H$ = INKEY$: IF LEN (H$) = 0 THEN 1280
1290 REM
1300 REM .  ZOOM NO ZOOM
1310 REM
1320 INPUT "ARE YOU ZOOMING? (y/n): ", H$
1330 IF H$ = "Y" OR H$ = "y" THEN 1360
1340 IF H$ = "N" OR H$ = "n" THEN 1770
1350 GOTO 1320
1355 REM    INITIALLIZE NUMBER OF ZOOMS VARIABLE
1360 ZOOMS = 0
1365 REM    CLEAR SCREEN AND PRINT MENU
1370 PRINT CLS$
1380 PRINT "#  ZOOM OPTION"; TAB(30); "  MAX       MIN      INTERVAL"
1390 PRINT
1400 FOR MENU = 1 TO 9
1410   PRINT USING "#  "; MENU;
1420   PRINT OPTN$ (MENU);
1430   IF MENU > 7 THEN 1540
1435   REM    CYCLES VARIABLE IS NUMBER OF ZOOMS FOR EACH OPTION
```

```
1440   CYCLES = ZOOM (MENU, 0,0)
1450   IF CYCLES = 0 THEN PRINT
1460   FOR CYCLE = 1 TO CYCLES
1470     MAXIND = ZOOM (MENU, CYCLE, 0)
1480     MININD = ZOOM (MENU, CYCLE, 1)
1490     INTVAL = ZOOM (MENU, CYCLE, 2)
1500     PRINT TAB(30);
1510     PRINT USING "####.##   "; MAXIND; MININD; INTVAL
1520   NEXT
1530   GOTO 1550
1540   PRINT
1550 NEXT
1555 REM    UPDATE NUMBER OF ZOOMS SELECTED AND PROMPT NEXT ZOOM
1560 PRINT
1570 PRINT USING "## "; ZOOMS;
1580 PRINT "ZOOMS SELECTED:  MAX = 10"
1590 PRINT
1600 INPUT "ENTER ZOOM FUNCTION:  ", OPTN
1610 IF OPTN < 0 OR OPTN > 9 THEN 1600
1620 OPTN = INT (OPTN)
1625 REM    EXIT, RUN OR INPUT ZOOM RANGE?
1630 IF OPTN = 9 THEN 5490
1640 IF OPTN = 8 THEN 1770
1650 ZOOMS = ZOOMS + 1
1655 REM    PROMPT FOR MAXIMUM AND MINIMUM INDEPENDANT VARIABLE VALUES FOR ZOOM
1660 INPUT "MAXIMUM: "; MAXIND
1670 INPUT "MINIMUM: "; MININD
1680 INTVAL = (MAXIND - MININD) / 20
1685 REM    UPDATE NUMBER OF CYCLES FOR SELECTED ZOOM OPTION
1690 CYCLES = ZOOM (OPTN, 0, 0) + 1
1695 REM    STORE INFORMATION IN ZOOM ARRAY (MENU OPTION, CYCLE NUMBER, PARAM)
1700 ZOOM (OPTN, 0, 0) = CYCLES
1710 ZOOM (OPTN, CYCLES, 0) = MAXIND
1720 ZOOM (OPTN, CYCLES, 1) = MININD
1730 ZOOM (OPTN, CYCLES, 2) = INTVAL
1735 REM    IF NUMBER OF ZOOMS = MAX EXIT MENU TO PLOT
1740 IF ZOOMS = 10 THEN 1770 ELSE 1370
1750 REM
1760 REM    LOAD DATA FROM FILE INTO RAM DISK IF NOT ALREADY LOADED
1770 REM
1780 IF LOADED = 1 THEN 2070
1790 PRINT
1800 PRINT "LOADING DATA"
1810 OPEN "I", #1, F$
1815 REM    'GET DATA FILE COMMENT, SCREEN RESOLUTION AND NUMBER OF GRAINS
1820 INPUT #1, COMMENT$, RES, GRAINS%
1825 REM    SET UP A RAM DISK COPY OF DATA FILE
1830 RAM$ = "C:TEMP.DAT"
1840 OPEN "O", #2, RAM$
1850 FOR GRAIN = 1 TO GRAINS% + 1
1860   INPUT #1, AREA, PERIM%, PROJMAX%, PROJMIN%
```

```
1875  REM    FOR ALL BUT LAST ENTRY (MAXIMUMS) STORE COPY TO RAM DISK
1880   IF GRAIN > GRAINS% THEN 1900
1890   PRINT #2, AREA; PERIM%; PROJMAX%; PROJMIN%;
1900 NEXT
1905 REM    GET DATA FILE REJECTION INFORMATION AND CLOSE FILES
1910 INPUT #1, ZEROVAL, SMALL, BADPROJ, TOOLONG, BADVAL, PCT
1920 CLOSE #1: CLOSE #2
1925 REM    SET DATA LOADED INDICATOR
1930 LOADED = 1
1940 REM
1950 REM    MORE FILE/HOUSE KEEPING
1960 REM
1965 REM    IF ZOOMING SKIP
1970 IF OPTN <> 0 THEN 2070
1975 REM    FIND AREA AND PERIMETER MAXIMUMS AND INTERVALS
1980 AMAX = AREA
1990 PERMAX = PERIM% / 10
2000 AINT = 1.0001 * AMAX / 20
2010 PERMINT = 1.0001 * PERMAX / 20
2020 ZOOM (1, 1, 2) = AINT
2030 ZOOM (2, 1, 2) = PERMINT
2035 REM    SET EACH OPTION CYCLE COUNT TO 1
2040 FOR X = 1 TO 7
2050   ZOOM (X, 0, 0) = 1
2060 NEXT
2065 REM    FIND MAXIMUM VALUE OF CYCLES
2070 FOR X = 1 TO 5
2080   CYCLE = ZOOM (X, 0, 0)
2090   IF CYCLE > CYCLMAX THEN CYCLMAX = CYCLE
2100 NEXT
2105 REM    SET UP HISTOGRAM INTEGER DATA ARRAY (CYCLE, BAR NUM, MENU OPTION)
2110 DIM HIST% (CYCLMAX, 20, 5)
2120 REM
2130 REM    AREA HISTOGRAM
2140 REM
2150 PRINT "BAR LENGTH CALCULATIONS
2155 REM    IF NO AREA CYCLES SKIP TO PERIMETER
2160 CYCLES = ZOOM (1, 0, 0)
2170 IF CYCLES = 0 THEN 2360
2180 PRINT "    AREA"
2190 FOR CYCLE = 1 TO CYCLES
2200   MININD = ZOOM (1, CYCLE, 1)
2210   INTVAL = ZOOM (1, CYCLE, 2)
2220   OPEN "I", #2, RAM$
2230   FOR GRAIN = 1 TO GRAINS%
2240     INPUT #2, AREA, WASTE1, WASTE2, WASTE3
2250     TEMP = (AREA - MININD) / INTVAL
2260     IF TEMP < 0 OR TEMP => 20 THEN 2290
2270     TEMP% = INT (TEMP) + 1
2280     HIST% (CYCLE, TEMP%, 1) = HIST% (CYCLE, TEMP%, 1) + 1
2290   NEXT
2300   CLOSE #2
2310 NEXT
```

