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Roth

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[54] **PULSE-ECHO ULTRASONIC IMAGING METHOD FOR ELIMINATING SAMPLE THICKNESS VARIATION EFFECTS**

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[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**, Washington, D.C.

[21] Appl. No.: **546,972**

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[51] **Int. Cl.**^{6} **G01N 29/00**; G01N 29/04

[52] **U.S. Cl.** **364/508**; 73/602; 73/620; 73/600

[58] **Field of Search** 364/507, 508; 73/597, 598, 599, 600, 602, 606, 607, 609, 610, 615, 620, 627, 634; 367/8, 13

[56] **References Cited**

U.S. PATENT DOCUMENTS

H1082	8/1992	Bylenok et al.	73/602
3,848,460	11/1974	Bantz et al.	73/67.5 R
4,471,785	9/1984	Wilson et al.	128/660
4,866,614	9/1989	Tam	364/413.25
4,947,351	8/1990	Moran et al.	364/507
5,533,401	7/1996	Gilmore	73/622

OTHER PUBLICATIONS

Simultaneous Determination of Ultrasonic Velocity, Plate Thickness and Wedge Angle Using One–Side Contact Measurements —David K. Hsu, Allan M. Ayers et al.

NASA Technical Paper 3377 1993–Quantitative Mapping of Pore Fraction Variations in Silicon Nitride Using an Ultrasonic Contact Scan Technique –Don J. Roth.

NASA Technical Memorandum 4545–PSIDD: A Post–Scan Interactive Data Display System for Ultrasonic Scans. Don J. Roth.

Numerical Recipes —The Art of Scientific Computing —William Press, Brian Flannery, Saul A. Teukolsky and William T. Vetterling.

NASA Technical Memorandum 4106 —Interfacing Laboratory Instruments to Multiuser, Virtual Memory Computers by Edward R. Generazio, David B. Stang, and Don J. Roth.

Ultrasonic Velocity Measurement for the Determination of Density in Polyethylene by L. Piche —reprinted from Polymer Engineering and Science, vol. 24, No. 17, Mid Dec. 1984.

"Ultrasonic Velocity Measurement for the Determination of Density in Polyethylene", L. Piche, Polymer Engineering and Science, vol. 24, No. 17.

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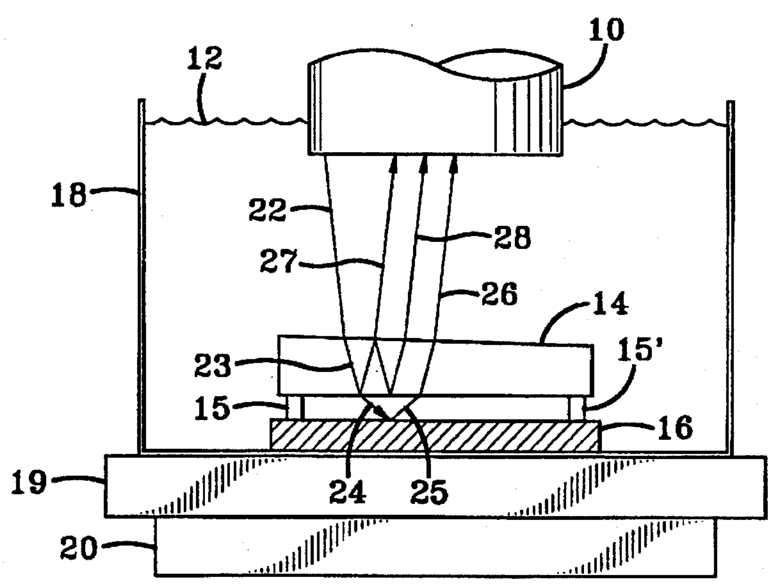
Assistant Examiner—Tony M. Cole
Attorney, Agent, or Firm—Kent N. Stone

[57] **ABSTRACT**

A pulse-echo, immersion method for ultrasonic evaluation of a material which accounts for and eliminates nonlevelness in the equipment set-up and sample thickness variation effects employs a single transducer and automatic scanning and digital imaging to obtain an image of a property of the material, such as pore fraction. The nonlevelness and thickness variation effects are accounted for by pre-scan adjustments of the time window to insure that the echoes received at each scan point are gated in the center of the window. This information is input into the scan file so that, during the automatic scanning for the material evaluation, each received echo is centered in its time window. A cross-correlation function calculates the velocity at each scan point, which is then proportionalized to a color or grey scale and displayed on a video screen.

15 Claims, 5 Drawing Sheets
(1 of 5 Drawings in Color)



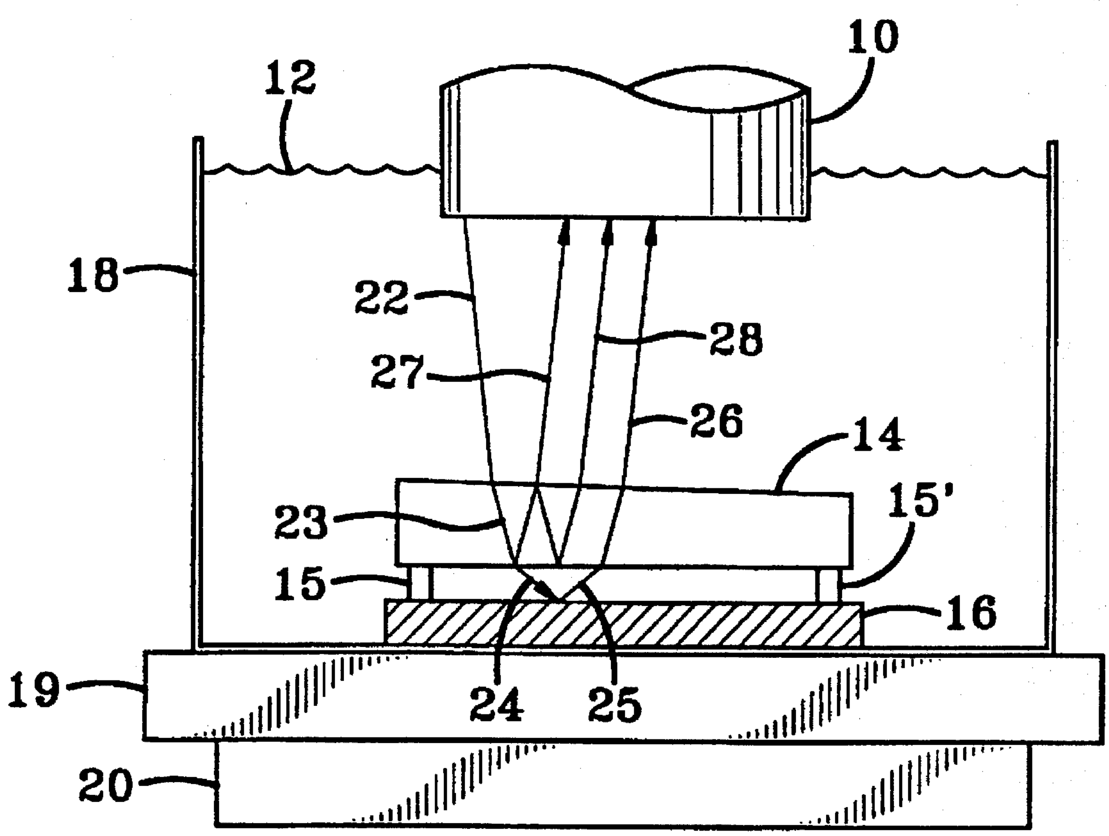


FIG. 1

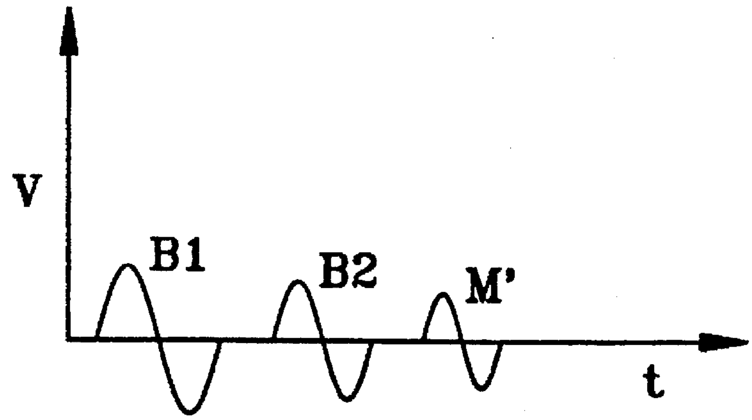


FIG. 2A

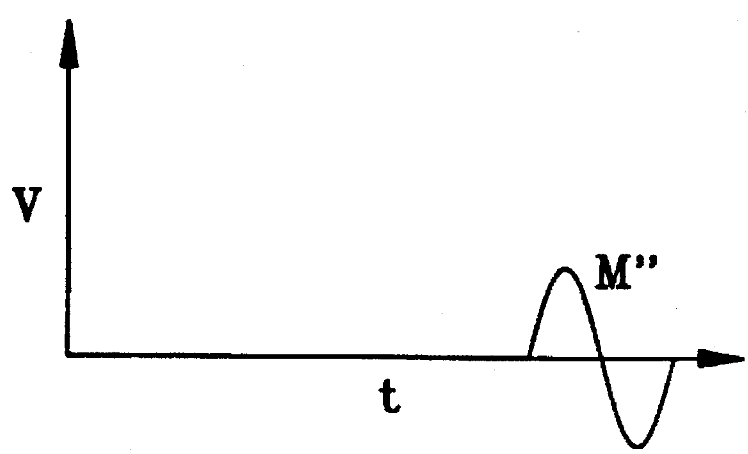


FIG. 2B

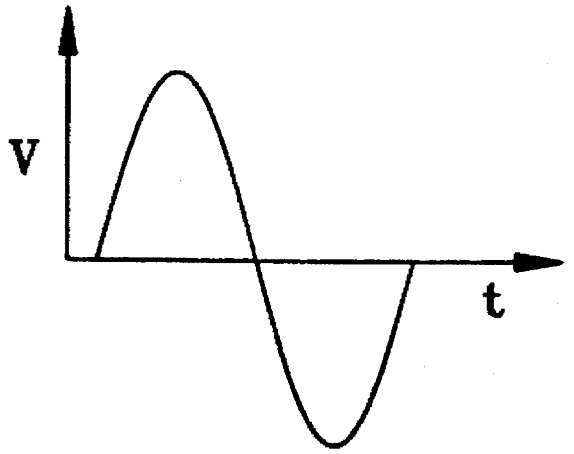


FIG. 3a

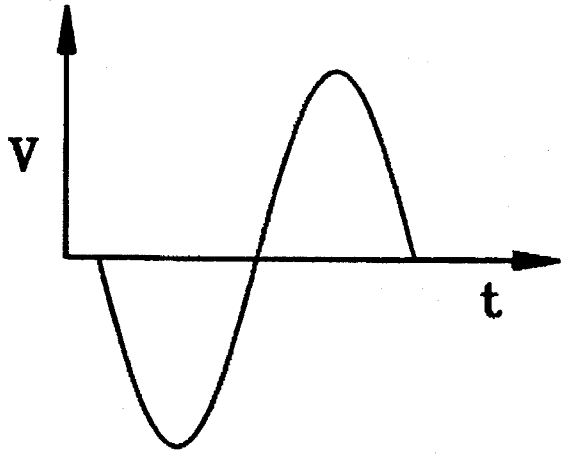
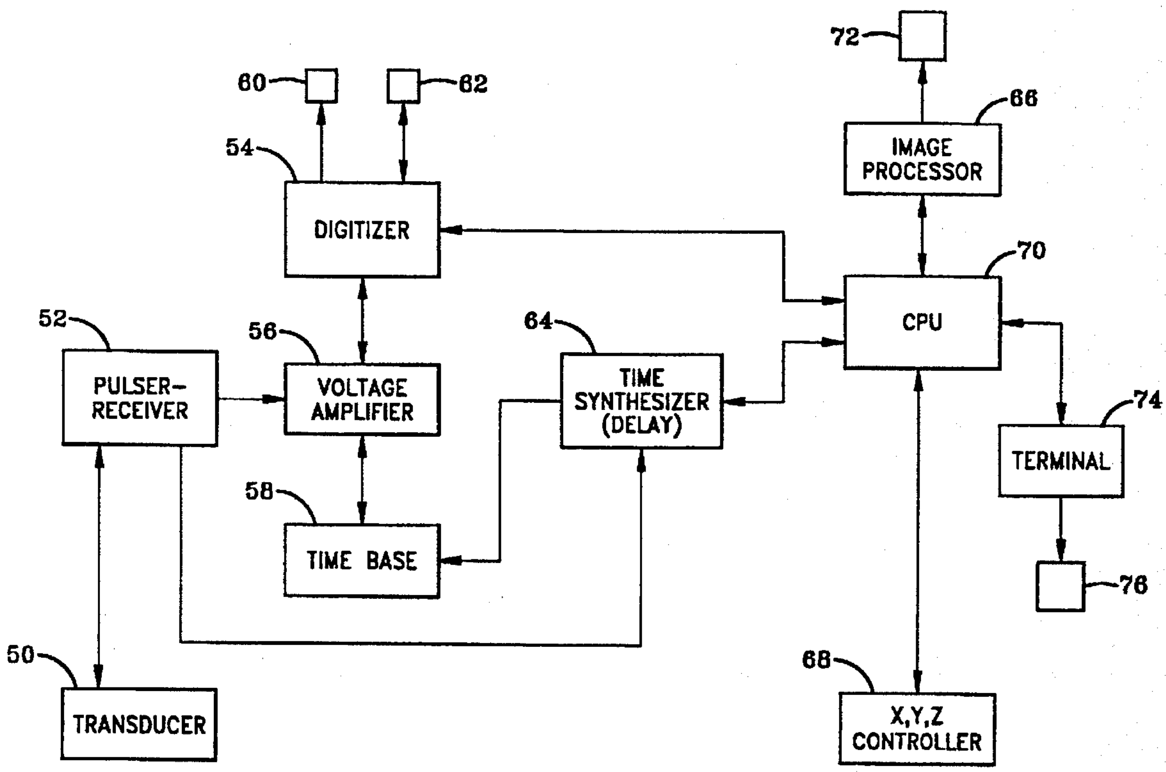
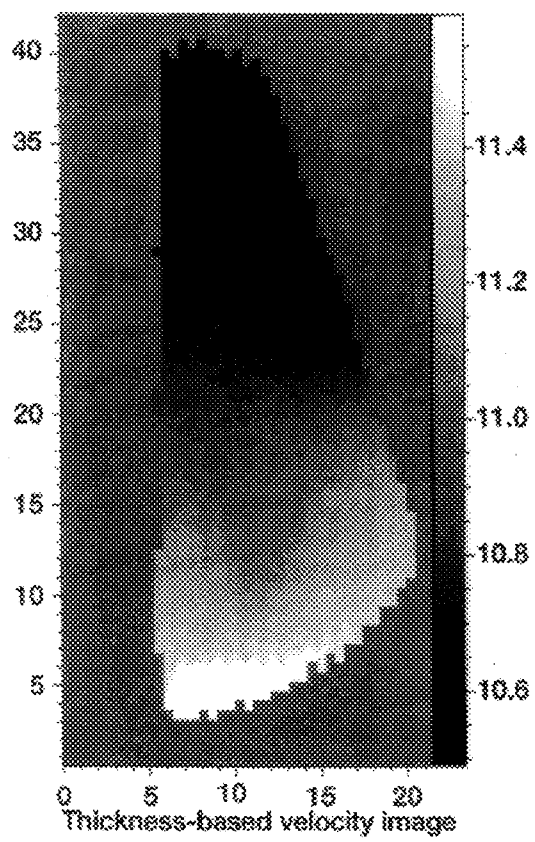


FIG. 3b



60
62
54
DIGITIZER
72
66
IMAGE PROCESSOR
70
CPU
52
PULSER-RECEIVER
56
VOLTAGE AMPLIFIER
64
TIME SYNTHESIZER (DELAY)
74
TERMINAL
58
TIME BASE
76
50
TRANSDUCER
68
X,Y,Z CONTROLLER

FIG. 4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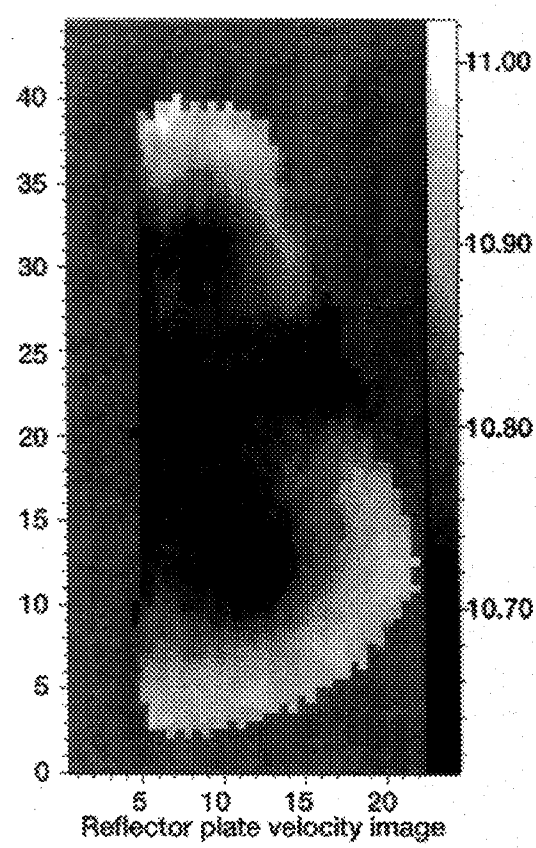
Thickness-based velocity image

FIG. 5A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Reflector plate velocity image

FIG. 5B

PULSE-ECHO ULTRASONIC IMAGING METHOD FOR ELIMINATING SAMPLE THICKNESS VARIATION EFFECTS

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to ultrasonic evaluation of material properties. More particularly, the invention relates to nondestructive ultrasonic evaluation of materials by measuring velocity using a single transducer pulse-echo immersion system, automatic scanning and digital imaging, which provides a video image of the sample in color or grey scale which is a map of a material property such as porosity fraction.