```
2315 REM    ARE ALL ZOOMS DONE?
2320 ZOOM = CYCLES
2330 IF ZOOM = ZOOMS THEN 3770
2340 REM
2350 REM    PERIMETER HISTOGRAM
2360 REM
2365 REM    IF NO PERIMETER CYCLES SKIP TO EXTENDED CALCULATIONS
2370 CYCLES = ZOOM (2, 0, 0)
2380 IF CYCLES = 0 THEN 2570
2390 PRINT "    PERIMETER"
2400 FOR CYCLE = 1 TO CYCLES
2410   MININD = ZOOM (2, CYCLE, 1)
2420   INTVAL = ZOOM (2, CYCLE, 2)
2430   OPEN "I", #2, RAM$
2440   FOR GRAIN = 1 TO GRAINS%
2450     INPUT #2, WASTE1, PERIM, WASTE2, WASTE3
2460     TEMP = ((PERIM / 10) - MININD) / INTVAL
2470     IF TEMP < 0 OR TEMP => 20 THEN 2500
2480     TEMP% = INT (TEMP) + 1
2490     HIST% (CYCLE, TEMP%, 2) = HIST% (CYCLE, TEMP%, 2) + 1
2500   NEXT
2510   CLOSE #2
2520 NEXT
2525 REM    AREA ALL ZOOMS DONE?
2530 ZOOM = ZOOM + CYCLES
2540 IF ZOOM = ZOOMS THEN 3770
2550 REM
2560 REM    CALCULATE DIAMETERS, ROUNDNESS, ELONGATION RATIO AND VOLUMES
2565 REM                                          IF NOT ALREADY DONE
2570 REM
2580 IF CALCLTD = 1 THEN 2820
2590 PRINT "EXTENDED CALCULATIONS
2595 REM    PREPARE A RAM DISK FILE FOR CALCULATIONS AND OPEN INPUT FILE
2600 CALC$ = "C:CALC.DAT"
2610 OPEN "I", #2, RAM$
2620 OPEN "O", #3, CALC$
2630 FOR GRAIN = 1 TO GRAINS%
2640   INPUT #2, AREA, PERIM, PROJMAX, PROJMIN
2650   PERIM = PERIM / 10: PROJMAX = PROJMAX / 10: PROJMIN = PROJMIN / 10
2660   DIA1 = 2 * (AREA / PIE) ^ .5
2670   DIA2 = 2 * ((AREA * PROJMAX) / (PIE * PROJMIN)) ^ .5
2680   DIA3 = 2 * ((AREA * PROJMIN) / (PIE * PROJMAX)) ^ .5
2685   REM    SHIFT DEC POINT TO CARRY 3 SIG FIGS THROUGH TRUNCATION & STORAGE
2690   ELONG = ((PROJMAX / PROJMIN) - 1) * 1000
2700   RNDNESS = ((PERIM ^ 2 / (AREA * RNDCNST)) - 1) * 1000
2710   VOL1 = DIA1 ^ 3 * VOLCNST
2720   VOL2 = DIA2 * DIA3 ^ 2 * VOLCNST
2725   REM    STORE TO RAM DISK AND UPDATE MAXIMUMS
2730   PRINT #3, INT(DIA1 * 10); INT(ELONG); INT(VOL1); INT(VOL2); INT(RNDNESS);
2740   IF DIA1 > DIAMAX THEN DIAMAX = DIA1
2750   IF ELONG > ELONGMX THEN ELONGMX = ELONG
2760   IF RNDNESS > RNDMAX THEN RNDMAX = RNDNESS
2770 NEXT
```

```
2775 REM    CLOSE FILES AND SET CALULATIONS COMPLETED FLAG
2780 CLOSE #2: CLOSE #3
2790 CALCLTD = 1
2800 REM
2810 REM    DIAMETER, ELONGATION AND ROUNDNESS HISTOGRAMS
2820 REM
2830 PRINT "BAR LENGTH CALULATIONS"
2840 IF OPTN <> 0 THEN 2950
2850 DIAINT = 1.0001 * DIAMAX / 20
2855 REM    SHIFT DEC POINT TO RETURN 3 SIG FIG AFTER DEC POINT
2860 ELNGINT = 1.0001 * ELONGMX / (20 * 1000)
2870 RNDINT = 1.0001 * RNDMAX / (20 * 1000)
2880 ZOOM (4, 1, 1) = .9999
2890 ZOOM (5, 1, 1) = .9999
2900 ZOOM (3, 1, 2) = DIAINT
2910 ZOOM (4, 1, 2) = ELNGINT
2920 ZOOM (5, 1, 2) = RNDINT
2930 ZOOM (6, 1, 2) = DIAINT
2940 ZOOM (7, 1, 2) = DIAINT
2950 PRINT "    DIAMETER, ELONGATION AND ROUNDNESS
2960 OPEN "I", #3, CALC$
2970 FOR GRAIN = 1 TO GRAINS%
2980   INPUT #3, DIA1, ELONG, WASTE1, WASTE2, RNDNESS
2990   REM
3000   REM    DIAMETER
3010   REM
3015   REM    IF NO DIAMETER CYCLES SKIP TO ELONGATION
3020   CYCLES = ZOOM (3, 0, 0)
3030   IF CYCLES = 0 THEN 3140
3040   FOR CYCLE = 1 TO CYCLES
3050     MININD = ZOOM (3, CYCLE, 1)
3060     INTVAL = ZOOM (3, CYCLE, 2)
3070     TEMP = ((DIA1 / 10) - MININD) / INTVAL
3080     IF TEMP < 0 OR TEMP => 20 THEN 3110
3090     TEMP% = INT (TEMP) + 1
3100     HIST% (CYCLE, TEMP%, 3) = HIST% (CYCLE, TEMP%, 3) +1
3110   NEXT
3120   REM
3130   REM    ELONGATION
3140   REM
3145   REM    IF NO ELONGATION CYCLES SKIP TO ROUNDNESS
3150   CYCLES = ZOOM (4, 0, 0)
3160   IF CYCLES = 0 THEN 3280
3170   ELONG = ELONG / 1000
3180   FOR CYCLE = 1 TO CYCLES
3190     MININD = ZOOM  (4, CYCLE, 1)
3200     INTVAL = ZOOM (4, CYCLE, 2)
3210     TEMP = (ELONG - MININD + 1) / INTVAL
3220     IF TEMP < 0 OR TEMP => 20 THEN 3250
3230     TEMP% = INT (TEMP) + 1
3240     HIST% (CYCLE, TEMP%, 4) = HIST% (CYCLE, TEMP%, 4) + 1
3250   NEXT
```

```
3260  REM
3270  REM    ROUNDNESS
3280  REM
3285  REM    IF NO ROUNDNESS CYCLES SKIP TO VOLUME
3290  CYCLES = ZOOM (5, 0, 0)
3300  IF CYCLES = 0 THEN 3410
3310  RNDNESS = RNDNESS / 1000
3320  IF RNDNESS < 0 THEN NOROUND = NOROUND + 1: GOTO 3410
3330  FOR CYCLE = 1 TO CYCLES
3340    MININD = ZOOM (5, CYCLE, 1)
3350    INTVAL = ZOOM (5, CYCLE, 2)
3360    TEMP = (RNDNESS - MININD + 1) / INTVAL
3370    IF TEMP < 0 OR TEMP => 20 THEN 3400
3380    TEMP% = INT (TEMP) + 1
3390    HIST% (CYCLE, TEMP%, 5) = HIST% (CYCLE, TEMP%, 5) + 1
3400  NEXT
3410 NEXT
3415 REM    CLOSE FILES AND CHECK IF ALL ZOOMS DONE
3420 CLOSE #3
3430 ZOOM = ZOOM + ZOOM (3, 0, 0) + ZOOM (4, 0, 0) + ZOOM (5, 0, 0)
3440 IF ZOOM = ZOOMS THEN 3770
3450 REM
3460 REM    VOLUME 1, VOLUME 2 AND AREA vs. DIAMETER 1 HISTOGRAMS
3470 REM
3475 REM    FIND MAXIMUM NUMBER OF CYCLES
3480 CYCLE1 = ZOOM (6, 0, 0)
3490 CYCLE2 = ZOOM (7, 0, 0)
3500 IF CYCLE1 > CYCLE2 THEN CYCLMAX = CYCLE1 ELSE CYCLMAX = CYCLE2
3510 PRINT "    VOLUME 1, VOLUME 2 AND AREA"
3515 REM    SET UP HISTOGRAM REAL DATA ARRAY (CYCLE, BAR NUMBER, MENU OPTION)
3520 DIM HIST (CYCLMAX, 20, 3)
3530 FOR CYCLE = 1 TO CYCLMAX
3540  MININD1 = ZOOM (6, CYCLE, 1)
3550  MININD2 = ZOOM (7, CYCLE, 1)
3560  INTVAL1 = ZOOM (6, CYCLE, 2)
3570  INTVAL2 = ZOOM (7, CYCLE, 2)
3580  OPEN "I", #2, RAM$
3590  OPEN "I", #3, CALC$
3600  FOR GRAIN = 1 TO GRAINS%
3610    INPUT #2, AREA, WASTE1, WASTE2, WASTE3
3620    INPUT #3, DIA1, WASTE1, VOL1, VOL2, WASTE2
3630    TEMP = ((DIA1 / 10) - MININD1) / INTVAL1
3640    IF TEMP < 0 OR TEMP => 20 THEN 3680
3650    TEMP% = INT (TEMP) + 1
3660    HIST (CYCLE, TEMP%, 1) = HIST (CYCLE, TEMP%, 1) + VOL1
3670    HIST (CYCLE, TEMP%, 2) = HIST (CYCLE, TEMP%, 2) + VOL2
3680    TEMP = ((DIA1 / 10) - MININD2) / INTVAL2
3690    IF TEMP < 0 OR TEMP => 20 THEN 3720
3700    TEMP% = INT (TEMP) + 1
3710    HIST (CYCLE, TEMP%, 3) = HIST (CYCLE, TEMP%, 3) + AREA
3720  NEXT
3730  CLOSE #2: CLOSE#3
3740 NEXT
```

```
3750 REM
3760 REM    PLOT AREA, PERIMETER, DIAMETER, ELONGATION AND ROUNDNESS HISTOGRAMS
3770 REM
3780 ZOOM = 0
3790 PRINT "PLOT HISTOGRAMS"
3795 REM    SET PRINTER FOR COMPRESSED MODE AND SET PLOTS PER FORM FEED COUNTER
3800 LPRINT CHR$ (15);
3810 FEED = 0
3815 REM    FOR AREA, PERIMETER, DIAMETER, ELONGATION AND ROUNDNESS
3820 FOR PLT = 1 TO 5
3825   REM    IF NO CYCLES FOR THIS PLOT GO TO NEXT PLOT
3830   CYCLES = ZOOM (PLT, 0, 0)
3840   IF CYCLES = 0 THEN 4710
3850   ZOOM = ZOOM + CYCLES
3860   PRINT "     "; OPTN$ (PLT)
3870   FOR CYCLE = 1 TO CYCLES
3880     FEED = FEED + 1: SCALE = 0: RUNTOT = 0: HISTTOT = 0
3885     REM    FIND TOTAL FOR CUMULATIVE PERCENT CALCULATIONS
3890     FOR BAR = 1 TO 20
3900       IF HIST% (CYCLE,BAR,PLT) > SCALE THEN SCALE = HIST% (CYCLE,BAR,PLT)
3910       HISTTOT = HISTTOT + HIST% (CYCLE, BAR, PLT)
3920     NEXT
3930     MININD = ZOOM (PLT, CYCLE, 1): INTVAL = ZOOM (PLT, CYCLE, 2)
3935     REM    IF NOT ZOOMING OR ROUNDNESS
3940     IF OPTN = 8 OR PLT <> 5 THEN 3970
3950     IF NOROUND > SCALE THEN SCALE = NOROUND
3960     HISTTOT = HISTTOT + NOROUND
3965     REM    FIND SCALE FACTOR TO SCALE BARS TO PAGE
3970     IF SCALE < 100 THEN SCALE = 1 ELSE SCALE = SCALE / 100
3975     REM    PRINT PLOT TITLE HEADINGS ETC.
3980     LPRINT "DATA SET: "; F$; " -"; OPTN$ (PLT); "- grains = ";
3990     LPRINT USING "####"; GRAINS%;
4000     LPRINT ", resolution =";
4010     LPRINT USING " #.### "; RES;
4020     LPRINT "uM / pixel";
4030     LPRINT "     "; COMMENT$
4040     LPRINT
4050     IF PLT = 1 THEN LPRINT "  sq. uM";
4060     IF PLT > 1 AND PLT < 4 THEN LPRINT "     uM";
4070     IF PLT > 3 THEN LPRINT "  RATIO";
4080     LPRINT TAB(45);
4090     LPRINT "EACH # REPRESENTS ";
4100     LPRINT USING "####"; SCALE;
4110     LPRINT " GRAIN(S), (* - LESS)";
4120     LPRINT TAB(114);
4130     LPRINT "GRAINS   SUM %"
4140     LPRINT
4145     REM    IF ZOOMING OR NOT ROUNDNESS
4150     IF OPTN = 8 OR PLT < 5 THEN 4380
```

```
4160    REM
4170    REM    IMPOOSIBLE ROUNDNESS
4180    REM
4190    LPRINT "  0.00  ";
4200    COUNT = NOROUND
4210    IF COUNT = 0 THEN 4300
4220    LOOP1 = COUNT / SCALE
4230    LOOP2 = INT (LOOP1)
4240    IF LOOP2 = 0 THEN LPRINT "*";
4250    IF LOOP2 = 0 THEN 4300
4260    FOR X = 1 TO LOOP2
4270      LPRINT "#";
4280    NEXT
4290    IF LOOP1 > LOOP2 THEN LPRINT "*";
4300    LPRINT TAB(115);
4310    LPRINT USING "####"; COUNT;
4320    RUNTOT = RUNTOT + COUNT
4330    PCTTOT = (RUNTOT / HISTTOT) * 100
4340    LPRINT TAB(123);
4350    LPRINT USING "###.#"; PCTTOT
4360    REM
4370    REM    ALL OTHER GRAINS
4380    REM
4385    REM    FIND RESOLUTION FOR PRINT FORMATTING HEADING
4390    HEADRES = 20 * INTVAL + MININD
4400    HEADING = MININD
4410    IF PLT = 1 AND HEADRES => 100 THEN LPRINT USING "######  "; HEADING
4420    IF PLT = 1 AND HEADRES < 100 THEN LPRINT USING "##.##  "; HEADING
4430    IF PLT = 2 OR PLT = 3 THEN LPRINT USING "####.#  "; HEADING
4440    IF PLT > 3 THEN LPRINT USING "###.##  "; HEADING
4445    REM    PLOT BARS
4450    FOR BAR = 1 TO 20
4460      COUNT = HIST% (CYCLE, BAR, PLT)
4465      REM    CALC CUMULATIVE PERCENT
4470      RUNTOT = RUNTOT + COUNT
4480      PCTTOT = (RUNTOT / HISTTOT) * 100
4490      HEADING = (BAR * INTVAL) + MININD
4495      REN    PRINT HEADING
4500      IF PLT = 1 AND HEADRES => 100 THEN LPRINT USING "######  "; HEADING;
4510      IF PLT = 1 AND HEADRES < 100 THEN LPRINT USING " ##.##  "; HEADING;
4520      IF PLT = 2 OR PLT = 3 THEN LPRINT USING "####.#  "; HEADING;
4530      IF PLT > 3 THEN LPRINT USING "###.##  "; HEADING;
4535      REM    PLOT BAR, VALUE AND CUMULATIVE PERCENT
4540      IF COUNT = 0 THEN 4630
4550      LOOP1 = COUNT / SCALE
4560      LOOP2 = INT (LOOP1)
4570      IF LOOP2 = 0 THEN LPRINT "*";
4580      IF LOOP2 = 0 THEN 4630
4590      FOR X = 1 TO LOOP2
4600        LPRINT "#";
4610      NEXT
4620      IF LOOP1 > LOOP2 THEN LPRINT "*";
4630      LPRINT TAB(115);
```