2. Background Of the Disclosure

Nondestructive evaluation applicable to evaluating properties of materials such as ceramics, metals, plastics and various composites are known to those skilled in the art and include x-radiography, ultrasound or ultrasonic evaluation, and thermal methods. These methods provide an efficient, quasi-quantitative measure of material homogeneity, but often lack the precision necessary for microstructure evaluation of high-performance materials, such as high temperature oxidation resistant ceramics and the like. The development and use of materials for high-performance applications requires detailed, quantitative knowledge of microstructural and compositional variability for defining acceptable levels of variability and for rejecting those materials and processes that yield sample-to-sample and within-sample variations likely to result in unacceptable property (e.g., strength, thermal conductivity, oxidation resistance, resistance to spalling, etc.) variations. Such variability must be precisely characterized either directly in terms of property measurement or indirectly through microstructural characterization where microstructure-property relations have been previously established.

Repeated, uniformly spaced ultrasonic contact measurements have been successful for quantifying and mapping inhomogeneity in various ceramics (e.g., SiC, Al_2O_3, $YBa_2Cu_3O_7$ and Si_3N_4) and metals in terms of ultrasonic material properties such as reflection coefficient, velocity and attenuation coefficient as mentioned, for example, by Roth, et. al. in *Quantitative Mapping of Pore Fraction Variations in Silicon Nitride Using an Ultrasonic Contact Scan Technique*, NASA TP 3377 (1993). This publication describes quantitatively characterizing material (e.g., Si_3N_4) microstructure in terms of actual ultrasonic wave parameters. The wave parameters include reflection coefficient, attenuation coefficient and velocity. A post-scan interactive data display system is used for comparing ultrasonic properties at different locations within samples and viewing the resultant ultrasonic images. Further refinement of this process is disclosed by Roth, et. al. in *PSIDD: A Post-Scan Interactive Data Display System for Ultrasonic Scans*, NASA TM-4545 (1993). This process relates to contact scans and does not disclose how to account for thickness variations in the sample being measured. Piche discloses a single transducer immersion method for evaluating plastic using a technique in which 16 scan points are pulsed for the sample and the results evaluated using regression analysis [L. Piche, *Ultrasonic Velocity Measurement for the Determination of Density in Polyethylene*, Polymer Eng. &. Sci.,v. 24, n.17, p. 1358–58 (Dec. 1984]. This method does not relate to forming an image of the sample property, nor does it provide an experimental technique that automatically accounts for nonlevelness and thickness variation during a scan procedure required to form an image. Consequently, a need still exists for a method which will permit ultrasonic material evaluation that will account for nonlevelness and thickness variations in the material, require only a single transducer, eliminate problems associated with physical contact between the transducer and sample or buffer rod, and display, on a video screen in gray scale or color, an image of the scanned material which is a map of an internal structural property of the material, such as porosity fraction.

SUMMARY OF THE INVENTION

The invention relates to a method for nondestructive ultrasonic evaluation of materials by measuring velocity using a pulse-echo immersion system with automatic scanning, echo cross-correlation and digital imaging to obtain a grey scale or color image of the sample. The velocity values obtained for each scan point are scaled on a grey or color scale and displayed on a video screen which shows a material property, such as porosity fraction. Prior to the automatic scanning, nonlevelness in the set-up and sample thickness variation effects are accounted for and eliminated by insuring that the echoes at each scan point are first gated and input into a scan parameter file in a computer, so that during the subsequent automatic scanning each received echo is centered in the time window set for it. While it is possible, but not practical to do a manual prescan at each and every scan point needed for a two dimensional video image of the material property being evaluated, many sample thickness variations are in the form of a uniform thickness variation from one edge to another. In this case of uniform thickness variations from one edge to another, preliminary scans are performed along a single line in both the x- and y-directions of the sample to provide slant correction factors. The slant correction factors are input into the scan parameter file so that any wedge-shape variations are taken into account during the automatic scanning for the material evaluation, to insure that each echo received during the automatic scanning is centered within the time window. A single transducer is used in a preferred embodiment of the invention.

In the immersion method of the invention, the material to be evaluated is surrounded by a liquid and positioned over an acoustic reflector which is also immersed in the liquid. An ultrasonic wave of a known frequency is transmitted through the liquid and four separate echoes are recorded and evaluated at each scan point. Each echo is received as an analog waveform which is digitized and stored in a computer. The echoes received, digitized and stored during the sample evaluation scans are the first two succesive echoes reflected off the back surface of the sample, the first echo reflected off the front surface of the accoustic reflector in which the received wave has passed through the sample, and the forth is the first echo reflected off the front surface of the reflector with the sample not present, so that the received wave does not pass through the sample. This means that at least two separate scans must be made, with and without the sample present between the transducer and reflector. However, as a practical matter it is difficult from both a hardware and software perspective to accomplish this in just two scans and obtain maximum time resolution and thus maximum accuracy. Consequently three or four separate scans are performed, with three being faster and four being more accurate. The choice is left to the discretion of the practitioner. In the embodiment in which four separate scans are performed during the sample evaluation, the ultrasonic wave goes through both the liquid and the material during the first three scans. For the forth scan the material sample is removed so that the transmitted wave is reflected off the front surface of the reflector without going through the material. Although the order is not important, it is convenient to receive the first echo reflected off the back surface of the material during the first scan and the second successive echo reflected off the back surface of the sample during the second scan. During the third scan in which the transmitted wave goes through both the immersion liquid and the material sample, the first echo reflected off the front surface of the reflector is received. The first echo reflected off the front reflector surface is received during the fourth scan when the sample is not present. This process is repeated at a plurality of scan points sufficient to produce a video image of a microstructural property, such as porosity, of the material. After the scanning is completed, the digitized waveforms are retrieved from the computer and the time delay between the first two successive echoes received from the back surface of the material at each scan point is determined. The time delay between the two different reflections or echoes received off the reflector (with and without the transmitted wave going through the sample) is also determined for each scan point. The wave velocity at each scan point is then calculated from the time delays and the speed of the transmitted wave in the liquid. The velocity values for all of the scan points are scaled to corresponding proportional color or grey scale values which are then displayed on a video screen or cathode ray tube (CRT). Thus, in this embodiment of the invention, four separate scans are made at each scan point to separately receive, as analog waveforms, the first two successive ultrasonic echoes off the back surface of the sample and the first echo off the front surface of the reflector both with and without going through said sample; digitizing and storing the waveforms; retrieving the digitized waveforms; determining the received time delay between the first two successive sample back surface echoes and between the two reflector front surface echoes; calculating the wave velocity at each scan point; scaling the calculated velocities to corresponding proportional color or gray scale values, and displaying the resulting image. The wave velocity at each scan point is calculated from

$$v=c\left(\frac{\Delta t}{2\tau}+1\right)$$

wherein 2τ is the received time delay between the two successive sample back surface echoes, wherein Δt is the time delay between the two different echoes received from the reflector with and without going through the sample, and wherein c is the speed of the transmitted ultrasound wave in the liquid. The embodiment in which three separate scans are made is similar to that in which four separate scans are made, with the difference being that during the first scan the first two succesive reflections or echoes off the back surface of the sample are received, digitized and stored. It will be noted that above equation does not include the sample thickness value. This means that the thickness of the sample need not be measured or known.

As set forth above, prior to the two, three or four scans during which the sample is evaluated, nonlevelness and sample thickness variations are accounted for and eliminated by pre-scans to insure that the received reflections or echoes are within their set time windows to provide a complete waveform for evaluation and cross-correlation to accurately obtain the time delay data used in calculating the velocity values. In the case of a sample having a thickness variation in the form of a uniform thickness variation from one edge to another, preliminary scans are performed along a single line in both the the x- and y-directions of the sample to provide slant correction factors. The slant correction factors are input into the computer scan parameter file so these variations are taken into account during the automatic scanning for the material evaluation.

BRIEF DESCRIPTION OF THE DRAWINGS

The file of this patent contains at least one drawing executed in color. Copies of this patent with color drawing(s) will be provided by the Patent and Trademark Office upon request and payment of the necessary fee.

FIG. 1 schematically illustrates the spatial relationship between the transducer, liquid, material sample, reflector plate and the transmitted and reflected ultrasonic echo waves in the practice of the invention.

FIGS. 2(*a*) and 2(*b*) graphically illustrate the amplitude and time delay of the received analog ultrasonic echoes reflected off the material sample and reflector.

FIGS. 3(*a*) and 3(*b*) graphically illustrate respective first and second sample back surface echoes in which the second is inverted with respect to the first.

FIG. 4 is a block diagram schematically illustrating the instrumentation used in the invention.

FIGS. 5(*a*) and 5(*b*) are photographs of video grey scale displays of a thickness based ultrasonic velocity image of a ceramic according to the prior art method and the method of the invention, respectively.

DETAILED DESCRIPTION

Referring to FIG. 1, transducer **10** is schematically shown as partially immersed in a liquid **12** which is the immersion fluid. Material sample **14** is shown positioned in the fluid **12** between the transducer **10** and reflector plate **16** in container or tank **18** located on top of x- and y-direction motorized stages **19** and **20**. Supports **15** and **15'** maintain sample **14** above reflector **16**. The transducer **10** and motorized x- and y-direction stages **19** and **20** are electrically connected by means not shown to a pulser-receiver (not shown) and to means (not shown) for moving the x- and y- stages in their respective directions. Similarly, liquid **12** is connected to means not shown for maintaining the temperature of the liquid preferably within at least about ± 1° F. of the temperature at which the scans are to be run. It is possible to maintain the liquid temperature within ±0.1° F. The better the temperature control, the more accurate the results will be. For example, if the temperature of the immersion liquid is ±1° F. and the liquid is water, a 1.5% error in velocity is possible. If the porosity fraction or other property of the material at a particular point is such as to result in a velocity value difference in the sample of 2%, only a 0.5% microstructural velocity difference might be detected if a ±1° F. temperature variation is present during the scan. At each scan point an ultrasonic wave **22** of a known frequency is transmitted from transducer **10** through liquid **12** and into material sample **14**. Entering material **14** causes part of wave **22** to be reflected (not shown) off the top surface of the sample, with the rest of the wave passing through the material as **23**. Part of wave **23** continues through the material and to the top surface of accoustic reflector **16** as **24**, is reflected back off the top surface of reflector **16** as **25**, passes back through the sample **14** and returns to the transducer **10** as wave **26**. A portion of wave **23** is reflected off the back surface of the sample and returns to the transducer as **27**. Part of the wave **23** reflected off the back surface of the material is reflected off the top surface, returns to the back surface, is again reflected back to the top surface and exits as wave **28**. Waves **27** and **28** are the first two successive back surface reflected waves used in the method of the invention at each scan point. Not shown is the wave transmitted through the liquid and reflected back to the transducer without going through the material. This wave which is not shown and wave **26** are the two reflector front surface echoes used in the method of the invention. Motorized stages **19** and **20** form part of an automated scanning system which incrementally moves in both the x- and y-directions to obtain an ordered array of points across the entire surface of the material sample. A 20 MHz, broadband transducer was used in the practice of the invention. Broadband transducers emit a broadband frequency content dominated by a center frequency. That is, they are made to emit at a nominal frequency proximate that of the design frequency (e.g., 20 MHz), with a Gaussian fall-off on either side of the nominal center frequency. Thus, a 20 MHz broadband transducer will also emit frequencies slightly above and below the nominal center frequency of 20 MHz. In the Piche article referred to above, although the two different reflector front surface echoes are captured and recorded, the first front surface echo and the first back surface echo are captured and recorded. This is different from the method of the invention which captures and records the first two successive sample back surface echoes and not the first front sample surface echo. Further, Piche does not use automatic sample scanning or digital imaging. FIGS. **2**(*a*) and **2**(*b*) graphically illustrate the reflected waveforms received and displayed on the CRT of an oscilloscope as time domain analog waveforms. Turning to FIGS. **2**(*a*) and **2**(*b*), the intensity or strength of the received waveform is displayed as voltage amplitude, which is the ordinate of the graph, and the received time delay as the abscissa. In this representation, B1, B2 and M' refer to waves **27.28** and **26** of FIG. **1**, respectively, with M" representing the wave transmitted through the liquid and reflected off the front surface of the reflector without passing through the material sample. The time delay between the first two successive echoes reflected from the back or bottom surface of the material back to the transducer, B1 and B2, is readily obtained, as is the time delay between the two reflections received from the front surface of the reflector, M' and M". Since the velocity of the ultrasonic wave is faster in denser media than in less dense media, voids, delaminations, porosity and other density variables within the material are obtained as a function of the speed of the wave, which is determined by the time delay between the first two successive echoes received which have been reflected off the back of the material, and the time delay between the two different reflections from the front surface of the reflector. As set forth above under SUMMARY, the speed or velocity of the transmitted wave traveling through the material sample is determined according to the simple equation:

$$v=c\left(\frac{\Delta t}{2\tau}+1\right)$$

wherein 2τ is the received time delay between the two successive material sample back surface echoes, wherein Δt is the time delay between the two different echoes received from the reflector with and without going through said sample, and wherein c is the speed of the transmitted wave in the liquid. This equation is accurate for a single point measurement. Prior art ultrasonic velocity scan techniques such as that of Roth et. al. in the quantitative mapping publication referred to above, assume that the material sample is of uniform thickness and do not take into account nonlevelness and material thickness variations as does the method of the invention.