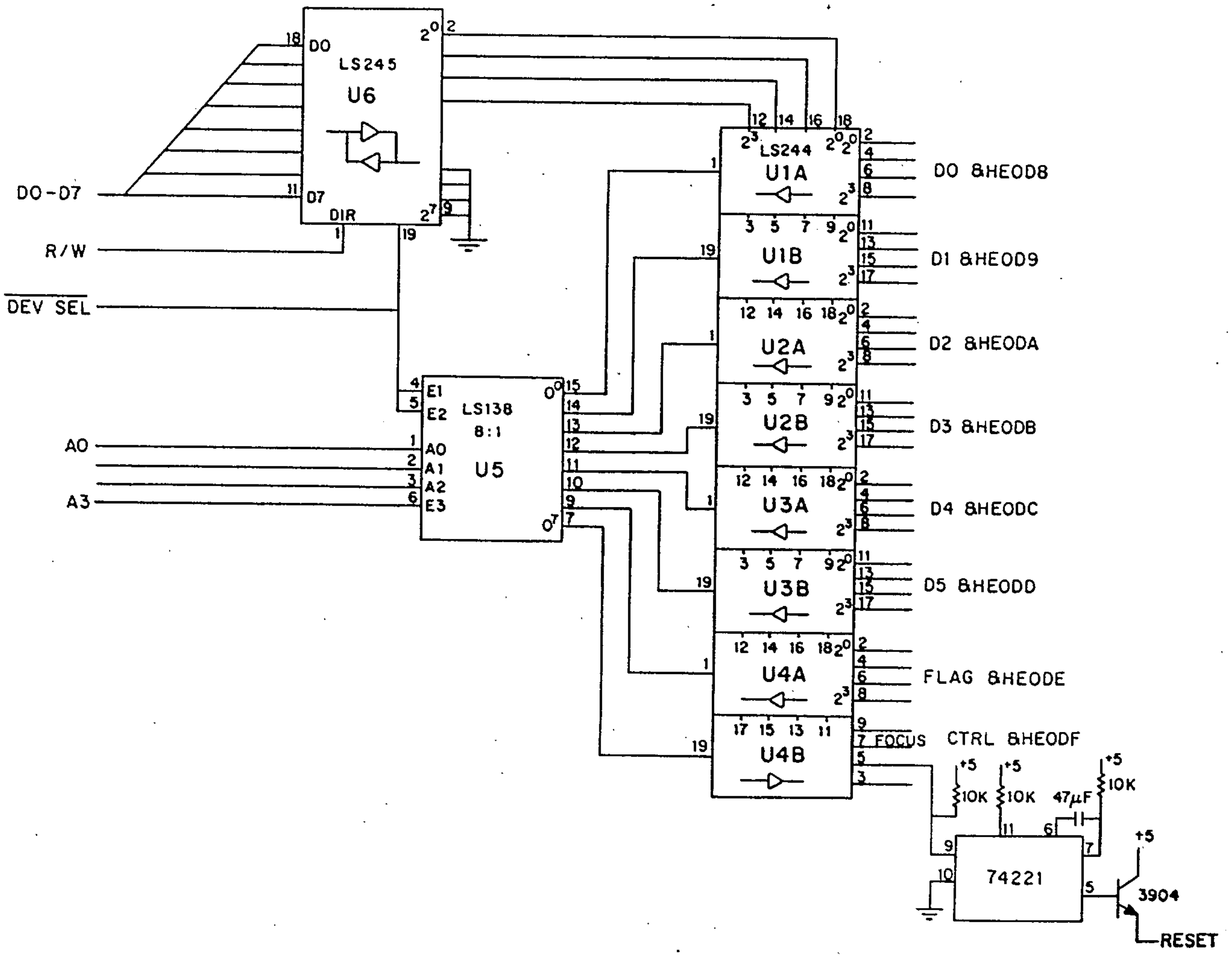
```
4640       LPRINT USING "####"; COUNT;
4650       LPRINT TAB(123);
4660       LPRINT USING "###.#"; PCTTOT
4670     NEXT
4675     REM    SPACE BETWEEN PLOTS
4680     LPRINT: LPRINT: LPRINT
4685     REM    IF SECOND PLOT ON PAGE GOTO NEXT PAGE
4690     IF FEED = 2 THEN LPRINT FFEED$: FEED = 0
4700   NEXT
4710 NEXT
4715 REM    IF NO MORE PLOTS SKIP TO REJECTION PRINT
4720 IF ZOOM = ZOOMS THEN 5380
4730 REM
4740 REM    PLOT VOLUME 1, VOLUME 2, AND AREA vs. DIAMETER 1
4750 REM
4755 REM    CURRENT PLOT HEADING VARIABLE
4760 CURRENT$ (1) = "VOLUME 1 vs. DIAMETER 1"
4770 CURRENT$ (2) = "VOLUME 2 vs. DIAMETER 1"
4780 CURRENT$ (3) = "AREA vs. DIAMETER 1"
4790 FOR PLT = 1 TO 3
4795   REM    GET NUMBER OF CYCLES FOR VOLUME 1 & 2 ELSE FOR AREA
4800   IF PLT < 3 THEN CYCLES = ZOOM (6, 0, 0) ELSE CYCLES = ZOOM (7, 0, 0)
4810   IF CYCLES = 0 THEN 5360
4820   PRINT "    "; CURRENT$ (PLT)
4830   FOR CYCLE = 1 TO CYCLES
4840     FEED = FEED + 1: SCALE = 0: RUNTOT = 0: HISTTOT = 0
4845     REM    GET MINIMUM AND INTERVAL FOR INDEPENDANT VARIABLE
4850     IF PLT < 3 THEN MININD = ZOOM (6, CYCLE, 1): INTVAL = ZOOM (6, CYCLE, 2)
4860     IF PLT = 3 THEN MININD = ZOOM (7, CYCLE, 1): INTVAL = ZOOM (7, CYCLE, 2)
4865     REM    FIND TOTAL FOR CUMULATIVE PERCENT CALCULATIONS
4870     FOR BAR = 1 TO 20
4880       IF HIST (CYCLE, BAR, PLT) > SCALE THEN SCALE = HIST (CYCLE, BAR, PLT)
4890       HISTTOT = HISTTOT + HIST (CYCLE, BAR, PLT)
4900     NEXT
4905     REM    FIND SCALE FACTOR TO SCALE BARS TO PAGE
4910     IF SCALE < 100 THEN SCALE = 1 ELSE SCALE = SCALE / 100
4915     REM    PRINT PLOT TITLE, HEADINGS ETC.
4920     LPRINT
4930     LPRINT "DATA SET: "; F$; " -"; CURRENT$ (PLT); "-  grains = ";
4940     LPRINT USING "####"; GRAINS%;
4950     LPRINT ", resolution = ";
4960     LPRINT USING "#.### "; RES;
4970     LPRINT "uM / pixel";
4980     LPRINT "    "; COMMENT$
4990     LPRINT
5000     LPRINT "    uM";
5010     LPRINT TAB(45);
5020     LPRINT "EACH # REPRESENTS ";
5030     LPRINT USING "##.##^^^^"; SCALE;
5040     IF PLT < 3 THEN LPRINT " cubic uM, (* - LESS)";
```

```
5050     IF PLT = 3 THEN LPRINT " sq. uM, (* - LESS)";
5060     LPRINT TAB(113);
5070     IF PLT < 3 THEN LPRINT "cubic uM";
5080     IF PLT = 3 THEN LPRINT " sq. uM";
5090     LPRINT TAB(125);
5100     LPRINT "SUM %"
5110     LPRINT
5120     LPRINT USING "######  "; MININD
5125     REM    PLOT BARS
5130     FOR BAR = 1 TO 20
5140       COUNT = HIST (CYCLE, BAR, PLT)
5145       REM    CALCULATE CUMULATIVE PERCENT
5150       RUNTOT = RUNTOT + COUNT
5160       PCTTOT = ( RUNTOT / HISTTOT) * 100
5170       HEADING = (BAR * INTVAL) + MININD
5175       REM    PRINT HEADING
5180       LPRINT USING "####.#  "; HEADING;
5190       IF COUNT = 0 THEN 5280
5200       LOOP1 = COUNT / SCALE
5210       LOOP2 = INT (LOOP1)
5220       IF LOOP2 = 0 THEN LPRINT "*";
5230       IF LOOP2 = 0 THEN 5280
5235       REM    PLOT BAR, VALUE AND CUMULATIVE PERCENT