In the practice of the method of the invention, tank **18** may be made of any suitable material. Clear plastic such as polymethylmethacrylate (e,g., Lucite or Plexoglass) has been found useful. The sample tank contains a suitable elastic liquid, such as water, as the immersion fluid to provide an accoustic coupling between the transducer, material and reflector plate. Since the x-, y-direction scans made across the sample surface in the method of the invention can take a significant amount of time compared to that for a single point measurement and since the speed of sound in a liquid is also a function of temperature, the water is maintained at a constant temperature during the scanning. This is readily accomplished simply by using a constant temperature regulating means, such as a constant temperature water circulator, for maintaining the desired temperature constant during the ultrasonic scanning. It is convenient to keep the temperature of the water at about ambient or 68° F. ±1° F. during the scan, although other temperatures may be used if desired, as long as the temperature is maintained within no more than ±1° F. In the case of distilled, deionized water, the wave velocity may be obtained from published tables. However, tap water may be used as long as the velocity in the water is actually measured. The reflector is placed on the bottom of the tank. Other immersion liquids may be used, if desired, such as Dow Corning 704 vacuum pump oil.

The reflector is a solid plate of material having an accoustic impedance significantly different from that of the liquid or water. A flat plate of tungsten (e.g., 1/16"–1/8" thick) is preferably used, because tungsten has an accoustic impedance almost two orders of magnitude higher than water in units of g/cm^2-sec. The use of a tungsten plate results in the highest possible reflection amplitude of any solid material for the echoes reflecting off the front surface of the reflector plate. This large difference in accoustic impedance is important when attempting to obtain ultrasonic echoes that have to travel into and through immersion liquid and the sample, bounce off the reflector plate, and travel back through the liquid and sample to the the transducer for reception. High frequency ultrasound provides greater time resolution than lower frequencies and is therefore more desireable for greater accuracy of the velocity of the ultrasound through the sample and corresponding velocity image. The higher the frequency, the greater the velocity accuracy. By having the highest reflection amplitude possible, it is possible to use the method of the invention (a) at higher frequencies where attenuation through the sample is greater than if using lower frequencies and (b) with materials that significantly attenuate ultrasound, such as composite materials. By high frequency ultrasound is meant from 1–100 MHz, typically 3–50 MHz and more typically 10–30 MHz.

The material sample is easily positioned over the reflector plate by using spacers on top of the plate and placing the material on top of the spacers. It is important that the spacers have the same height or thickness so that the material is as level as possible. Lucite is available as sheets which are very uniformly thick and it is convenient to use 0.5" cubes of this plastic as spacers. The material sample, such as a plate of silicon nitride ceramic, is placed on the plastic spacers over the tungsten reflector plate prior to scanning.

FIG. **4** schematically illustrates, in block diagram fashion, the basic system and instrumentation used for the scanning and ultrasonic imaging according to an embodiment used in the practice of the invention.

Thus, referring to FIG. 4, the basic instrumentation includes a transducer **50**, a pulser-receiver **52**, and a programmable waveform digitizer **54** having associated with it a vertical voltage amplifier **56**, programmable time base **58**, and anolog and digital monitors **60** and **62**, respectively. Also included are a time delay or synthesizer **64**, an image processor **66**, an X, Y, Z controller **68**, computer or central processing unit (CPU) **70**, and video display **72**. In the embodiment shown, the computer **70** is a CPU with terminal **74** and associated video display **76** also forming part of the system. Monitors **60** and **62**, along with digitizer **54**, voltage amplifier **56** and time base **58** also serve as respective analog and digital oscilloscopes. The time synthesizer, time base, voltage amplifier and waveform digitizer are all general purpose interface [IEEE- 488]bus (hereinafter "GPIB") programmable and interconnected via GPIB cables. The computer **70** is programmed in Fortran and contains an image processor system which is connected to the video color and gray scale display **72**. The computer controls the GPIB instrumentation and acquiring of the desired waveforms via the GPIB. The process includes data acquisition, analysis/calculation, image processing and display. The Fortran software, with callable routines in in IEX-VMS interface software to communicate with the GPIB instruments is written for instrument control and waveform acquisition following the method of Generazio, et. al. in *Interfacing Laboratory Instruments to Multiuser Virtual Memory Computers*, NASA Technical Memorandum 4106 (1985), the disclosure of which is incorporated herein by reference. The Fortran programs used in the practice of the invention including the scanning program, the analysis and cross-correlation program, the grey scale imagemaker program, and the display program are contained in the attached Appendix. The wave form digitizer is a Tektronics 7912 AD Programmable Digitizer along with a Tektronics 7A16 P Programmable Vertical Voltage Amplifier (voltage base) and a Tektronics 7B90 P Programmable Time Base. The time delay (time synthesizer) is a Hewlett Packard Model 5359A and the X, Y, Z programmable stepper motor controller and associated tables is a Klinger Scientific C-1.22. The ultrasonic pulser-receiver is a Panametrics Model 5601 and the transducer used in the scanning of the silicon nitride ceramic disk in the example below is a Panametrics 20 MHz, longitudinal, unfocused, broad band transducer. The computer is a Digital Equipment model Microvax II.

In the practice of the invention, the image processer is a Grinnell Systems Grinnell 274 Image Processing System and the Grinnell Systems GMR Series Software Package, Release 2.2, Jun. 19,1981, available from McLoud Associates, 165-F Croftich Lane, Campbell, Calif. 95008, the disclosure of which is also incorporated herein by reference. Two video displays are used, one of which is a DEC VT340 terminal, which is the user terminal attached to the computer, and a Mitsubishi 20LP is the video display monitor attached to the image processing system. High level VAX Fortran software used for driving the system is included in the Appendix as set forth above. The Grinnell library of Fortran subroutines is called from this high level software. The video display shows ultrasonic images.

The pulser-receiver applies the voltage pulse to the transducer to generate the ultrasonic waves into the sample and to the reflector plate and also receives the raw ultrasonic echo waveforms from the transducer. The approximate times where the echo waveforms are expected to occur are determined a priori (prior to the automatic scanning for the material evaluation) using the time systhesizer to find and position the echo waveforms on the oscilloscope. The time base and voltage amplifier are used to modify the time and voltage scales to view the waveforms on the oscilloscope. Both the time base and the time synthesizer are externally triggered by the pulser-receiver (a+2 volt synchronizing pulse). Triggering occurs on the positive slope of the pulse. The time base is adjustable over the range of from 1 psec–500 msec/div on the oscilloscope, with the optimum setting for each waveform determined a priori and input to a data file in the computer. The pulser-receiver output is connected to the voltage amplifier. The voltage amplifier, selectable over the range 50 mV–1V/div, is automatically adjusted by the digitizer so that the entire received analog waveform is digitized with maximum amplitude fit onto the digital waveform monitor. The digitizer digitizes each waveform received into 512 point arrays (at a sampling rate ranging from 0.512 –1.024 GHz depending on the time base time/division setting). Each waveform is acquired 64 times and averaged to obtain a smoother waveform with averaged noise levels using a Fortran algorithm included in the scanning program in the Appendix and which is also found in the NASA Technical Memorandum 4106 referred to above. The X and Y positional and Z intensity outputs from the waveform digitizer are attached to the analog and digital monitors **60** and **62**. The analog monitor is used for the prescans and the digital for the automatic scanning.

As set forth under the SUMMARY, prior to the two, three or four scans during which the sample is evaluated, nonlevelness and sample thickness variations are accounted for and eliminated by pre-scans to insure that the received reflections or echoes are within their set time windows to provide a complete waveform for evaluation and cross-correlation to accurately obtain the time delay data used in calculating the velocity values. That is, during the nonlevelness and material thickness variation scans, the operator notes if the time delay of each echo received at each scan point is such that it is no longer centered within the oscilloscope time window. If a received echo is not centered within the time window on the scope, this is noted and the time window changed for each such echo received until the received echo time domain waveform is completely within the new time window set for it to insure that the complete time domain waveform is captured or gated completely within the new window. This time delay information at each scan point is inputted into the scan parameter file and recalled during the actual scanning during the material evaluation, to automatically adjust the time delay for the received echoes at each scan point so that each echo received during the scanning is centered within the time window set for it. This is very time consuming to do for each scan point. However, in the case of a sample having a thickness variation in the form of a uniform thickness variation from one edge to another, preliminary scans are performed along a single line in both the the x- and y-directions of the sample to provide slant correction factors. The slant correction factors are input into the computer scan parameter file so these variations are taken into account during the automatic scanning for the material evaluation. It is important that the echo at each scan point is centered in its time window, because the whole pulse or echo time domain waveform is needed to give the precise time delay between echoes for the cross-correlation which provides the velocity value. In doing this for a wedge shaped sample, prior to the automatic scan, the transducer scans along two straight lines over the sample, once in the the x-direction and once in the y-direction, during which an operator notes the echo received from the first and last scan points, starting from the first scan point which is generally at one corner of the area defined for scanning. The time difference from the sample end-to-end in each of the x- and y-directions of the first and last scan point is noted by the operator who then adjusts the time base for each echo if needed to insure that it is centered within the time frame set for it. This is done so that so that each echo received during the scans in which the material is being evaluated is centered (gated) within the oscilloscope time window set for it so that the received waveform is displayed with the maximum possible amplitude on the CRT and still have the complete waveform. This permits the maximum time resolution of individual echoes without losing any part of the time domain waveform which appears on the CRT screen as a function of voltage (amplitude) and time, wherein time is the x- axis and voltage or amplitude is the y- axis. It is important and forms an aspect of the invention that the complete waveform or pulse echo be captured or "gated" on the CRT screen in order to perform an accurate cross-correlation later on in the procedure of the process of the invention. The cross-correlation of echoes provides the precise time delay between received echoes or pulses which is required to calculate the velocity or speed of the ultrasound in the material evaluated which, in turn, provides the information to gray or color scale the velocity data into a digitized map of the material density. This slant correction procedure also allows an accurate evaluation to be made without the need for specialized leveling equipment. These x- and y-direction time window corrections are called slant correction factors and they are inputted into the scan parameter file in units of "nsec/pm" where (a) the number of nsec is the time extent from sample end-to-end that is required to keep the specific echo centered and is determined using the (a) time synthesizer to reposition echoes in time and (b) the number of μm is the distance traveled by the transducer for which this slant factor is determined. By way of an illustrative, but nonlimiting example, the first scan point (**0.0**) along the x- direction may have a **B1** echo centered at a time=6.77 μsec, while the last scan point (**40,0**), may have **B1** centered at time=7.14 μsec. If the x- direction scan line length is 40 mm, the x-direction

$$W_{DT}=T_I+[(X_{SC})(X_{SN})(X_{SI})+(Y_{SC})(Y_{SN})(Y_{SI})]$$

wherein W_{DT} is the correct delay time window at a particular scan location, T_I is the time delay at the the initial scan location, X_{SC} and Y_{SC} are the x- and y-direction slant correction factors, X_{SN} and Y_{SN} are the scan point numbers in the x- and y-directions, and X_{SI} and Y_{SI} are the x- and y-direction scan increments. With many samples it has been found that the slant correction factors turn out to be the same for the **B1** ,**B2** echoes and the slant correction factors for the M', M" echoes are the same. However, for some samples (e.g., thick samples), they may not be the same. In such cases a first x- and y-direction scan is made for the **B1** echoes and a second x- and y-direction scan made for the **B2** echoes. The same holds for the M' and M" echoes for which two separate scans are made in the x- and y-directions.

A scan parameter file is input into a computer which contains all of the information necessary to automatically scan the material sample being evaluated. This information includes a predefined and ordered array of scan points over which to run the scan. By way of an illustrative, but nonlimiting example, in an example of the method of the invention in which the material being evaluated was a monolithic ceramic wedge, the scan consisted of a 41 (X-direction) by 81 (y-direction) grid of measurements for a total of 3,200 scan points, with each measurement or scan point separated by 1 mm (x-) and y- scan increment). Information input into the scan parameter file (NOTHICK_ALLSHAPE1.DAT) includes the following:

```
C **TITLE** NOTHICK ALLSHAPE1.DAT
C ** SCAN INCREMENT (uM) IN X-DIRECTION IS:
1000.
C ** SCAN INCREMENT (uM) IN Y-DIRECTION IS:
1000.
C ** SCAN LENGTH (uM) IN X-DIRECTION IS:
40000.
C ** SCAN LENGTH (uM) IN Y-DIRECTION IS:
80000.
C ** X-DIRECTION SLANT CORRECTION FACTOR (nsec/uM) FOR B1 & B2 ECHOES IS:
-0.0055
C ** Y-DIRECTION SLANT CORRECTION FACTOR (nesec/uM) FOR REFLECTOR ECHOES IS:
-0.0055
C ** Y-DIRECTION SLANT CORRECTION FACTOR (nsec/uM) FOR B1 & B2 ECHOES IS:
-0.00175
C ** Y-DIRECTION SLANT CORRECTION FACTOR (nsec/uM) FOR REFLECTOR ECHOES IS
0.0
C ** TIME LOCATION (uSEC) OF B1 ECHO AT SCAN ORIGIN IS:
52.83
C ** TIME LOCATION (uSEC) OF B2 ECHO AT SCAN ORIGIN IS:
52.31
C ** TIME LOCATION (uSEC) OF REFLECTOR ECHO W/SAMPLE PRESENT AT SCAN LOCATION
IS:
69.46
C ** TIME LOCATION (uSEC) OF REFLECTOR ECHO W/O SAMPLE PRESENT AT SCAN LOCATION
IS:
72.48
C ** IMMERSION FLUID VELOCITY (cm/uSEC) IS:
0.148
C ** B2 PHASE-INVERTED WRT B1 (Y/N)?:
N
C ** M" PHASE INVERTED WRT M' (Y/N)?:
N
```

slant correction factor is obtained from (7.14–6.77)/40 μsec/mm. It should be noted that slant correction factors can be negative as well as positive numbers. The location of the time window during scanning for the material evaluation is automatically adjusted via computer control by using the formula:

As set forth above, in the method of the invention, the transducer is activated so that the first front surface echo off the sample, the first two successive back surface echoes, and the first echo off the reflector plate are all seen in the oscilloscope display at the same time by adjusting the the time base to the appropriate time per division setting and adjusting the time synthesizer delay time. Viewing the first front surface echo off the sample enables the operator to know if the back surface echoes are also on the CRT screen. The unfocused transducer is positioned above the sample at a distance determined initially by the natural focal distance. When using an unfocused transducer a good initial starting height is approximately one to two inches above the sample. The reflector plate front surface echo may be low in amplitude compared to the sample back surface echoes, so that the the pulser-receiver gain/attenuation or vertical amplifier gain settings may have to be increased to see this echo. It is important not to confuse the echoes off the front surface of the reflector plate with the second set of echoes originating from the front and back surfaces of the sample. The second set of echoes originating from the front and back surface of the sample will always occur at twice the delay time where the first set of these echoes appears. For example, if the first set of echoes begins at 50 msec on the digital oscilloscope, the second set will begin at 100 msec. If using, for example, a three milimeter thick sample placed on 0.5" thick plastic supports on the reflector plate, the first reflector echo will occur at about 20 msec after the time where the first set of echoes originates and thus the reflector echo will be seen at about 70 msec in this illustration. Another way to note the reflector plate echo is to raise and lower the sample while noting the location of the stationary echo corresponding to the stationary reflector plate. It is essential to have reflector plate echoes that will not interfere with the second set of echoes originating from the front and back sample surfaces. Attention is next focused on the first back surface echo from the sample, B1. The echo is centered in the oscilloscope time window to obtaining maximum time resolution by adjusting the time base time per division and the time synthesizer delay. The synthesizer time is recorded and inputted into the scan parameter computer file. This procedure is repeated for the second back surface sample echo, B2, the first front surface echo off the reflector plate with the sample present, M' and the first echo off the reflector plate with the sample removed, M". The next step is to account for and eliminate any nonlevelness in the set-up and also sample thickness variations. This done at each scan point, except that in the case of uniform thickness variations in the sample, the slant correction factors outlined above are determined and input into the scan parameter file in the computer.