5240       FOR X = 1 TO LOOP2
5250         LPRINT "#";
5260       NEXT
5270       IF LOOP1 > LOOP2 THEN LPRINT "*";
5280       LPRINT TAB(112);
5290       LPRINT USING "##.##^^^^"; COUNT;
5300       LPRINT TAB(124);
5310       LPRINT USING "###.#"; PCTTOT
5320     NEXT
5325     REM    SPACE BETWEEN PLOTS
5330     LPRINT: LPRINT: LPRINT
5335     REM    IF SECOND PLOT ON PAGE GO TO NEXT PAGE
5340     IF FEED = 2 THEN LPRINT FFEED$: FEED = 0
5350   NEXT
5360 NEXT
5365 REM    ERASE VOLUME AND AREA HISTOGRAM AND CLEAR SCREEN
5370 ERASE HIST
5380 PRINT CLS$
5385 REM    PRINT REJECTION DATA
5390 LPRINT "ZERO READINGS = "; TAB(20); ZEROVAL
5400 LPRINT "SMALL GRAINS = "; TAB(20); SMALL
5410 LPRINT "BAD PROJECTIONS = "; TAB(20); BADPROJ
5420 LPRINT "TOO ELONGATED = "; TAB(20); TOOLONG
5430 LPRINT "TOTAL REJECTIONS = "; TAB(20); BADVAL; " = "; PCT; "%"
5435 REM    ERASE AREA PERIMETER ETC. ARRAY AND ZOOM ARRAY, REDIMENSION ZOOM ARRAY
5440 ERASE HIST%
5450 ERASE ZOOM
5460 DIM ZOOM (7, 10, 2)
```

```
5470 ZOOMS = 0
5480 GOTO 1360
5485 REM    RETURN TO ZOOM OPTION MENU
5490 END
5495 REM    ERRROR HANDLING FOR EMPTY DATA DISK SITUATION
5500 A = ERR: B = ERL
5510 IF A = 53 THEN PRINT "NO FILES ON DATA DISK": RESUME NEXT
5520 ON ERROR GOTO 0
```

APPENDIX XIV

CFFI BLOCK DIAGRAM

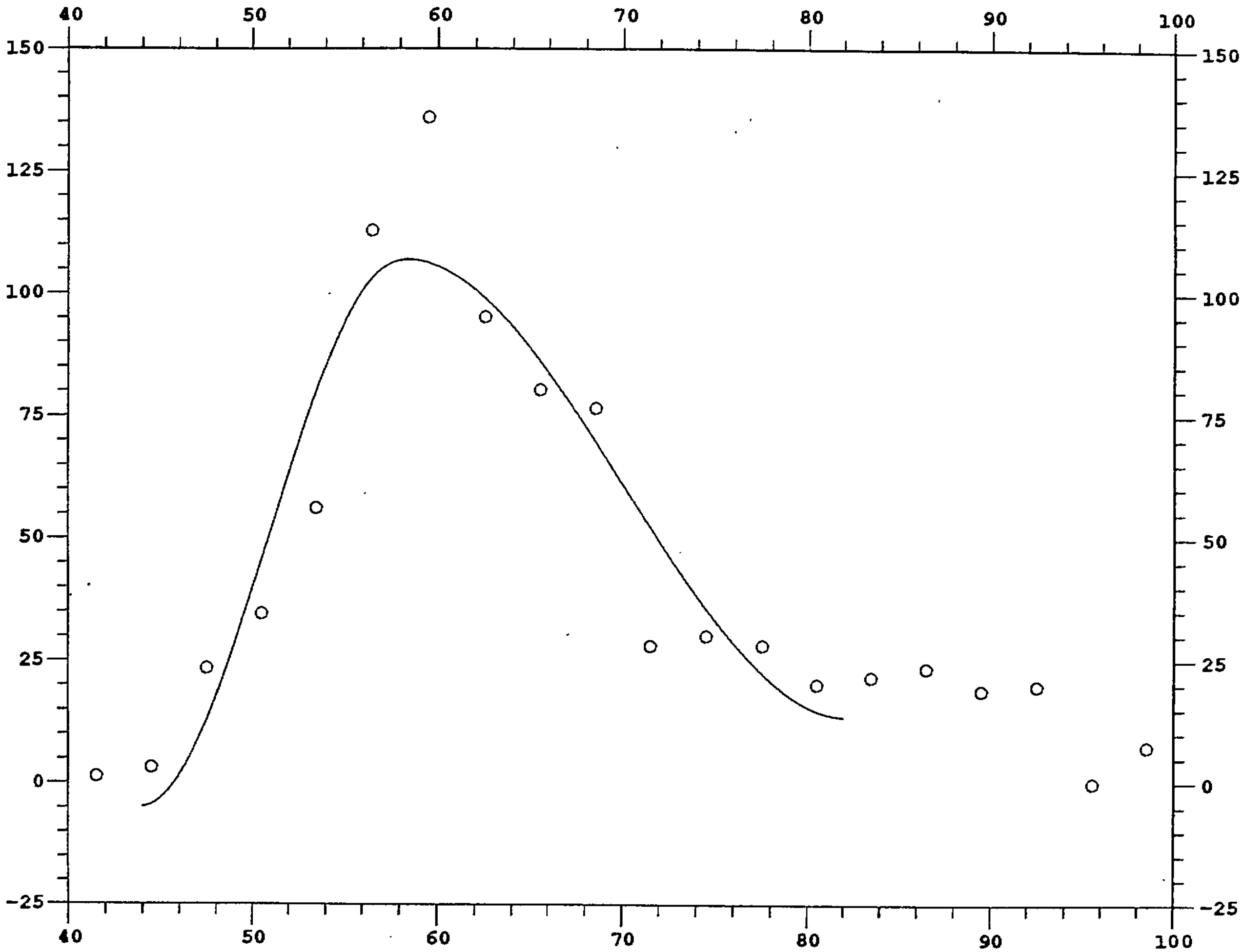


APPENDIX XV

CFFI Interface Cable Wiring Chart

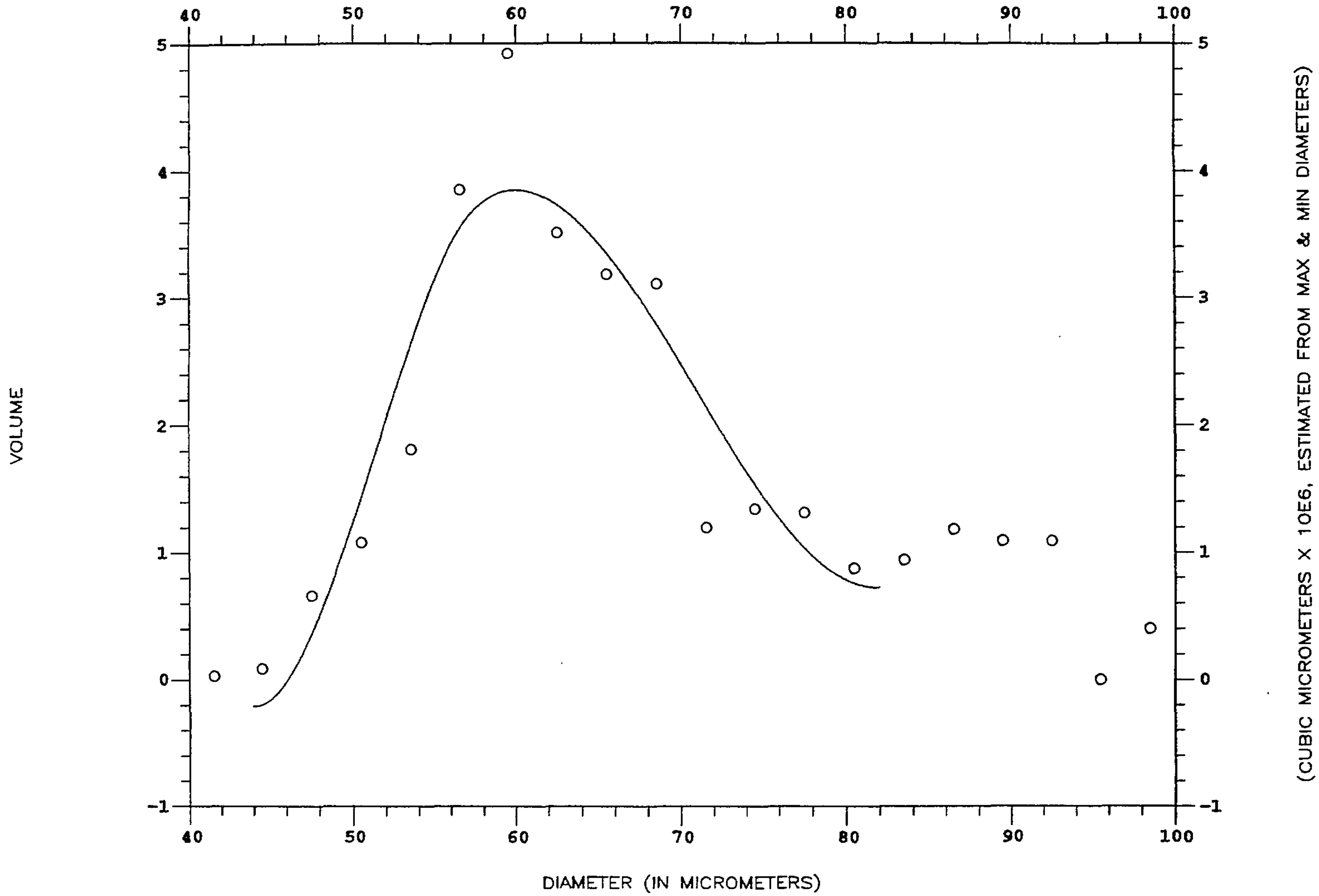
DATA Word	DATA Param	Origin Chip	Origin Pin	Card Edge Row	Card Edge Col	Cable Connector Pin #