The scanning is then automatically performed through the remainder of the scanning points previously inputted into the scan parameter file in the computer using a program written in Fortran and IEX GPIB to perform the scanning and also to obtain maximum vertical voltage resolution of the received ultrasonic waveforms. Scanning is accomplished through the use of computer controlled x-, and y- microscanning tables used to reposition the sample in the x- or y-direction in a 1 mm increment (other increments may be used at the convenience and discretion of the practitioner) for the next measurement. The ultrasonic waveforms received are then digitized (512×512 pixel resolution) at each scan location and stored successively in the scan data file in the computer. Four separate ultrasonic scans are performed at each scan location. As set forth above, the echoes are B1 (first echo off sample back surface, obtained in first scan), B2 (second echo off sample back surface, obtained in second scan), M' (first echo off front surface of reflector plate with the sample present, obtained in third scan), and M" (first echo off front surface of reflector plate without the sample present, obtained in fourth scan). Each of the four echoes is obtained in a separate scan to obtain the maximum time resolution for each echo by setting, before each scan during the nonlevelness and material thickness variation procedure, the optimum time per division setting on the oscilloscope time base that allows maximum time resolution. The minimum number of scans for this thickness-elimination procedure is two, but the time per division setting for only two scans cannot be obtained in this case as the time per division setting would be fixed for all three echoes obtained in the first of the scans using this scan procedure.

The following is an algorithm of a scanning program which accounts for and eliminates the nonlevelness of the set-up and uniform thickness variation effects of the sample in the resulting ultrasonic image displayed on the video, the code for which is included in the Appendix.

1) Determine the scan lengths and scan increments in the x- and y-directions, time positions of echoes at scan origin, slant correction factors, and immersion fluid velocity.
2) Edit NOTHICK_ALLSHAPE1.DAT FILE, which is the scan parameter file, and input information from 1) above.
3) Start scanner fortran program on computer which automatically does the following:

A) Initialize all GPIB instrumentation, which includes the time synthesizer, digitizer, time base, voltage amplifier, Klinger X, Y stages.

B) Perform scan to digitize B1 echoes and store in file
  I) Digitize B1 at scan origin
    Adjust voltage base for echo with maximum amplitude in video/oscilloscope window
    Move Klinger tables under transducer in x- direction specified x- direction increment
    Time synthesizer moves to delay time position determined by B1, B2, slant correction factors. This results in echo in video being centered in the Tektronics analog video/oscilloscope display and subsequently digitized and stored.

$$\text{Time position}=T_O+[(S_X)(N_X)(I_X)+(S_y)(N_y)(I_y)]$$

where T_0=correct delay time window at a particular scan location S_X=x- direction slant correction factor (nsec/μm)
N_X=scan point number in x- direction
I_X=x- direction scan increment (μm)
S_y=y- direction slant correction factor (nsec/μm)
N_y=scan point number in y- direction
I_y=y- direction scan increment (μm)

  II) Repeat I) until one scan line in x- direction is completed.
  III) Increment transducer in y- direction specified y-direction increment and repeat I)–II).
  IV) Repeat I)–III) until y- scan length is traversed and scan is completed.
  V) Return Klinger tables to scan origin.

C) Perform scan to digitize B2 echoes and store in file by repeating steps B(I–V)

D) Perform scan to digitize reflector echoes with sample present and store in file by repeating steps B(I–V), but using reflector echo slant correction factor

E) Remove sample. Perform scan to digitize reflector echoes without sample present and store in file by repeating steps B(I–V), but using reflector echo slant correction factor

4) Start velocity calculation Fortran program on computer to produce a file of velocities at each scan location by performing the cross-correlation algorithm.

5) Start image formation Fortran program on computer which results in a file of values between 0 and 255 which scale directly with the velocity values.

6) Start image display program which brings grey scale level image up on video.

Before initiating the scanning procedure, the temperature of the water or other immersion fluid is measured. If the fluid is water, published tables or graphs of temperature and velocity can be used to determine the velocity of the ultrasound in the constant temperature water bath. If the immersion liquid is a liquid other than water, or if a more precise temperature than that available in published graphs and tables is desired, the velocity of the ultrasound in the liquid is determined by recording the times (T_P) where ultrasonic peaks occur for two different vertical positions (Z1 and Z2) of the transducer above the reflector plate. The velocity, V, is then determined from

$$V=(Z1-Z2)/(T_P1-T_P2)$$

The phase relationships of (a) B1 compared to B2 and also (2) the reflector front surface echo with the sample present (M') compared to that without the sample present (M") are examined. These phase relationships are important for the computation of the velocity image of the scanned sample. The quantity 2τ is obtained by cross-correlating echoes **B1** and **B2** which is defined as the precise time delay between the **B1** and **B2** echoes. If **B1** and **B2** are phase inverted with respect to each other, the time occurrence of the minimum in the cross-correlation function is used to obtain 2τ. If M' and M" are phase inverted with respect to each other, the time occurrence of the minimum in the cross-correlation function is used to obtain Δt. Otherwise, at the time occurence of the maximum in the cross-correlation function is used.

FIGS. **3**(*a*) and **3**(*b*) graphically illustrate the case in which **B2** is phase inverted with respect to **B1**. The same holds for M' and M". Phase relationships generally remain the same throughout the scan, unless significant discrete microstructural defects are encountered by the ultrasonic wave.

After the scan has been completed and all the received echoes have been digitized and stored in the scan data file in the computer, they are recalled from the data file to perform the velocity image calculation for each scan location. In performing this cross-correlation, an overlap method is used by the computer based on a cross-correlation program using Fast Fourier transforms published in pages 415 and 416 (Correlation and Autocorrolation Using the FFT) in the book *Numerical Recipes—The Art of Scientific Computing*, by Press, et. al., 1988 Edition, Cambridge Univ. Press.. The Fortran program used is in the Appendix. Echoes M' and M" are also cross-correlated to obtain Δt where where M' is the echo reflected off the reflector plate front surface with the sample present, M" is the echo reflected off the reflector plate front surface without the sample present, and Δt is the time delay between them. If M' and M" are phase inverted with respect to each other, the time occurrence of the minimum in the cross-correlation function is used to obtain Δt. Otherwise the time occurence of the maximum in the cross-correlation function is used. The velocity, V, at each scan location is then calculated from the equation referred to above. The velocity value for each scan location is sequentially stored in the computer. After the scan is completed the velocity values are scaled on a gray or color scale with a value directly proportional to the velocity values, with the highest and lowest scale values corresponding to the highest and lowest velocity values.

The invention will be further understood with reference to the example below.

EXAMPLE

In this example, a sample of silicon nitride ceramic was evaluated using the thickness based velocity image method disclosed in the NASA Technical Memorandum TP 3377 referred to under Background. This method is based on a velocity, cross-correlation ultrasonic imaging method without the pre-scan to account for and eliminate nonlevelness in the set-up and sample thickness variations. In this method, only the first two sample back surface echoes are captured and evaluated. The silicon nitride ceramic was 3.5 mm thick with a uniform 300 micron thickness gradient. Very coarse time scaling was used so that the B1 and B2 echoes stayed in the time window while the sample thickness changed as the scan proceeded.

The same silicon nitride ceramic sample was also scanned and velocity imaged on a grey scale according to the method of the invention which included the prescans to eliminate set-up and sample thickness variations and which also captured and cross-corrolated both the first two successive sample back surface echoes and the two different reflector front surface echoes.

In both cases, the 20 MHz broad band transducer was used, the immersion liquid was water and the back plate was tungsten as set forth above.

FIGS. **5**(*a*) and **5**(*b*) are photographs of video grey scale displays of the thickness based ultrasonic velocity image of a ceramic according to the prior art method, and an image according to the method of the invention which included the prescans, respectively. Referring to FIG. **5**(*a*), it is seen that the top defect is masked due to that part of the sample being thicker than the bottom part. Also, the defect near the bottom is not too discernable and the lower portion is very light due to it being thinner. In marked contrast and as shown in FIG. **5**(*b*), the method of the invention clearly and correctly illustrates the defect areas, including resolution of the upper defect and an overall porosity gradient in the sample. It is believed that this demonstrates the efficacy and improvement to the art of the invention.

It is understood that various other embodiments and modifications in the practice of the invention will be apparent to, and can be readily made by, those skilled in the art without departing from the scope and spirit of the invention described above. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the exact description set forth above, but rather that the claims be construed as encompassing all of the features of patentable novelty which reside in the present invention, including all the features and embodiments which would be treated as equivalents thereof by those skilled in the art to which the invention pertains.

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Patent

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SUBSTITUTE APPENDIX

Kent N Stone

A P P E N D I X

```
C
C   nothick_SCAN.FOR --- 4 SCAN METHOD
C
C    Scan and data aquisition for the modified ultrasonic Immersion scanner
C
C          by Don J.Roth
C
C  PLEASE USE CLNEW.COM TO COMPILE & LINK
C
C                              Latest Update 20-sep-94
C
       integer*4 SCANSTEP,INDXSTEP
       integer*4 SCANAXIS, INDXAXIS, ZSTEP
       INTEGER*4 I17
       character VOLANS*1,TSCHEME*1,UOLANS*1
       CHARACTER LOOPANS*1,SHAPEANS*1,ZIGANS*1,FLAG*1
       character TBUF*8,SCHEME*1,FILENAME*34,SCANMODE*1
       real    DELAY(0:4),VOLTSET(0:4),MAXVALF,MAXVALT,VOL(4)
       real    slant1,slant2,slant3,slant4
       integer*2 NSCAN, NINDX,PLACE,ZIGCOUNT,JXXX,SCANKNT
       integer*2 A(512).NAVE,CHECKP,WWFLAG
       INTEGER*2   I15,I16,I26,I27,MAXFS1P,MAXFS1PT
       INTEGER*2   I36,I37,I46,I47
       INTEGER*2   LOOPTHRU_II,LOOPTHRU_S,LLL,IT,I,J,JJ,II
       BYTE  WRK0(80)
   common /IBLK/ WRK0,BUFFER
   common /SBLK/ A, DELAY,VOLTSET,MAI
       data   CHECKP/0/ZIGCOUNT/1/
       DATA  I6/1/I15/1/I16/1/I17/1/PLACE/0/
       data   I26/1/I27/1/I36/1/I37/1/I46/1/I47/1/
10010  format( A )
10012  format( A2 )
10020  format( I )
10030  format( F )
       OPEN( unit=8, file='TXA1:', status='NEW' )
       CALL ENTERPARAM( SCANSTEP,INDXSTEP, NSCAN,NINDX,NAVE,VOLTAGEL
   1   ,VOLTAGEU,VOLTAGE_MAX,SHAPEANS,LOOPANS,LOOPTHRU_H,LOOPTHRU_S,
   1   ZIGANS,SCHEME,TSCHEME,UZEROO,FILENAME,I15,SCANMODE,SLANT1,SLANT2
   1  ,SLANT3,SLANT4)

4328   SCANAXIS = 1
       INDXAXIS = 2
       ZSTEP = 10

       CALL STRTGPIB
       DO 1800 IADDR= 5,1,-1
 1800  CALL INITINSTR( IADDR )
C
C  Setup of 7912: begin with V/D =.5, then automatically find
C          the best intensity and Digitize Defects
C
C      NOTE:MAY NEED TO CHANGE THIS V/D TO START
C
 2000  CALL TEKGTL
C***************************************************************
```

```
10      FORMAT (3F)
        READ (10,65403) DELAY1        !NOTHICK - STARTING 1ST BACK SURFACE ECHO
                                                 WINDOW TIME
        READ (10,65403) DELAY2        !NOTHICK - STARTING 2ND BACK SURFACE ECHO
                                                 WINDOW TIME
        READ (10,65403) DELAY3        !NOTHICK - STARTING (W/SAMPLE) REFLECTOR ECHO
                                                        WINDOW TIME
        READ (10,65403) DELAY4        !NOTHICK - STARTING (WO/SAMPLE) REFLECTOR
                                                 ECHO WINDOW TIME
        READ (10,65402) VOLANS
        READ (10,65403) VOL(1)
        READ (10,65403) VOL(2)
        READ (10,65403) VOL(3)
        READ (10,65402) UOLANS
        READ (10,65403) VOL(4)
65402   FORMAT (A)
65403   FORMAT (F)
51      FORMAT(A32)
52      FORMAT(A2)
53      FORMAT(A4)
54      FORMAT(A2)
        TYPE *,'DELAY TIMES (B1,B2,RS,RNS)'
        TYPE *,'DELAY1=',DELAY1
        TYPE *,'DELAY2=',DELAY2
        TYPE *,'DELAY3=',DELAY3
        TYPE *,'DELAY4=',DELAY4
        TYPE *,' '
        CLOSE (10)
        DELAY(1)=DELAY1/(1.*10.**6.)
        DELAY(2)=DELAY2/(1.*10.**6.)
        DELAY(3)=DELAY3/(1.*10.**6.)
        DELAY(4)=DELAY4/(1.*10.**6.)
        TYPE *,'  '
        TYPE *,DELAY
        TYPE *,'  '
C**************************************************************
        CALL INITINSTR(0)
        CALL SETVOLTDIV(0.5)
        CALL TEKGTL
        CALL GETMAI(MAI)
        CALL TEKGTL
        CALL PUTTIME(DELAY(1))
        CALL TEKGTL
        CALL GETBESTMAI( MAI )
        CALL DIGDEF
C
C       !Preliminary Digitizations to get Watch level and Timeset (Time/div)
C
        CALL TEKGTL
        CALL AUTOSETVOLTS( MAI, VOLTSET(1),NUMINT )
C       TYPE *,'AUTOSET VOLTS'
          IF( VOLTSET(1).EQ. 999. )THEN
                TYPE *,'DIGITIZER IS SCREWED UP'
                GOTO 2000
                ENDIF
```

2

```
        CALL GETGRID( TIMESET, X )
        CALL GETSA( NAVE,MAI,A )
        CALL TEKGTL

        TYPE *,'Timeset=',TIMESET,'     Delay=',DELAY(1),
    +    '    Voltset=',VOLTSET(1)

        TYPE *,'I16= ',I16,' I17= ',I17
C*********************************************************
        WRITE(16,rec=I16,fmt=53)TIMESET
        I16=I16+1

C
C  Get WATCH - standard ground level
C
        TYPE *,' '
        TYPE *,' '
        TYPE *,' '
        TYPE *,' '
        W = A(1)/NAVE
        WATCH = W - 100.
        WRITE( 8,12030 )WATCH
        TYPE *,' '
        TYPE *,' '
        TYPE *,' '
        TYPE *,' '
12030   format( ' Minimum acceptable ground level =',F )


C       SCANSTEP = 1000*SCANSTEP
C       INDXSTEP = 1000*INDXSTEP
        CALL SETXYZ( SCANSTEP, INDXSTEP, ZSTEP )
        WRITE( 5,12140 )
12140   format( ///' ### S C A N N I N G ###'// )
        IDIR=1

        WWFLAG=0

        do 2600 noth_I = 1,4        ! nothickness mod
        if (noth_I.ge.2)then
        CALL MOVORGXY (ZIGANS,SCANAXIS,NSCAN,INDXAXIS,NINDX)
        REWIND(12) ! .DATHS FILE
        IF (ZIGANS.EQ.'Y')ZIGCOUNT=1
        ENDIF

        IF (NOTH_I.EQ.4)THEN
        type *,'              '
        type *,'              '
        type *,'              '
        type *,' *******  Finished w/ Sample Scan ************ '
        type *,' *** Remove Sample from tray & Hit <RET> to perform water scan'
        type *,'              '
        type *,'              '
        type *,'              '
        Read (5,10020) IO
```

```
      ENDIF

      DO 2400 I=1.NINDX            ! Outer loop over index
      DO 2200 J=1,NSCAN            !     Inner loop over scan

      IF (NOTH_I.ge.2)THEN
      READ(12)JJ,II,FLAG,SCANKNT  !READ WHETHER 'H' OR 'S'

      type *,' '
      type *,' '
      type *,' '
      type *,'second time around for',jj,ii
      type *,'FLAG =',FLAG
      type *,' '
      type *,' '

      ENDIF


      IF ((SCANMODE.EQ.'P'.OR.SCANMODE.EQ.'L').AND.I.GT.1)GOTO 2400 !MOD FOR LINE / POINT
SCAN
      IF (NOTH_I.EQ.1)TYPE *,'I= ',I,' AND J=',J
      PLACE=PLACE+1
      WRITE( 8,13000 )J,I,PLACE                !
C****************************************************************C

      IF (SHAPEANS.EQ.'N')THEN
      CALL TAKEDATA_O(FILENAME,VOLANS,UOLANS,VOL,I16,I17,I26,I27,
   I  I36,I37,I46,I47,NAVE,WATCH,I,J,noth_I,SLANT1,
   I SLANT2,SLANT3,SLANT4,SCANSTEP,INDXSTEP,ZIGANS,NSCAN)
      ELSEIF (SHAPEANS.EQ.'Y')THEN
      IF (NOTH_I.EQ.2.AND.FLAG.EQ.'H')GOTO 3429
      CALL TAKEDATA(PLACE,SCHEME,TSCHEME,VOLANS,VOL,UZEROO,FILENAME,
   I  UOLANS,I26,I27,NOTH_I,I36,I37,I46,I47,
   1  SLANT1,SLANT2,SLANT3,SLANT4,SCANSTEP,INDXSTEP,ZIGANS,NSCAN,
   I  RCMAX,MAXFS1P,MAXVALF,RF1,RF2,MAXFS1PT,MAXVALT,RT1,RT2,I16,I17,
   1  NAVE,WATCH,J,I,I15,IT)
      ENDIF
C****************************************************************C


3429  CONTINUE
      IF (NOTH_I.EQ.1.AND.IT.LT.4)THEN
      TYPE *,'I16= ',I16,' I17= ',I17
      ELSEIF (NOTH_I.EQ.1.AND.IT.EQ.4)THEN
      TYPE *,'I46= ',I46,' I47= ',I47
      ENDIF

      IF( J.EQ.NSCAN )GOTO 2200        !

      IF (LOOPANS.EQ.'N')GOTO 22001  !DON'T PICK UP XDUCER EACH TIME

      IF (NOTH_I.EQ.1)TYPE *,'IT=',IT
      IF (NOTH_I.EQ.1)TYPE *,' '
```

```
        IF (NOTH_I.EQ.1)TYPE *,' '
        IF (NOTH_I.EQ.1)TYPE *,'VOLANS (WRT "ON SAMPLE")= ',VOLANS
        IF (NOTH_I.EQ.1)TYPE *,'UOLANS (WRT "NOT ON SAMPLE)= ',UOLANS
        IF (NOTH_I.EQ.1)TYPE *,' '


C************* MOD FOR ZIGZAG SCAN ******************************C
22001   IF (ZIGANS.EQ.'Y'.AND.ZIGCOUNT.EQ.0)THEN  !ZIGZAG SCAN
        IF (SCANMODE.EQ.'P')GOTO 12306  !FOR POINT MEASURE, DON'T MOVE X-AXIS
        CALL MOVXYZ(SCANAXIS,-1)  ! MOVE X-AXIS BACKWARD
        ELSEIF (ZIGANS.EQ.'Y'.AND.ZIGCOUNT.EQ.1)THEN
        IF (SCANMODE.EQ.'P')GOTO 12306  !FOR POINT MEASURE, DON'T MOVE X-AXIS
        CALL MOVXYZ(SCANAXIS,1)  !MOVE X-AXIS FORWARD
        ENDIF
12306   CONTINUE
        CALL WAIT2(1000)  !ADD DELAY SO THAT DATA IS NOT TAKEN BEFORE
C                          KLINGER STAGES STOP MOVING
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        IF (ZIGANS.EQ.'Y')GOTO 12305
C***********************************C
        IF (SCANMODE.EQ.'P')GOTO 2402  !FOR POINT MEASURE, DON'T MOVE X-AXIS

2402    CONTINUE

        IF (LOOPANS.EQ.'N')GOTO 2200

12305   CONTINUE      !NOTHICK

 2200  CONTINUE

                !    ---

        IF( I.EQ.NINDX )GOTO 2400        !

C  !FOR LINE SCAN OR POINT MEASURE, DON'T MOVE Y-AXIS

        IF (SCANMODE.EQ.'P'.OR.SCANMODE.EQ.'L')GOTO 2401
        CALL MOVXYZ( INDXAXIS, 1 )        !  Move

        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
        CALL WAIT2(1000)
```

5

```
      CALL WAIT2(1000)
      CALL WAIT2(1000)
      CALL WAIT2(1000)
      CALL WAIT2(1000)
      CALL WAIT2(1000)
      CALL WAIT2(1000)
      CALL WAIT2(1000)
      CALL WAIT2(1000)
      CALL WAIT2(1000)

2401  NTOGO = NINDX-I              !

      IF (ZIGANS.EQ.'N')THEN !NORMAL SCAN
      CALL MOVORG(SCANAXIS,NSCAN,VOLTAGEL,VOLTAGEU,
   1  LOOPTHRU_H)           !Move back to the X origin
C****************** MOD FOR ZIGZAG SCAN ******************C
      ELSEIF (ZIGANS.EQ.'Y')THEN
      IF (ZIGCOUNT.EQ.1)THEN
      ZIGCOUNT=0
      GOTO 15021
      ELSEIF(ZIGCOUNT.EQ.0)THEN
      ZIGCOUNT=1
      ENDIF
      ENDIF
C********************************C
15021 CONTINUE      !NOTHICK

 2400 CONTINUE                     ! ---
 2600 continue
      CALL TIME(TBUF)
      WRITE( 8,13100 )TBUF
      CLOSE( 8 )
      CLOSE( 6 )
      CLOSE(14)
      JXXX=I-1   !!!!!!!!!!!!!!!!! Y-LOCATION
      IF (SCANMODE.EQ.'L'.OR.SCANMODE.EQ.'P')JXXX=1  !MOD FOR LINE SCAN & POINT
MEASURE
      WRITE(15,REC=I15,FMT=52)JXXX
      I15=I15+1
C     ENDIF
      STOP
13000 format(' ',I3,I3,I5)
13100 format(' ',A8 )
      end


   SUBROUTINE TAKEDATA_O(FILENAME,VOLANS,UOLANS,VOL,I16,I17,I26,I27,
   1         I36,I37,I46,I47,NAVE,WATCH,I,J,noth_I,SLANT1,
   1     SLANT2,SLANT3,SLANT4,SCANSTEP,INDXSTEP,ZIGANS,NSCAN)
      integer*2 A(512), WFLAG,I16,I26,WWFLAG,I,J,ILOCX,NSCAN,ILOCY,I36,I46
      INTEGER*4     I17SUB,I17,I27,SCANSTEP,INDXSTEP
      INTEGER*4 I27SUB,I37SUB,I47SUB
```

6

```
      real   DELAY(0:4), VOLTSET(0:4),VOLTAGE(4),VOL(4),SLANT1,SLANT2,SLANT
      REAL   SLANT3,SLANT4
      character DAY*9, TIM*9,VOLANS*1,UOLANS*1,C1*80,FILENAME*34,ZIGANS*1
   common    /SBLK/ A, DELAY, VOLTSET, MAI
C
      DATA I14/0/
C
            if (noth_I.eq.1)then
            OPEN( unit=14, file='[ROTH.MENU]DONSCAN_INTERP.LOG',
  +                  status='NEW',ACCESS='SEQUENTIAL',
  +                  FORM='UNFORMATTED')
            endif
C
51    FORMAT(A32)
52    FORMAT(A2)
53    FORMAT(A4)
54    FORMAT(A2)
      WFLAG = 0
10600 format(' ',I15 )

      if (noth_I.eq.1)then
      IX=1
      IY=1
      elseif (noth_I.eq.2)THEN
      IX=2
      IY=2
      elseif (noth_I.eq.3)THEN
      IX=3
      IY=3
      elseif (noth_I.eq.4)THEN
      IX=4
      IY=4
      ENDIF

      DO 600 IT = IX,IY

      IF (IT.EQ.1.OR.IT.EQ.2)THEN
      SLANTX=SLANT1
      SLANTY=SLANT3
      ELSEIF (IT.EQ.3.OR.IT.EQ.4)THEN
      SLANTXR=SLANT2
      SLANTYR=SLANT4
      ENDIF

C ***** MODIFICATION FOR ZIGZAG SCAN ******************************C
      IF (ZIGANS.EQ.'Y')THEN
      IF (I.EQ.2.OR.I.EQ.4.OR.I.EQ.6.OR.I.EQ.8.OR.I.EQ.10
   1 .OR.I.EQ.12.OR.I.EQ.14.OR.I.EQ.16.OR.I.EQ.18.OR.I.
   1 EQ.20.OR.I.EQ.22.OR.I.EQ.24.OR.I.EQ.26.OR.I.EQ.28.OR.
   1 I.EQ.30.OR.I.EQ.32.OR.I.EQ.34.OR.I.EQ.36.OR.I.EQ.38.
   1 OR.I.EQ.40.OR.I.EQ.42.OR.I.EQ.44.OR.I.EQ.46.OR.I.EQ.
   1 48.OR.I.EQ.50.OR.I.EQ.52.OR.I.EQ.54.OR.I.EQ.56.OR.
   1 I.EQ.58.OR.I.EQ.60.OR.I.EQ.62.OR.I.EQ.64.OR.I.EQ.66
   1 .OR.I.EQ.68.OR.I.EQ.70.OR.I.EQ.72.OR.I.EQ.74.OR.I.
   1 EQ.76.OR.I.EQ.78.OR.I.EQ.80.OR.I.EQ.82.OR.I.EQ.84.OR
```

```
 1 .I.EQ.86.OR.I.EQ.88.OR.I.EQ.90.OR.I.EQ.92.OR.I.
 1 EQ.94.OR.I.EQ.96.OR.I.EQ.98.OR.I.EQ.100)THEN
  ILOCX=NSCAN-J  !FOR ZIGZAG SCAN, REVERSE BACK FOR DISPLAY
      ELSE
      ILOCX=J-1
      ENDIF
      elseif(zigans.eq.'N')then !george wood addition
      ILOCX=J-1  !George Wood addition
      ENDIF
      ILOCY=I-1

      IF (IT.EQ.1.OR.IT.EQ.2)THEN   !CORRECT DELAY WINDOW FOR NONLEVELNESS
      DELAY_CORR=DELAY(IT)+(SLANTX*ILOCX*SCANSTEP)+(SLANTY*ILOCY*INDXSTEP)
      ELSEIF (IT.EQ.3.OR.IT.EQ.4)THEN
      DELAY_CORR=DELAY(IT)+(SLANTXR*ILOCX*SCANSTEP)+(SLANTYR*ILOCY*INDXSTEP)
      ENDIF


      TYPE *,' '
      TYPE *,' '
      TYPE *,' '
      TYPE *,'J=',J,' DELAY(',IT,')= ',DELAY(IT)
      TYPE *,'DELAY_CORR= ',DELAY_CORR
      TYPE *,' '
      TYPE *,' '
      TYPE *,' '
      CALL PUTTIME( DELAY_CORR )         !  Set delay

100   CONTINUE

      IF ((IT.NE.4.AND.VOLANS.EQ.'U').OR.(IT.EQ.4.AND.UOLANS.EQ.'U'))THEN
C                                      !!!! USER-DEFINED VOLTAGE SETTINGS
      VOLTS=VOL(IT)
      CALL SETVOLTDIV(VOLTS)
      GOTO 1132
      ENDIF

      CALL AUTOSETVOLTS( MAI,VOLTS,NUMINT )          !  Set V/D
1132  IF((VOLTS.GT.1.0).OR.(VOLTS.LT.0.01))THEN
      WRITE(5,1131)VOLTS
1131  FORMAT('+','BAD VOLTAGE SETTING',E10.5)
      CALL TEKRESET(MAI)
      GOTO 100
      ENDIF

      CALL GETSA(NAVE,MAI,A)     !  Get waveform

      WATCH1 = A(1)/ NAVE        !  Make sure its acceptable
      TYPE *,' '
      TYPE *,' '
      TYPE *,' '
      WRITE(5,1133)WATCH1,WATCH
1133  FORMAT('+','CURRENT WATCH LEVEL IS',F10.5,'MIN =',F10.5)
      TYPE *,' '
      TYPE *,' '
```

```
      TYPE *,' '

      IF ((IT.NE.4.AND.VOLANS.EQ.'U').OR.(IT.EQ.4.AND.UOLANS.EQ.'U'))GOTO 56732
C                                        !!!! USER-DEFINED VOLTAGE SETTINGS

C     IF (VOLANS.EQ.'U')GOTO 56732  !! SKIP WATCH


      IF( WATCH1.LT.WATCH )THEN
            WWFLAG = WWFLAG+1
            IF (WWFLAG.EQ.1)THEN
            OPEN( unit=88, file='[ROTH.MENU]DONSCAN.LOG',
  +               status='NEW' )
            ENDIF
            WRITE( 5,10200 )
            CALL TIME(TIM)
            CALL DATE(DAY)
      TYPE *,' '
      TYPE *,' '
      TYPE *,' '
            type *,'watch1=',watch1,' < watch=',watch
      TYPE *,' '
      TYPE *,' '
      TYPE *,' '
      TYPE *,' '
            WRITE( 88,10201 )FILENAME,DAY,TIM,J,I,C1
10201       format(' ',A,' ',A,' X= ',I3,' Y= ',I3,'MAY LEAD TO BAD PROPERTY VALUE' )
10200       format('  WAVEFORM BELOW "WATCH",MAY LEAD TO BAD PROPERTY VALUE')
C           GOTO 100
            ENDIF

C************************************************************
56732 CONTINUE

      IF (noth_I.eq.1)then
 500  WRITE(16,REC=I16,FMT=53)DELAY_CORR
      I16=I16+1
      WRITE(16,REC=I16,FMT=53)VOLTS
      I16=I16+1
C
      DO 54321 IJI=1,512
      I17SUB=((I17-1)*512)+IJI
54321 WRITE(17,REC=I17SUB,FMT=54) A(IJI)
      I17=I17+1

      elseif (noth_I.eq.2)then

 5500 WRITE(26,REC=I26,FMT=53)DELAY_CORR
      I26=I26+1
      WRITE(26,REC=I26,FMT=53)VOLTS
      I26=I26+1
C
      DO 54329 IJI=1,512
      I27SUB=((I27-1)*512)+IJI
54329 WRITE(27,REC=I27SUB,FMT=54) A(IJI)
```

```
        I27=I27+1

        elseif (noth_l.eq.3)then

 5800   WRITE(36,REC=I36,FMT=53)DELAY_CORR
        I36=I36+1
        WRITE(36,REC=I36,FMT=53)VOLTS
        I36=I36+1
C
        DO 58329 IJI=1,512
        I37SUB=((I37-1)*512)+IJI
58329   WRITE(37,REC=I37SUB,FMT=54) A(IJI)
        I37=I37+1

        elseif (noth_l.eq.4)then

 5900   WRITE(46,REC=I46,FMT=53)DELAY_CORR
        I46=I46+1
        WRITE(46,REC=I46,FMT=53)VOLTS
        I46=I46+1
C
        DO 59329 IJI=1,512
        I47SUB=((I47-1)*512)+IJI
59329   WRITE(47,REC=I47SUB,FMT=54) A(IJI)
        I47=I47+1

        endif

C**********************************************************C
        IF (IT.EQ.1)VOLTAGE(1)=VOLTS
        IF (IT.EQ.2)VOLTAGE(2)=VOLTS
        IF (IT.EQ.3)VOLTAGE(3)=VOLTS
        IF (IT.EQ.4)VOLTAGE(4)=VOLTS
C*********************************************************C
 600  CONTINUE
C**************************************************C
        IF (I.EQ.0.AND.J.EQ.0) GOTO 20000  !SKIP NEXT STEP (NOISE MEASURE)
C       CHECK FOR ERROR IN FS2 VOLTSET
C
c       IF (VOLTAGE(1).EQ..01) THEN
c       WRITE (14) I,J,' VOLT FOR FS2= ',VOLTAGE(1),
c   +   ' #INT.PO.= ',NUMINT
C       GOTO 100
c       ENDIF
C
C       CHECK FOR ERROR IN B1 VOLTSET
C
c       IF (VOLTAGE(1).LT.VOLTAGE(2)) THEN
c       WRITE (14) I,J,' VOLT FOR B1= ',VOLTAGE(1),
c   +   ' #INT.PO.= ',NUMINT
C       GOTO 100
c       ENDIF
7       FORMAT (A4)
C**************************************************C
20000   CONTINUE
```