D0	0	U1	2	L	34	1
	1		4	K	34	2
	2		6	L	35	3
	3		8	K	35	4
D1	0	U1	11	L	36	5
	1		13	K	36	6
	2		15	L	37	7
	3		17	K	37	8
D2	0	U2	2	L	38	9
	1		4	K	38	10
	2		6	L	39	11
	3		8	K	39	12
D3	0	U2	11	L	40	13
	1		13	K	40	14
	2		15	L	41	15
	3		17	K	41	16
D4	0	U3	2	K	48	30
	1		4	K	42	18
	2		6	L	43	19
	3		8	K	43	20
D5	0	U3	11	L	44	21
	1		13	K	44	22
	2		15	L	45	23
	3		17	L	48	
FLAG	0	U4	2	K	50	29
	1		4	L	24	25
	2		6	L	26	26
	3		8	L	28	27
CTRL	EXECUTE	U4	9	L	50	31
	FOCUS		7	L	22	28
	RESET		5	L	20	24

APPENDIX XVI



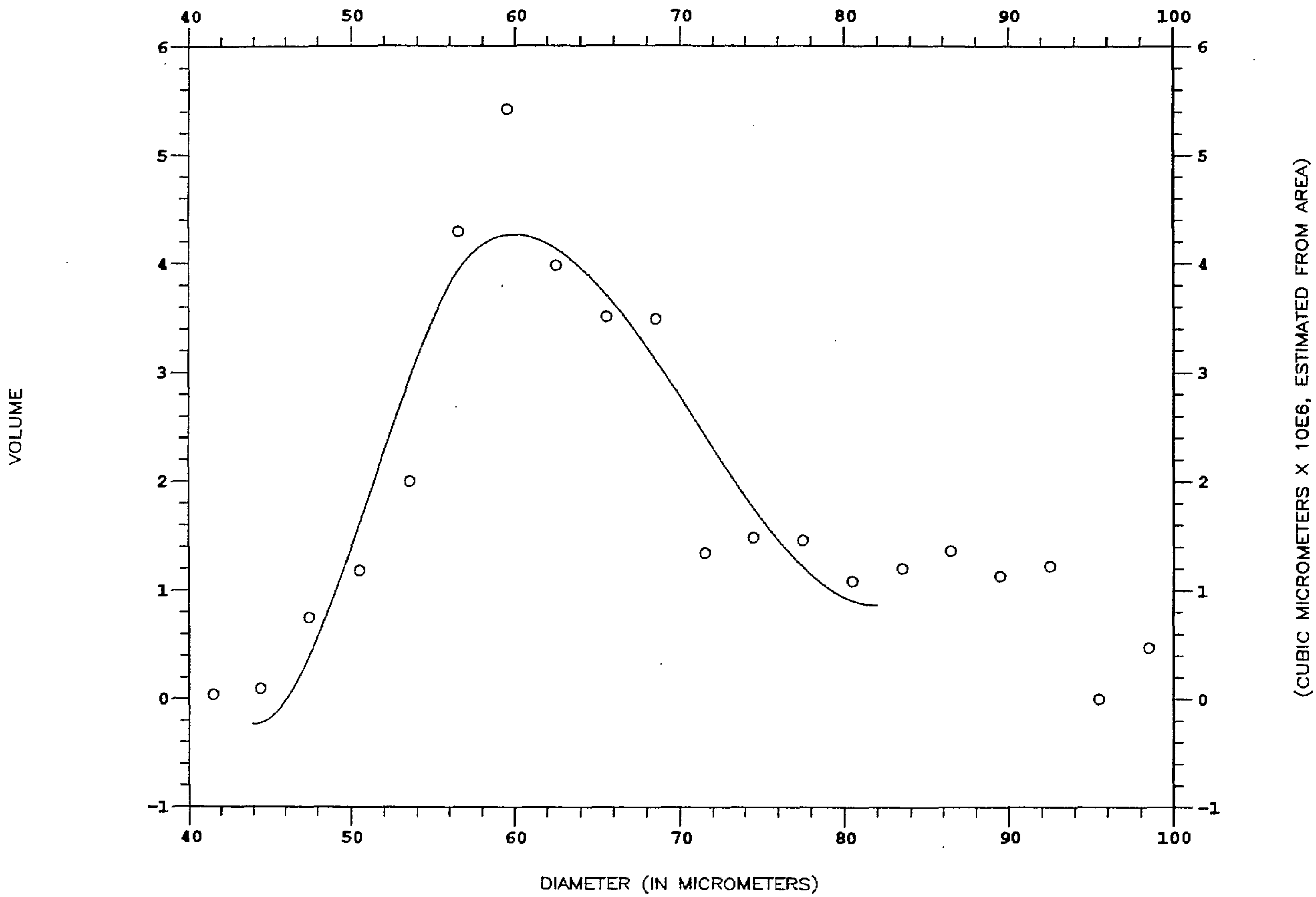
AREA VS DIAMETER WITHIN 325–400 FRACTION

1	41.5	1.32
2	44.5	3.15
3	47.5	23.4
4	50.5	34.6
5	53.5	56.2
6	56.5	113
7	59.5	136
8	62.5	95.3
9	65.5	80.5
10	68.5	76.7
11	71.5	28.1
12	74.5	30.1
13	77.5	28.2
14	80.5	20.2
15	83.5	21.7
16	86.5	23.5
17	89.5	19
18	92.5	20
19	95.5	0
20	98.5	7.41



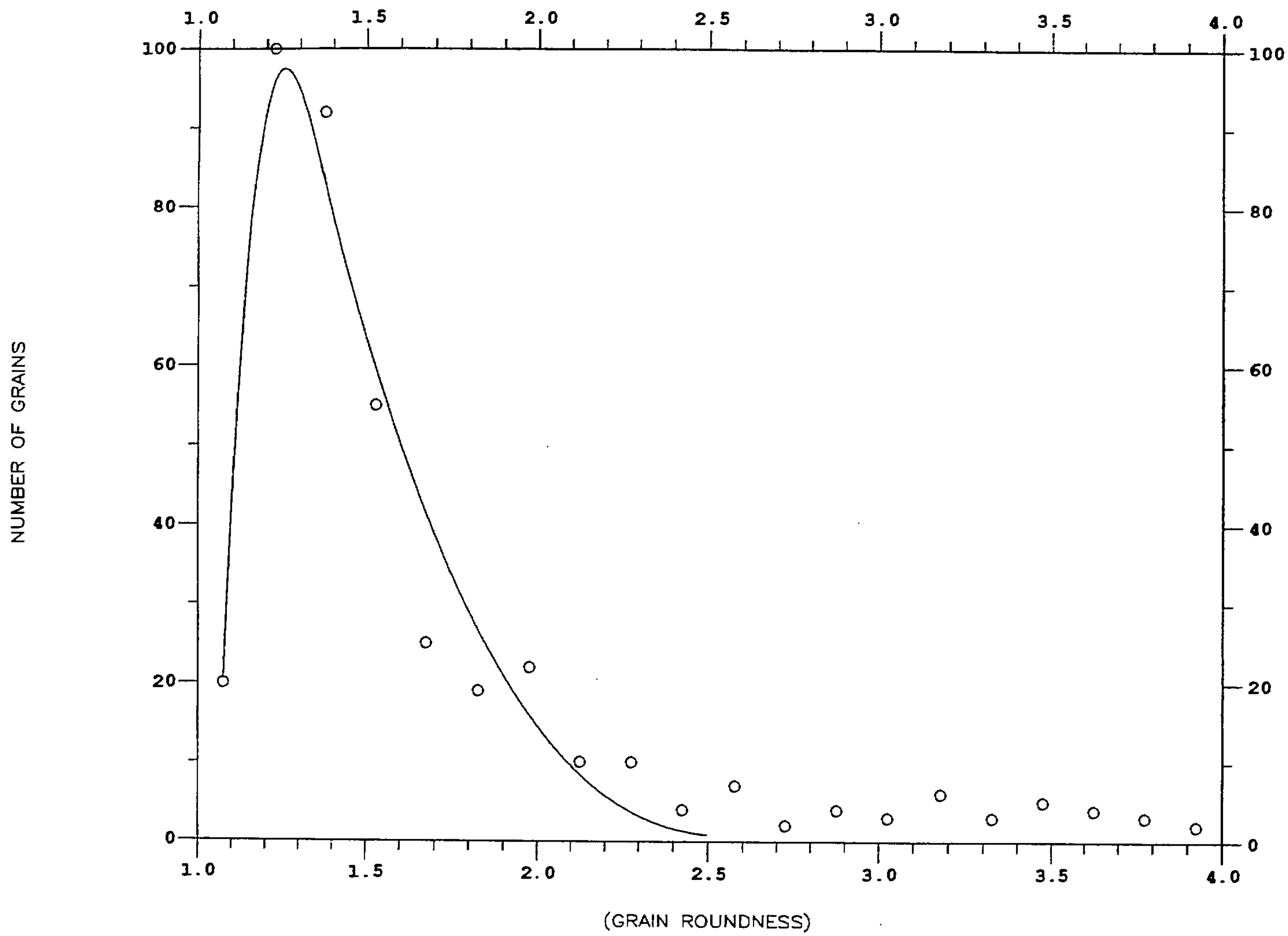
VOLUME 1 VS DIAMETER WITHIN 325–400 FRACTION

1	41.5	0.035
2	44.5	0.089
3	47.5	0.66
4	50.5	1.08
5	53.5	1.81
6	56.5	3.85
7	59.5	4.92
8	62.5	3.51
9	65.5	3.18
10	68.5	3.11
11	71.5	1.19
12	74.5	1.34
13	77.5	1.31
14	80.5	0.875
15	83.5	.941
16	86.5	1.18
17	89.5	1.09
18	92.5	1.09
19	95.5	0
20	98.5	0.403



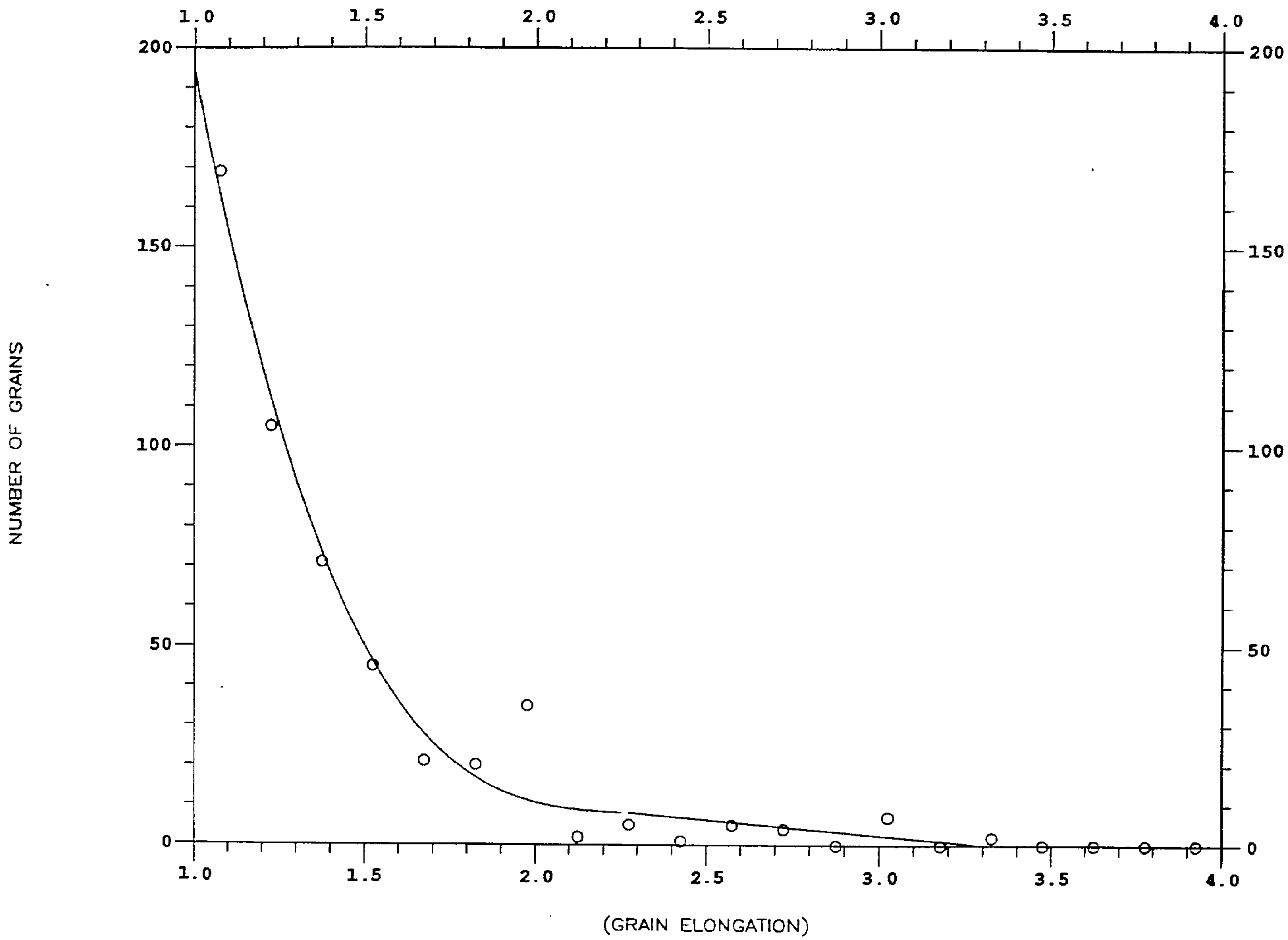
VOLUME 1 VS DIAMETER WITHIN 325–400 FRACTION

1	41.5	0.036
2	44.5	0.094
3	47.5	0.749
4	50.5	1.18
5	53.5	2
6	56.5	4.29
7	59.5	5.42
8	62.5	3.98
9	65.5	3.51
10	68.5	3.49
11	71.5	1.34
12	74.5	1.48
13	77.5	1.46
14	80.5	1.08
15	83.5	1.2
16	86.5	1.36
17	89.5	1.13
18	92.5	1.22
19	95.5	0