10

```
      RETURN
   end
C
```

```
      SUBROUTINE TAKEDATA(PLACE,SCHEME,TSCHEME,VOLANS,VOL,UZEROO,FILENAME,
     1    UOLANS,I26,I27,NOTH_I,I36,I37,I46,I47,
     1    SLANT1,SLANT2,SLANT3,SLANT4,SCANSTEP,INDXSTEP,ZIGANS,NSCAN,
     1    RCMAX,MAXFS1P,MAXVALF,RF1,RF2,MAXFS1PT,MAXVALT,RT1,RT2,I16,
     1    I17,NAVE,WATCH,J,I,I15,IT)

      integer*2 A11(512),I26,I,J,ILOCX,NSCAN,WFLAG,I16,MAXFS1PT,PLACE
      INTEGER*2 WATCH_COUNT,IHT,ILOCY,I36,I46
      INTEGER*2 MAXFS1P,NAVE,A(512),IT,SCANKNT
      INTEGER*4 I17SUB,I17,ISTAT,I27,SCANSTEP,INDXSTEP,I37,I47
      INTEGER*4 I27SUB,I37SUB,I47SUB
      REAL*4        ASPECF1(1024),PHASE(1024),MAXVALF,MAXVALT,VOL(3),SLANT3,SLANT4
      real*4   DELAY(0:4),VOLTSET(0:4),VOLTAGE(4),SLANT,SLANT1,SLANT2,F1(512)
      COMPLEX CF1(1024),CSPEC(1024)
      character SCHEME*1,FLAG*1,FILENAME*34,UOLANS*1,ZIGANS*1
      CHARACTER  VOLANS*1,TSCHEME*1
      common   /SBLK/ A, DELAY, VOLTSET, MAI
C
      DATA I14/0/IHT/0/
C
            IF (NOTH_I.EQ.1)THEN
            OPEN( unit=14, file='[ROTH.MENU]DONSCAN_INTERP.LOG',
     +            status='NEW',ACCESS='SEQUENTIAL',
     +            FORM='UNFORMATTED')
            ENDIF
C
51    FORMAT(A32)
52    FORMAT(A2)
53    FORMAT(A4)
54    FORMAT(A2)
      WFLAG = 0
C     WATCH_COUNT=0
10600 format(' ',I15 )

      IF (noth_I.eq.1.and.PLACE.EQ.1)THEN
      OPEN( unit=12, file=FILENAME//'HS', status='NEW',
     +       form='UNFORMATTED',ORGANIZATION='SEQUENTIAL' )
      SCANKNT=0
      ENDIF

      if (noth_I.eq.1)then
      IX=1
      IY=1
      elseif (noth_I.eq.2)THEN
      IX=2
      IY=2
      elseif (noth_I.eq.3)THEN
      IX=3
      IY=3
      elseif (noth_I.eq.4)THEN
      IX=4
      IY=4
      ENDIF
```

```
10386 DO 600 IT = IX,IY

C ***** MODIFICATION FOR ZIGZAG SCAN ******************************C
      IF (ZIGANS.EQ.'Y')THEN
      IF (I.EQ.2.OR.I.EQ.4.OR.I.EQ.6.OR.I.EQ.8.OR.I.EQ.10
   1 .OR.I.EQ.12.OR.I.EQ.14.OR.I.EQ.16.OR.I.EQ.18.OR.I.
   1 EQ.20.OR.I.EQ.22.OR.I.EQ.24.OR.I.EQ.26.OR.I.EQ.28.OR.
   1 I.EQ.30.OR.I.EQ.32.OR.I.EQ.34.OR.I.EQ.36.OR.I.EQ.38.
   1 OR.I.EQ.40.OR.I.EQ.42.OR.I.EQ.44.OR.I.EQ.46.OR.I.EQ.
   1 48.OR.I.EQ.50.OR.I.EQ.52.OR.I.EQ.54.OR.I.EQ.56.OR.
   1 I.EQ.58.OR.I.EQ.60.OR.I.EQ.62.OR.I.EQ.64.OR.I.EQ.66
   1 .OR.I.EQ.68.OR.I.EQ.70.OR.I.EQ.72.OR.I.EQ.74.OR.I.
   1 EQ.76.OR.I.EQ.78.OR.I.EQ.80.OR.I.EQ.82.OR.I.EQ.84.OR
   1 .I.EQ.86.OR.I.EQ.88.OR.I.EQ.90.OR.I.EQ.92.OR.I.
   1 EQ.94.OR.I.EQ.96.OR.I.EQ.98.OR.I.EQ.100)THEN
    ILOCX=NSCAN-J  !FOR ZIGZAG SCAN, REVERSE BACK FOR DISPLAY
      ELSE
      ILOCX=J-1
      ENDIF
      elseif(zigans.eq.'N')then !george wood addition
      ILOCX=J-1  !George Wood addition
      ENDIF
      ILOCY=I-1

      IF (IT.EQ.1.OR.IT.EQ.2)THEN
      SLANTX=SLANT1
      SLANTY=SLANT3
      ELSEIF (IT.EQ.3.OR.IT.EQ.4)THEN
      SLANTXR=SLANT2
      SLANTYR=SLANT4
      ENDIF

      IF (NOTH_I.EQ.1)TYPE *,'  '
      IF (NOTH_I.EQ.1)TYPE *,'IT=',IT
      IF (NOTH_I.EQ.1)TYPE *,'PLACE=',PLACE
      IF (NOTH_I.EQ.1)TYPE *,'SCHEME=',SCHEME
      IF (NOTH_I.EQ.1)TYPE *,'  '

      IF (IT.EQ.1.OR.IT.EQ.2)THEN  !CORRECT DELAY WINDOW FOR NONLEVELNESS
      DELAY_CORR=DELAY(IT)+(SLANTX*ILOCX*SCANSTEP)+(SLANTY*ILOCY*INDXSTEP)
      ELSEIF (IT.EQ.3.OR.IT.EQ.4)THEN
      DELAY_CORR=DELAY(IT)+(SLANTXR*ILOCX*SCANSTEP)+(SLANTYR*ILOCY*INDXSTEP)
      ENDIF

      TYPE *,'  '
      TYPE *,'  '
      TYPE *,'  '
      TYPE *,'J=',J,' DELAY(',IT,')= ',DELAY(IT)
      TYPE *,'DELAY_CORR= ',DELAY_CORR
      TYPE *,'  '
      TYPE *,'  '
      TYPE *,'  '
```

```
    IF (PLACE.GE.1.AND.SCHEME.EQ.'B'.AND.NOTH_I.EQ.1)THEN
        IHT=2  !CORRECT DELAY WINDOW FOR NONLEVELNESS
        DELAY_CORR=DELAY(2)+(SLANTX*ILOCX*SCANSTEP)+(SLANTY*ILOCY*INDXSTEP)

        CALL PUTTIME(DELAY_CORR)           !   Set delay FOR B2

!!! USER-DEFINE VOLTAGE SETTINGS?

        IF (VOLANS.EQ.'U')THEN
        VOLTS=VOL(2)
        CALL SETVOLTDIV(VOLTS)
        ENDIF
        IF (VOLANS.EQ.'A')CALL AUTOSETVOLTS( MAI,VOLTS,NUMINT )!Set V/D
        GOTO 1132
          ENDIF

C  !KEEP TRACK OF POSITION WHERE DATA IS ACTUALLY TAKEN WITH A COUNTER
        IF (IT.EQ.1.AND.PLACE.GE.1.AND.SCHEME.EQ.'X')SCANKNT=SCANKNT+1
        IF (NOTH_I.EQ.1)TYPE *,' '
        IF (NOTH_I.EQ.1)TYPE *,' X=',J,' Y=',I,' SCANKNT=',SCANKNT
        IF (NOTH_I.EQ.1)TYPE *,' '

        CALL PUTTIME( DELAY_CORR )         !   Set delay AS USUAL

100     CONTINUE

        IF ((VOLANS.EQ.'U'.AND.(IT.EQ.1.OR.IT.EQ.2.OR.IT.EQ.3)).OR.
   1    (UOLANS.EQ.'U'.AND.IT.EQ.4))THEN  !!! USER-DEFINE VOLTAGE SETTINGS
        VOLTS=VOL(IT)
        CALL SETVOLTDIV(VOLTS)
        GOTO 1132
        ENDIF


        CALL AUTOSETVOLTS( MAI,VOLTS,NUMINT )        !   Set V/D
1132    IF((VOLTS.GT.1.0).OR.(VOLTS.LT.0.01))THEN
        WRITE(5,1131)VOLTS
1131    FORMAT('+','BAD VOLTAGE SETTING',E10.5)
        CALL TEKRESET(MAI)
        GOTO 100
        ENDIF

        CALL GETSA(NAVE,MAI,A)      !   Get waveform
        WATCH1 = A(1)/ NAVE         !   Make sure its acceptable
        TYPE *,' '
        TYPE *,' '
        TYPE *,' '
        WRITE(5,1133)WATCH1,WATCH
1133    FORMAT('+','CURRENT WATCH LEVEL IS',F10.5,'MIN =',F10.5)
        TYPE *,' '
        TYPE *,' '
        TYPE *,' '

        IF (VOLANS.EQ.'U'.OR.UOLANS.EQ.'U')GOTO 56732  !! SKIP WATCH
```

```
        IF( WATCH1.LT.WATCH )THEN
              WFLAG = 1
              WRITE( 5,10200 )
            FLAG='H'  !H = SAMPLE HOLDER
            TYPE *,'FLAG=',FLAG
C
C !COUNTER FOR BAD WATCH LEVEL, IE. ON WHICH WAVEFORM (B1 OR B2) DOES IT OCCUR
C
C             IF (SCHEME.EQ.'X'.AND.IT.EQ.1)WATCH_COUNT=1
C             IF (SCHEME.EQ.'X'.AND.IT.EQ.2)WATCH_COUNT=2
C             TYPE *,'WATCH_COUNT=',WATCH_COUNT

            GOTO 20000
10201         format(' ',A,' ',A,' X= ',I3,' Y= ',I3 )
10200         format('  WAVEFORM BELOW "WATCH", GOING TO NEXT SCAN POINT')
C             GOTO 100
              ENDIF
C************************************************************

56732  CONTINUE
C************************************************************

        IF (NOTH_I.EQ.1)TYPE *,' '
        IF (NOTH_I.EQ.1)TYPE *,'PLACE=',PLACE
        IF (NOTH_I.EQ.1)TYPE *,'SCHEME=',SCHEME
        IF (NOTH_I.EQ.1)TYPE *,'TSCHEME=',TSCHEME
        IF (NOTH_I.EQ.1)TYPE *,'ZEROO=',ZEROO
        IF (NOTH_I.EQ.1)TYPE *,'IIIT=',IIIT
C       IF (NOTH_I.EQ.1)TYPE *,'WATCH_COUNT=',WATCH_COUNT
        IF (NOTH_I.EQ.1)TYPE *,' '
C **** EXAMINE B2(t) APPROACH FOR SAMPLE HOLDER ******* C
        IF (PLACE.GE.1.AND.SCHEME.EQ.'B'.AND.IIIT.EQ.2)THEN
        AA = 0.                          !
         DO 499 III=1,512                ! Subtract average from wave,
         A11(III)=A(III)
         A11(III)=A11(III)/NAVE          !
499      AA=AA + A11(III)                ! REALWAVE = Waveform in volts
        ZERO = AA/512.                          !
        IF (NOTH_I.EQ.1)TYPE *,'ZERO=',ZERO
        FF=0.
         DO 599 III=1,512
         F1(III) = ( REAL(A11(III)) - ZERO )*( VOLTS )*10./512.
599     FF=FF+ABS(F1(III))
        ZEROO=FF/512.
        IF (NOTH_I.EQ.1)TYPE *,' '
        IF (NOTH_I.EQ.1)TYPE *,'ZEROO=',ZEROO
        IF (NOTH_I.EQ.1)TYPE *,' '
C******** MOD FOR AUTOMATIC NOISE THRESHOLD ******************
C  SET UZEROO = 2*(FIRST "NOISE" LEVEL DETECTED --> ASSUME WE ARE STARTING
C                                              ON SAMPLE HOLDER)
        IF (TSCHEME.EQ.'A'.AND.PLACE.EQ.1)THEN
        UZEROO=2*ZEROO
        IF (NOTH_I.EQ.1)TYPE *,'  '
        IF (NOTH_I.EQ.1)TYPE *,' AUTO THRESHOLD VOLTAGE NOISE LEVEL =',UZEROO
        IF (NOTH_I.EQ.1)TYPE *,'  '
```

15

```
      ELSEIF (TSCHEME.EQ.'M'.AND.PLACE.EQ.1)THEN
      IF (NOTH_I.EQ.1)TYPE *,'  '
      IF (NOTH_I.EQ.1)TYPE *,' MANUALLY-SET THRESHOLD VOLTAGE NOISE LEVEL =',UZEROO
      IF (NOTH_I.EQ.1)TYPE *,'  '
      ENDIF
C ********************************************************
      IF (ZEROO.LT.UZEROO)THEN  !!!< EX..002 VOLTS - ON SAMPLE HOLDER
56120 FLAG='H'  !H = SAMPLE HOLDER
      IF (NOTH_I.EQ.1)TYPE *,'FLAG=',FLAG
      GOTO 20000
      ELSEIF (ZEROO.GE.UZEROO)THEN !!!> EX..002 VOLTS - ON SAMPLE
56121 FLAG='S'  !S = SAMPLE
      IF (NOTH_I.EQ.1)TYPE *,'FLAG=',FLAG
      SCHEME='X'
      GOTO 10386 !START TAKEDATA LOOP AGAIN
      ENDIF
      ENDIF

      IF (NOTH_I.EQ.1)THEN
 500  WRITE(16,REC=I16,FMT=53)DELAY_CORR
      I16=I16+1
      WRITE(16,REC=I16,FMT=53)VOLTS
      I16=I16+1
C
      DO 54321 IJI=1,512
      I17SUB=((I17-1)*512)+IJI
54321 WRITE(17,REC=I17SUB,FMT=54) A(IJI)
      I17=I17+1

      elseif (noth_I.eq.2)then

 5500 WRITE(26,REC=I26,FMT=53)DELAY_CORR
      I26=I26+1
      WRITE(26,REC=I26,FMT=53)VOLTS
      I26=I26+1
C
      DO 54329 IJI=1,512
      I27SUB=((I27-1)*512)+IJI
54329 WRITE(27,REC=I27SUB,FMT=54) A(IJI)
      I27=I27+1


      elseif (noth_I.eq.3)then

 5800 WRITE(36,REC=I36,FMT=53)DELAY_CORR
      I36=I36+1
      WRITE(36,REC=I36,FMT=53)VOLTS
      I36=I36+1
C
      DO 58329 IJI=1,512
      I37SUB=((I37-1)*512)-IJI
58329 WRITE(37,REC=I37SUB,FMT=54) A(IJI)
      I37=I37+1

      elseif (noth_I.eq.4)then
```

```
 5900   WRITE(46,REC=I46,FMT=53)DELAY_CORR
        I46=I46+1
        WRITE(46,REC=I46,FMT=53)VOLTS
        I46=I46+1
C
        DO 59329 IJI=1,512
        I47SUB=((I47-1)*512)+IJI
59329   WRITE(47,REC=I47SUB,FMT=54) A(IJI)
        I47=I47+1


        endif


C
C       WRITE( 8,10600 )A(200)
C*********************************************************C
        IF (IT.EQ.1)VOLTAGE(1)=VOLTS
        IF (IT.EQ.2)VOLTAGE(2)=VOLTS
        IF (IT.EQ.3)VOLTAGE(3)=VOLTS
        IF (IT.EQ.4)VOLTAGE(4)=VOLTS
C*********************************************************C
 600  CONTINUE
C**************************************************C
7       FORMAT (A4)
C**************************************************C
20000  IF( WFLAG.EQ.1 )THEN
         CLOSE(8)
         OPEN( unit=8, file='TXA1:', status='OLD' )
         ENDIF
        IF (SCHEME.EQ.'X')SCHEME='B'  !RESET BACK TO 'B' FOR NEXT SCAN POINT

C       IF (I.NE.0.AND.J.NE.0)THEN


C  !RESET COUNTERS TO EXCLUDE DATA GATHERED ON POINT
C   WHERE BAD WATCH LEVEL WAS FOUND


C        IF (WATCH_COUNT.EQ.1)THEN  !B1 HAD BAD WATCH LEVEL
C        SCANKNT=SCANKNT-1
C        I16=I16-2
C        I17=I17-1
C        ELSEIF (WATCH_COUNT.EQ.2)THEN !B2 HAD BAD WATCH LEVEL
C        SCANKNT=SCANKNT-1
C        I16=I16-4
C        I17=I17-2
C        ENDIF

        if(noth_1.eq.1)WRITE(12)J,I,FLAG,SCANKNT  !NOTE LOCATION WITH FLAG & LEAVE SUBR.
        IF (NOTH_1.EQ.1)TYPE *,' '
        IF (NOTH_1.EQ.1)TYPE *,' '
        IF (NOTH_1.EQ.1)TYPE *,' '
        IF (NOTH_1.EQ.1)TYPE *,'NOW IN TAKEDATA:','X=',J,' Y=',I,'   FLAG=',FLAG
        IF (NOTH_1.EQ.1)TYPE *,' '
```

```
        IF (NOTH_I.EQ.1)TYPE *,' '
        IF (NOTH_I.EQ.1)TYPE *,' '
        IF (NOTH_I.EQ.1)TYPE *,' '
C       ENDIF
C       WATCH_COUNT=0
        RETURN
      end
C
```

```
      SUBROUTINE PRESSURE(VOLTAGEL,VOLTAGEU)
C
C ****   PRESSURE=20*VOLTAGE ****  (PLOWER.LE.VOLTAGE.GE.PUPPER)
C
C       Adjust Z axis to get good pressure (PSI)
C          <<<  I1 = DOWN  >>>
C
C       PUPPER -- .85   !  Upper Pressure = 17
C       PLOWER = .75  !  Lower Pressure = 15
C       PUPPER = .3    !  UPPER PRESSURE = 6
C       PLOWER = .2   !  LOWER PRESSURE = 4
C       PUPPER = .5    !  UPPER PRESSURE = 10
C       PLOWER = .4   !  LOWER PRESSURE = 8
C       PLOWER = .5   !  LOWER PRESSURE = 10
C       PUPPER = .6    !  UPPER PRESSURE = 12
C       PLOWER = .7   !  LOWER PRESSURE = 14
C       PUPPER = .8    !  UPPER PRESSURE = 16
C       PLOWER = .6   !  LOWER PRESSURE = 12
C       PUPPER = .61   !  UPPER PRESSURE = 12.2
        PLOWER=VOLTAGEL
        PUPPER=VOLTAGEU
 200    CALL GETFLUKE( P )
        IF( P.GE.PLOWER .AND. P.LE.PUPPER )GOTO 900
        IF( P.LT.PLOWER )CALL MOVXYZ( 3, 1 )
        IF( P.GT.PUPPER )CALL MOVXYZ( 3, -1 )
        GOTO 200
 900  RETURN
        end
C
```

```
      SUBROUTINE PRESSURE_MAX(VOLTAGE_MAX,LLL,FILENAME,J,I,I15,CHECKP)
C
      CHARACTER FILENAME*34
      INTEGER*2 CHECKP,LLL,LINCR,I,J,JXXX,I15,ITTT
52    FORMAT(A2)
      P_MAX=VOLTAGE_MAX
200   CALL GETFLUKE( P )
      IF( P.GT.P_MAX)THEN
      CHECKP=CHECKP+1
      IF (CHECKP.EQ.1)LINCR=LLL/3
      IF (CHECKP.EQ.2)LINCR=LLL/2
      IF (CHECKP.EQ.3)LINCR=1000
      DO 2900 ITTT=1,LINCR
2900  CALL MOVXYZ( 3,-1 ) !3 IS Z-AXIS, MOVE Z-AXIS UP
      IF (CHECKP.EQ.3)THEN
      JXXX=I-1 !I IS Y-LOC; GO BACK TO PREVIOUS ROW
      WRITE(15,REC=I15,FMT=52)JXXX
      I15=I15+1
      STOP
      ENDIF
      ENDIF
900   RETURN
      end
C
```

```
      SUBROUTINE MOVORG( SCANAXIS, NSTEPS,VOLTAGEL,VOLTAGEU,
     1      LOOPTHRU_H)
C
C      Run the thing back to the SCANAXIS origin
C
        integer*4  SCANAXIS
        integer*2  NSTEPS,LOOPTHRU_H

C       DO 1000 K=1,LOOPTHRU_H
C 1000  CALL MOVXYZ( 3,-1 )      !  Move up
        DO 1200 K=1,NSTEPS-1
 1200  CALL MOVXYZ( SCANAXIS, -1 ) !  Move back
C       DO 1400 K=1,LOOPTHRU_H
C 1400  CALL MOVXYZ( 3, 1 )       !  Move down
C       CALL PRESSURE(VOLTAGEL,VOLTAGEU) !nothick
C       CALL MOVXYZ( SCANAXIS, -1 ) !  Move back & forth
C       CALL MOVXYZ( SCANAXIS, 1 )
        RETURN
        end

      SUBROUTINE MOVORGXY( ZIGANS,SCANAXIS,NSCAN,INDXAXIS,NINDX)
C
C      Run the thing back to the SCAN origin
C
        CHARACTER   ZIGANS*1
        integer*4  SCANAXIS,INDXAXIS
        integer*2  NSCAN,NINDX,I


        IF (ZIGANS.EQ.'Y')THEN
        I=Nindx

        IF (I.EQ.1.OR.I.EQ.3.OR.I.EQ.5.OR.I.EQ.7.OR.I.EQ.9
     1 .OR.I.EQ.11.OR.I.EQ.13.OR.I.EQ.15.OR.I.EQ.17.OR.I.
     1 EQ.19.OR.I.EQ.21.OR.I.EQ.23.OR.I.EQ.25.OR.I.EQ.27.OR.
     1 I.EQ.29.OR.I.EQ.31.OR.I.EQ.33.OR.I.EQ.35.OR.I.EQ.37.
     1 OR.I.EQ.39.OR.I.EQ.41.OR.I.EQ.43.OR.I.EQ.45.OR.I.EQ.
     1 47.OR.I.EQ.49.OR.I.EQ.51.OR.I.EQ.53.OR.I.EQ.55.OR.
     1 I.EQ.57.OR.I.EQ.59.OR.I.EQ.61.OR.I.EQ.63.OR.I.EQ.65
     1 .OR.I.EQ.67.OR.I.EQ.69.OR.I.EQ.71.OR.I.EQ.73.OR.I.
     1 EQ.75.OR.I.EQ.77.OR.I.EQ.79.OR.I.EQ.81.OR.I.EQ.83.OR
     1 .I.EQ.85.OR.I.EQ.87.OR.I.EQ.89.OR.I.EQ.91.OR.I.
     1 EQ.93.OR.I.EQ.95.OR.I.EQ.97.OR.I.EQ.99)THEN


        DO 1200 K=1,NSCAN-1
 1200  CALL MOVXYZ( SCANAXIS, -1 ) !  Move back X
        ENDIF
        ENDIF

        DO 1400 K=1,NINDX-1
 1400  CALL MOVXYZ( INDXAXIS, -1 ) !  Move back Y
```

```
      RETURN
      end

c
```

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```
      SUBROUTINE ENTERPARAM( SCANSTEP,INDXSTEP,NSCAN,NINDX,NAVE,VOLTAGEL
     1     ,VOLTAGEU,VOLTAGE_MAX,SHAPEANS,LOOPANS,LOOPTHRU_H,LOOPTHRU_S,
     1 ZIGANS,SCHEME,TSCHEME,UZEROO,FILENAME,I15,SCANMODE,SLANT1,SLANT2,
     1 SLANT3,SLANT4)
        integer*4  SCANSTEP,INDXSTEP
        real       SCANDIST, INDXDIST,PU,PL,SLANT,rslant1,RSLANT2,SLANT1,SLANT2
        REAL       SLANT3,SLANT4,RSLANT3,RSLANT4
        INTEGER*2  LOOPTHRU_H,LOOPTHRU_S,ISLANT1,ISLANT2
        integer*2  NSCAN,NINDX, IDIST1,IDIST2,I6,I15
        integer*2  FREQ,NAVE,ISLANT3,ISLANT4
        character  FILENAME*34, FILEEXT*23, CHEADER*32
        CHARACTER  LOOPANS*1,SCHEME*1
        CHARACTER  SHAPEANS*1,ZIGANS*1
        CHARACTER  TSCHEME*1,SCANMODE*1
        DATA I6/1/
        I15=1
10010   format( A )
10012   format( A2 )
10020   format( I )
10030   format( F )
C
C Initialization and entry of parameters
C
C
C
        TYPE *,' '
        TYPE *,' *****> DONSCAN.FOR.......AUTO SCAN'
        TYPE *,'  '
        OPEN (UNIT=10,FILE='NOTHICK_ALLSHAPE1.DAT',STATUS='OLD',
     1  FORM='FORMATTED')
        READ (10,93764) SCANMODE
        READ (10,93765) XSCANSTEP  !(X IND)
        IF (SCANMODE.EQ.'P')XSCANSTEP=2000.
        READ (10,93765) YINDXSTEP !(Y IND)
        IF (SCANMODE.EQ.'P')YINDXSTEP=2000.
        SCANSTEP=JNINT(XSCANSTEP)
        INDXSTEP=JNINT(YINDXSTEP)

        READ (10,93765) SCANDIST !(X DIST)

        IF (SCANMODE.EQ.'P')SCANDIST=2000.

        READ (10,93765) INDXDIST !(Y DIST)

        IF (SCANMODE.EQ.'P')INDXDIST=2000.
        IF (SCANMODE.EQ.'L')THEN
        YINDXSTEP=20000.
        INDXSTEP=JNINT(YINDXSTEP)
        INDXDIST=20000.
        ENDIF

        READ (10,93764) ZIGANS
        READ (10,93765) PL
```

```
      READ (10,93765) PU
      READ (10,93765) PM
      READ (10,93764) SHAPEANS
      READ (10,93764) LOOPANS
      READ (10,93766) LOOPTHRU_H
      READ (10,93766) LOOPTHRU_S
      READ (10,93764) TSCHEME
      READ (10,93765) UZEROO
C     READ (10,93765) THICKN
C      ************** "SLANT" IS THE NUMBER OF NANOSECONDS / MICRONS
C                     THAT THE ECHOES MOVE DUE TO NONLEVELNESS OF
C                     EXPERIMENT OR THICKNESS VARIATION. IT MUST BE
C                     INCORPORATED INTO THE PROGRAM AS AN ADDITIVE OR
C                     SUBTRACTIVE VALUE TO ALL THE DELAY TIMES BY FIRST
C                     MULTIPLYING "SLANT" BY THE CUMULATIVE INDEXING DISTANCE
C                     IN THE X-DIRECTION (N*XSCANSTEP) AS THE SCAN IS
C                     BEING PERFORMED AND THEN ADDING / SUBTRACTING THIS
C                     VALUE TO EACH DELAY. "SLANT" MUST BE DETERMINED
C                     BEFORE THE SCAN IS RUN BY MOVING THE X AND Y STAGES
C                     OVER THE SCAN LENGTH AND NOTING THE SHIFT TIME OF
C                     AN ECHO, SAY B1. THIS SHIFT WILL BE CONSISTENT FOR
C                     B1 AND B2 ECHOES IN MOST CASES BUT ANOTHER SLANT
C                     FACTOR WILL HAVE TO BE DEFINED FOR THE ECHO OFF THE
C                     REFLECTOR PLATE. SO WE HAVE SLANT 1 AND SLANT 2.

      READ (10,93765) SLANT1
      SLANT1=SLANT1/10.**9.
      RSLANT1=SLANT1*10.**13.      !CONVERT SLANT TO INTEGER FOR STORAGE IN
C                                                       .DATI2 FILE
      ISLANT1=IINT(RSLANT1)

      READ (10,93765) SLANT2
      SLANT2=SLANT2/10.**9.
      RSLANT2=SLANT2*10.**13.      !CONVERT SLANT TO INTEGER FOR STORAGE IN
C                                                       .DATI2 FILE
      ISLANT2=IINT(RSLANT2)

      READ (10,93765) SLANT3
      SLANT3=SLANT3/10.**9.
      RSLANT3=SLANT3*10.**13.      !CONVERT SLANT TO INTEGER FOR STORAGE IN
C                                                       .DATI2 FILE
      ISLANT3=IINT(RSLANT3)

      READ (10,93765) SLANT4
      SLANT4=SLANT4/10.**9.
      RSLANT4=SLANT4*10.**13.      !CONVERT SLANT TO INTEGER FOR STORAGE IN
C                                                       .DATI2 FILE
      ISLANT4=IINT(RSLANT4)

      READ (10,93765) FREQUENCY
      READ (10,93764) FILEEXT

            K=0
126         K=K+1
```

```
        IF( FILEEXT(K:K).NE.' ' )GOTO 126  !
        FILEEXT(K+1:K+4)='.DAT'                ! UNIT 6 = raw data

      READ (10,93764) CHEADER
93764 FORMAT (A)
93765 FORMAT (F)
93766 FORMAT (I)
C     VOLTAGEL=PL/20.
C     VOLTAGEU=PU/20.
C     VOLTAGE_MAX=PM/20.
C     TYPE *,'RUN TEMPDIRSCAN_COM – DIRSCAN SMALLTRANS_DATA.DAT'
      TYPE *,'DATA FOR ULTRASONIC SCAN (ALL FLOATING PT. EXCEPT INDEXES)'
      TYPE *,'SCAN DIMENSIONS/INDEXING DATA (MICRONS)'
      TYPE *,'X INDEX - INTEGER EXPRESSION'
      TYPE *,SCANSTEP
      TYPE *,'Y INDEX - INTEGER EXPRESSION'
      TYPE *,INDXSTEP
      TYPE *,' X SCAN DISTANCE (MICRONS) - FLOATING POINT'
      TYPE *,SCANDIST
      TYPE *,' X SCAN DISTANCE (MICRONS) - FLOATING POINT'
      TYPE *,INDXDIST
C     TYPE *,' LOWER & UPPER PRESSURES FOR CONTACT SCAN'
C     TYPE *,PL,PU
C     TYPE *,'THICKNESS (MM)'
C     TYPE *,THICKN
      TYPE *,'SLANT1 (X-LEVELNESS TIME CORRECTION FACTOR for b1,b2) (nsec / um )'
      TYPE *,SLANT1
      TYPE *,'SLANT2 (X-LEVELNESS TIME CORRECTION FACTOR for reflector echoes) (nsec / um )'
      TYPE *,SLANT2
      TYPE *,'SLANT3 (Y-LEVELNESS TIME CORRECTION FACTOR for b1,b2) (nsec / um )'
      TYPE *,SLANT3
      TYPE *,'SLANT4 (Y-LEVELNESS TIME CORRECTION FACTOR for reflector echoes) (nsec / um )'
      TYPE *,SLANT4
      TYPE *,'TRANSDUCER CENTER FREQUENCY (FLOATING POINT)'
      TYPE *,FREQUENCY
      TYPE *,'FILENAME FOR RAW DATA '
      TYPE *,FILEEXT
      TYPE *,'CHEADER INFO (UP TP 32 CHARACTERS)'
      TYPE *,CHEADER
      TYPE *,' '
 1000 NSCAN = (SCANDIST/SCANSTEP) + 1
      NINDX = (INDXDIST/INDXSTEP) – 1
      SCANDIST = SCANSTEP*(NSCAN-1)            ! SCANDIST = negative
      INDXDIST = INDXSTEP*(NINDX-1)
      IF (SCANMODE.EQ.'S')THEN
      WRITE( 5,11100 )SCANDIST, NSCAN, SCANSTEP,
   +     INDXDIST, NINDX, INDXSTEP
      ELSEIF (SCANMODE.EQ.'L')THEN
      WRITE( 5,11200 )SCANDIST, NSCAN, SCANSTEP
      ELSEIF (SCANMODE.EQ.'P')THEN
      WRITE( 5,11300 )
      ENDIF
11100 format( /' ',
   + //' X scan to ',F7.0,', ',I3,' steps of ',I5,
   + //' Y index to ',F7.0,', ',I3,' steps of ',I5)
```