20	98.5	0.48



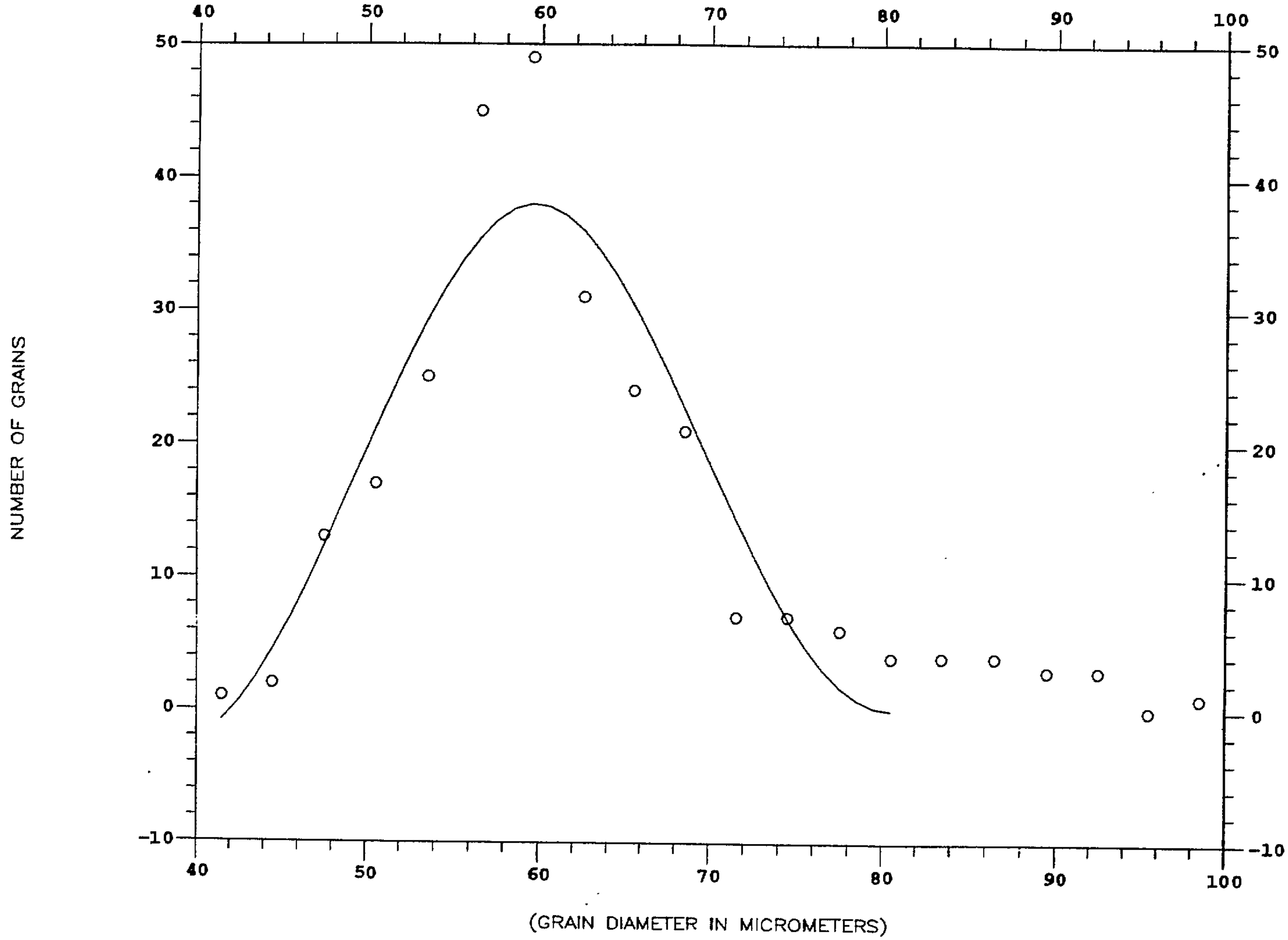
DISTRIBUTION BY ROUNDNESS WITHIN 325–400 FRACTION

1	1.075	20
2	1.225	100
3	1.375	92
4	1.525	55
5	1.675	25
6	1.825	19
7	1.975	22
8	2.125	10
9	2.275	10
10	2.425	4
11	2.575	7
12	2.725	2
13	2.875	4
14	3.025	3
15	3.177	6
16	3.325	3
17	3.475	5
18	3.625	4
19	3.775	3
20	3.925	2



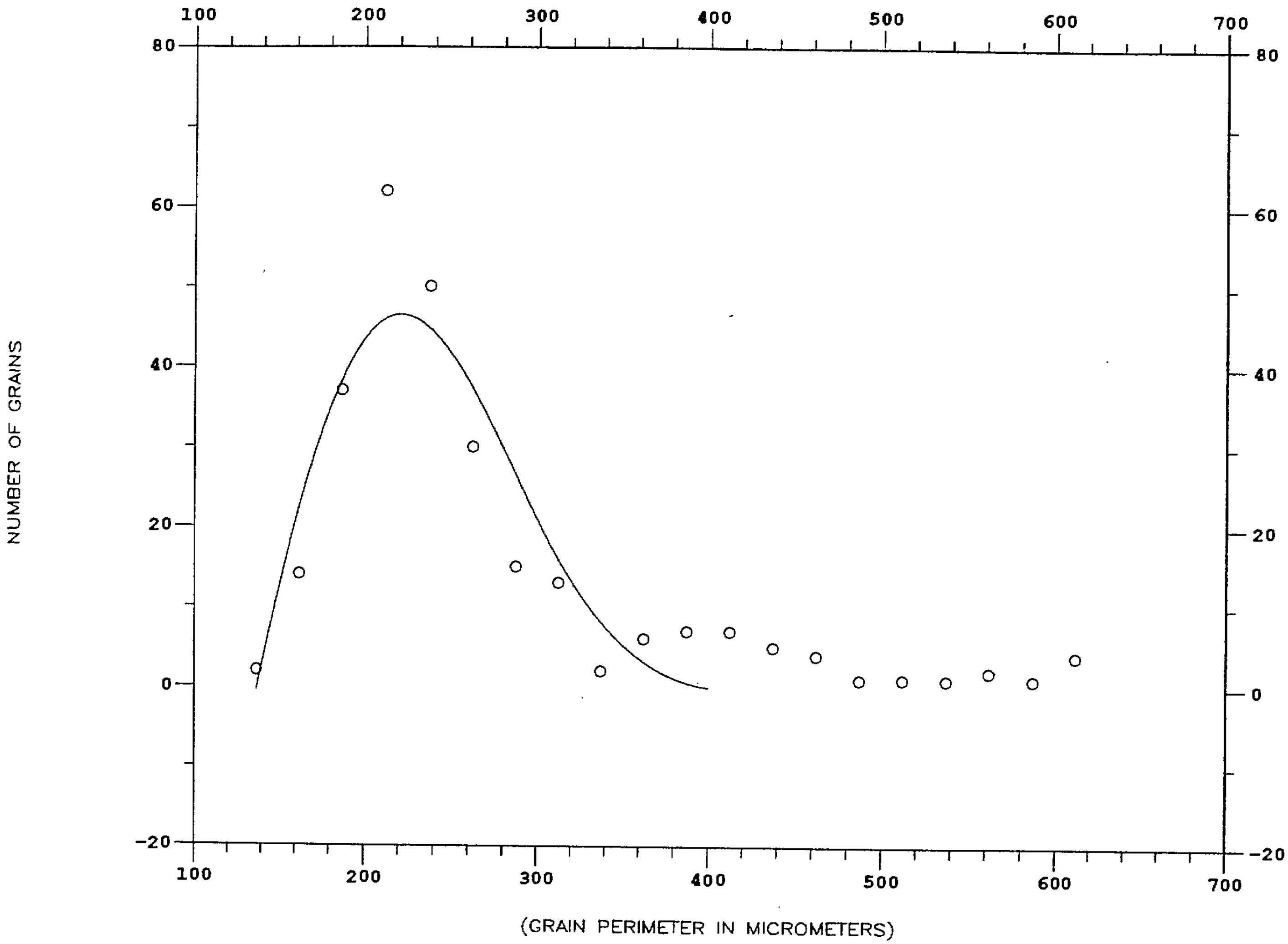
DISTRIBUTION BY ELONGATION WITHIN 325–400 FRACTION

1	1.075	169
2	1.225	105
3	1.375	71
4	1.525	45
5	1.675	21
6	1.825	20
7	1.975	35
8	2.125	2
9	2.275	5
10	2.425	1
11	2.575	5
12	2.725	4
13	2.875	0
14	3.025	7
15	3.177	0
16	3.325	2
17	3.475	0
18	3.625	0
19	3.775	0
20	3.925	0



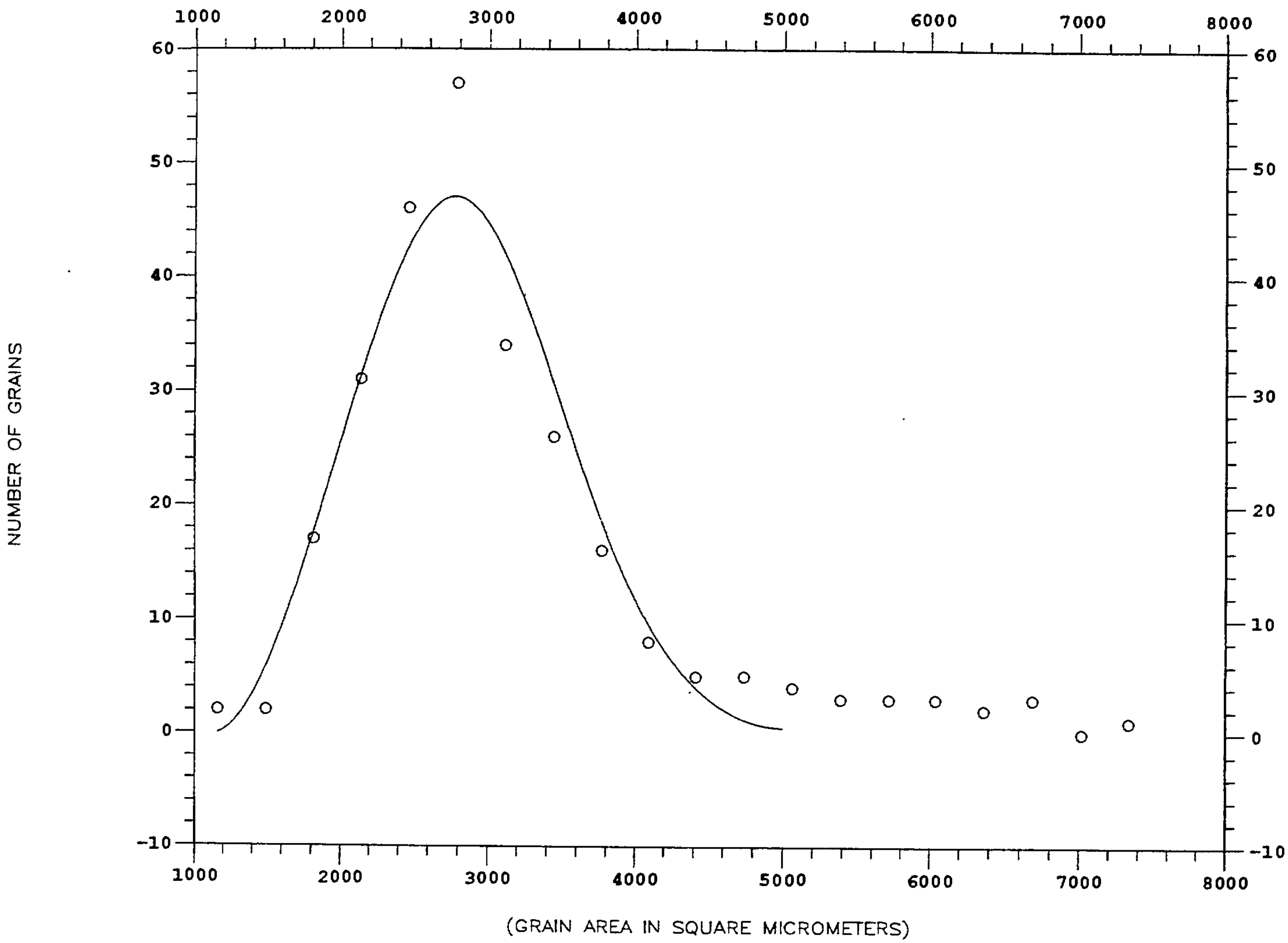
DISTRIBUTION BY DIAMETER WITHIN 325–400 FRACTION

1	41.5	1
2	44.5	2
3	47.5	13
4	50.5	17
5	53.5	25
6	56.5	45
7	59.5	49
8	62.5	31
9	65.5	24
10	68.5	21
11	71.5	7
12	74.5	7
13	77.5	6
14	80.5	4
15	83.5	4
16	86.5	4
17	89.5	3
18	92.5	3
19	95.5	0
20	98.5	1



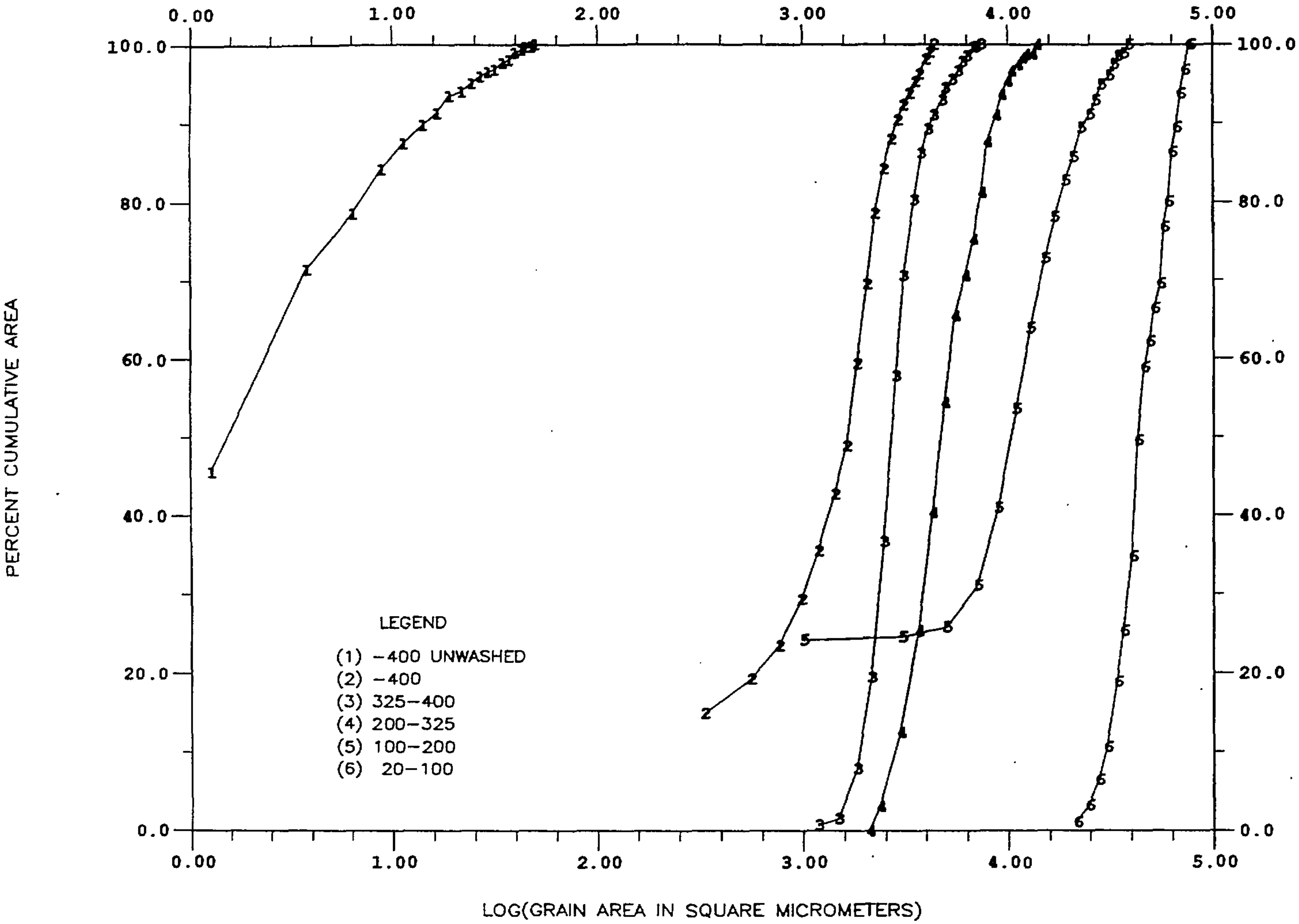
DISTRIBUTION BY PERIMETER WITHIN 325-400 FRACTION

1	137	2
2	162	14
3	187	37
4	212	62
5	237	50
6	262	30
7	287	15
8	312	13
9	337	2
10	362	6
11	387	7
12	412	7
13	437	5
14	462	4
15	487	1
16	512	1
17	537	1
18	562	2
19	587	1
20	612	4



DISTRIBUTION BY AREA WITHIN 325–400 FRACTION

1	1162	2
2	1487	2
3	1812	17
4	2137	31
5	2462	46
6	2787	57
7	3112	34
8	3437	26
9	3762	16
10	4087	8
11	4412	5
12	4737	5
13	5062	4
14	5387	3
15	5712	3
16	6037	3
17	6362	2
18	6687	3
19	7012	0
20	7337	1



DISTRIBUTION WITHIN GROUND PYRITE FRACTIONS