```
11200  format( /' ',
   - //' Line scan to  ',F7.0,', ',I3,' steps of',I5)
11300  format( /' ', //' Point Measure repeated 2 times')
              SCHEME='B'
C             THICK= IINT(THICKN*1000.)
              FREQ=FREQUENCY
              NAVE=64
       FILENAME = '[ROTH.DATA]'//FILEEXT
       WRITE( 5,11690 )
11690  format( /'SNUMBER OF AVERAGES SET AT 64' )
C***************************************************************
C
C             DIRECT ACCESS STORAGE
C

      OPEN( unit=6, file=FILENAME//'CH', status='NEW',
     -      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=32,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=15, file=FILENAME//'I2', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=16, file=FILENAME//'R4', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=17, file=FILENAME//'WAV', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=26, file=FILENAME//'RR4', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=27, file=FILENAME//'RWAV', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=36, file=FILENAME//'SR4', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=37, file=FILENAME//'SWAV', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=46, file=FILENAME//'TR4', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=47, file=FILENAME//'TWAV', status='NEW',
     +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
51     FORMAT(A32)
52     FORMAT(A2)
53     FORMAT(A4)
54     FORMAT(A2)
C
C  Write header : X, Y dist, X, Y scan points, dummies
C
       WRITE(6,REC=I6,FMT=51 )CHEADER
       I6=I6+1
       WRITE(6,REC=I6,FMT=51 )SHAPEANS
```

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```
      I6=I6+1
      WRITE(6,REC=I6,FMT=51 )ZIGANS
      I6=I6+1
      IDIST1 = - IIFIX(SCANDIST/1000.)
      IDIST2 = IIFIX(INDXDIST/1000.)
      IF (IDIST2.LT.1)IDIST2=1 !TRICK TO ALLOW DISPLAY OF IMAGE ON PSIDD
    WRITE(15,REC=I15,FMT=52 )IDIST1
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)IDIST2
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)NSCAN
      I15=I15+1
      IF (SCANMODE.EQ.'L'.OR.SCANMODE.EQ.'P')NINDX=1 !MOD FOR LINE/POINT SCAN
      WRITE(15,REC=I15,FMT=52)NINDX
      I15=I15+1
C     WRITE(15,REC=I15,FMT=52)THICK
      WRITE(15,REC=I15,FMT=52)ISLANT1
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)ISLANT2
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)ISLANT3
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)ISLANT4
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)DENS
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)FREQ
      I15=I15+1
      WRITE(15,REC=I15,FMT=52)NAVE
      I15=I15+1
      RETURN
      end

   SUBROUTINE XPARAM( SCANSTEP,INDXSTEP,NSCAN,NINDX )
      integer*4 SCANSTEP,INDXSTEP
      integer*2 NSCAN,NINDX
      SCANSTEP = 50
      INDXSTEP = 50
      NSCAN   = 50
      NINDX   = 50
      THICK   = 1
      OPEN( unit=6, file='XXX.DAT', status='OLD',
   +   form='UNFORMATTED' )
      SCANSTEP = 50
      RETURN
   end

      SUBROUTINE MOVKLING (AXIS,DIST)
C
C     MOVE KLINGER A SPECIFIED DISTANCE IN SPECIFIED DIRECTION
C
      byte IXYZ
      character*1 XYZ
      equivalence( XYZ, IXYZ )
   common   WRK0,BUFFER
```

```
      CALL STRTGPIB
      CALL INITINSTR(2)
      CALL INITINSTR(3)
      CALL INITINSTR(4)
10010 format(A)
10020 format(I)
10100 format( /'SDistance ?' )
 100   WRITE( 5,10000 )
10000 format( /'$X, Y, or Z ?' )
      READ( 5,10010 )XYZ
      IF( IXYZ.GT.90. OR .IXYZ.LT.88 )GOTO 900
      IPORN=1
      WRITE( 5,10100 )
      READ( 5,10020 )IREQ
      IF( IREQ.LT.0 )THEN
        IPORN=-1
        IREQ=ABS(IREQ)
        ENDIF
      CALL SETXYZ( IREQ,IREQ,IREQ )
      IAXIS = IXYZ - 87
      CALL MOVXYZ( IAXIS,IPORN )
      GOTO 100
 900  STOP
      RETURN
      end

      INCLUDE '[ROTH.MENU]BASE0_2SEC_M.FOR'
```

```
C       nothick_crunch.for --- 4 SCAN METHOD

C       Crunch program for Nothickness velocity scan

C       Don Roth 20-sep-1994

        integer*2  SCANDIST,INDXDIST,NSCAN,NINDX,JJ,II,SCANKNT
        integer*2  DENS,TRFREQ,AVES,NPOINT,I6,I15,I16,I18,I26
        integer*2  ARRAYSIZE,KCOUNT,SELFREQ,ENDFREQ,I85,I36,I46
        INTEGER*2  islant1,islant2,ISLANT3,ISLANT4,ACTPOINT,JXXX
        integer*2  rawwaveb1(512),rawwaveb2(512),rawwavers(512),rawwaverns(512)
        INTEGER*4  I17,I7,REC,I27,I7SUB,I37,I47,I27SUB,I37SUB,I47SUB,I17SUB
        real*4 L_VEL,U_VEL,AV_VEL
        real*4     ASPECB1(1024), ASPECB2(1024)
        real*4     B1ASPEC(256), B2ASPEC(256)
        real*4     ASPECRS(1024), ASPECRNS(1024)
        real*4     RSASPEC(256), RNSASPEC(256)

        REAL*4 B1PHASE(256),PHASEB1(1024)
        REAL*4 B2PHASE(256),PHASEB2(1024)
        REAL*4 RSPHASE(256),PHASERS(1024)
        REAL*4 RNSPHASE(256),PHASERNS(1024)
        REAL*4 BB1(512),BB2(512),RRS(512),RRNS(512)
        REAL*4 VEL(5000),TRDIAM,BUFLENGTH
        character  FILENAME*32, FILEEXT*26, CHEADER*32,NOISANS*1
        character  FS1EXT*16,CALNAME*32,FLAG*1
        CHARACTER  DIFFANS*1,PHASE*1,PHASE1*1
        CHARACTER  SELFREQANS*1
        CHARACTER  SHAPEANS*1,ZIGANS*1,DIR*5
        CHARACTER  CRUNCH_CODE*2,CFILTER*1
        character  actual_selfreqans*1

        byte       FILEFS1IN
        equivalence ( B1ASPEC,ASPECB1 )          !-------------------!
        equivalence ( B2ASPEC,ASPECB2 )          !  *ASPEC  256      !
        equivalence ( RSASPEC,ASPECRS )          !-------------------!
        equivalence ( RNSASPEC,ASPECRNS )        !  *ASPEC  256      !
        EQUIVALENCE (B1PHASE,PHASEB1)            !-------------------!
        EQUIVALENCE (B2PHASE,PHASEB2)
        EQUIVALENCE (RSPHASE,PHASERS)            !-------------------!
        EQUIVALENCE (RNSPHASE,PHASERNS)
        equivalence ( FS1EXT, FILEFS1IN )

        DATA I6/1/I15/1/I16/1/I17/1/I7/1/I18/1/
        DATA I26/1/I27/1/I85/1/I36/1/I37/1/I46/1/I47/1/

        NIPI=0

10010   format(A)
10014   format(' ',A )
10020   format(I)
10030   format(F)
C
```

```
      OPEN (UNIT=14,FILE='NOTHICK_SELFREQ1.DAT',
    1 STATUS='OLD',FORM='FORMATTED')
      READ (14,98652) FILEEXT
      READ (14,98652) DRIVE
      READ (14,98652) PHASE
      READ (14,98652) PHASE1
      READ (14,98652) DIFFANS
      READ (14,10030) BUFLENGTH
      READ (14,10030) BUFVEL
      READ (14,10030) TRDIAM
      CLOSE (14)
98652 FORMAT (A)
C ********** OPEN FILTER FILE FOR UPPER & LOWER LIMITS ********** C

      OPEN (UNIT=24,FILE='NOTHICK_LIMITS1.DAT',
    1 STATUS='OLD',FORM='FORMATTED')
      READ (24,98652) CFILTER
      READ (24,10030) L_VEL
      READ (24,10030) U_VEL
      L_VEL=L_VEL
      U_VEL=U_VEL
      AV_VEL=(L_VEL+U_VEL)/2.

C *************************************************** C

            K=0
 126        K=K+1
            IF( FILEEXT(K:K).NE.' ' )GOTO 126  !
            FILEEXT(K+1:K+4)='.DAT'               ! UNIT 6 = raw data

      IF (DRIVE.EQ.'A')DIR='DUC2:'
      IF (DRIVE.EQ.'C')DIR='DUC0:'


      FILENAME = '[ROTH.DATA]'//FILEEXT
C****************************************************************
C           DIRECT ACCESS STORAGE
C
      OPEN( unit=76, file=DIR//FILENAME//'GB', status='NEW',
    +  ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
    +           form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=66, file=FILENAME//'CH', status='OLD',
    +  ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=32,
    +           form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=15, file=FILENAME//'I2', status='OLD',
    +  ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
    +           form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=16, file=FILENAME//'R4', status='OLD',
    +  ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
    +           form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
      OPEN( unit=17, file=FILENAME//'WAV', status='OLD',
    +  ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
```

```
     +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
        OPEN( unit=26, file=FILENAME//'RR4', status='OLD',
     +   ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
     +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
        OPEN( unit=27, file=FILENAME//'RWAV', status='OLD',
     +   ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
        OPEN( unit=36, file=FILENAME//'SR4', status='OLD',
     +   ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
     +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
        OPEN( unit=37, file=FILENAME//'SWAV', status='OLD',
     +   ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
        OPEN( unit=46, file=FILENAME//'TR4', status='OLD',
     +   ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
     +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
        OPEN( unit=47, file=FILENAME//'TWAV', status='OLD',
     +   ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
     +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )
C
51      FORMAT(A32)
52      FORMAT(A2)
53      FORMAT(A4)
153     FORMAT(1X,I4,1X,I4,1X,I4,1X,E12.5,1X,E12.5,1X,E12.5,1X,E12.5,1X,
     +  E12.5,1X,E12.5)
54      FORMAT(A2)
                K=0
 120            K=K+1
                IF( FILEEXT(K:K).NE.'.' )GOTO 120  !
                FILEEXT(K+1:K+3)='SPC'              ! UNIT 6 = raw data
        FILENAME = '[ROTH.DATA]'//FILEEXT    !
C
C**************UNIT=7,.SPC FILE FOR SPECTRA, vel, FOR DIRECT ACCESS********C
C
        OPEN( unit=7, file=DIR//FILENAME, status='NEW',ACCESS='DIRECT',
     +  RECORDTYPE='FIXED',RECL=4,FORM='FORMATTED',
     +          ORGANIZATION='SEQUENTIAL')

        WRITE( 6,10200 )FILENAME                ! UNIT 8 = calibration
10200   format( ' Filename of analyzed data is ',A )
        FILEEXT(K+1:K+3)='CAL'
        CALNAME = '[ROTH.DATA]'//FILEEXT
        OPEN( unit=8, file=CALNAME, status='NEW', ACCESS='DIRECT',
     +  RECORDTYPE='FIXED',RECL=4,FORM='FORMATTED',
     +   ORGANIZATION='SEQUENTIAL' )

89651   DO 76065 IOPI=1,1024
        PHASEB1(IOPI)=0.
        PHASEB2(IOPI)=0.
        PHASERS(IOPI)=0.
        PHASERNS(IOPI)=0.
        ASPECB1(IOPI)=0.
        ASPECB2(IOPI)=0.
        ASPECRS(IOPI)=0.
76065   ASPECRNS(IOPI)=0.
```

```
      KCOUNT=1

C  #### Read preliminary scan info ####
C
79193 READ(66,REC=I6,FMT=51)CHEADER
      I6=I6+1
      READ(66,REC=I6,FMT=51)SHAPEANS
      I6=I6+1
      READ(66,REC=I6,FMT=51)ZIGANS
      I6=I6+1

      IF (SHAPEANS.NE.'Y')GOTO 89714
      OPEN(UNIT=12,FILE='[ROTH.DATA]'//FILEEXT(1:K)//'DATHS',
    1 STATUS='OLD',FORM='UNFORMATTED') !INFO ON WHETHER WE ARE ON HOLDER/SAMPLE

89714 READ(15,REC=I15,FMT=52)SCANDIST
      I15=I15+1
      READ(15,REC=I15,FMT=52)INDXDIST
      I15=I15+1
      READ(15,REC=I15,FMT=52)NSCAN
      I15=I15+1
      READ(15,REC=I15,FMT=52)NINDX
      I15=I15+1
      READ(15,REC=I15,FMT=52)islant1
      I15=I15+1
      READ(15,REC=I15,FMT=52)islant2
      I15=I15+1
      READ(15,REC=I15,FMT=52)islant3
      I15=I15+1
      READ(15,REC=I15,FMT=52)islant4
      I15=I15+1
      READ(15,REC=I15,FMT=52)DENS
      I15=I15+1
      READ(15,REC=I15,FMT=52)TRFREQ
      I15=I15+1
      READ(15,REC=I15,FMT=52)AVES
      I15=I15+1
      READ(15,REC=I15,FMT=52)JXXX
      I15=I15+1
      ARRAYSIZE=(NSCAN)*(JXXX) !IF SCAN FINISHED PROPERLY,JXXX=NINDX

      READ(16,REC=I16,FMT=53)TIMESET
      I16=I16+1

    ENDFREQ=TRFREQ*2.5
      CALL POINT_FROM_FREQ(ENDFREQ,TIMESET,ACTPOINT)


      DELTAF  = 1./(TIMESET*20.)
      NPOINT=NSCAN*JXXX  !IF SCAN FINISHED PROPERLY, JXXX=NINDX
      NWAVES  = 3*NPOINT

C     !!! Loop thru scan data

      ITEM_COUNT=0
```

```
99651 DO 1890 NIP=1,NPOINT !!NPOINT IS TOTAL OF ALL POINTS
      SCANKNT=NIP
    ITEM_COUNT=ITEM_COUNT+1
      IF (SHAPEANS.EQ.'N'.AND.NIP.GE.2)ITEM_COUNT=2
      TYPE *,' '
      TYPE *,' ITEM_COUNT= ',ITEM_COUNT
      TYPE *,' CRUNCH_CODE= ',CRUNCH_CODE
      TYPE *,' '
      CCVACCUM=0.
67519 CONTINUE

      NIPJ=((NIP-1)/NSCAN)+1          !Y LOCATION
      NIPI=NIPI+1  !X LOCATION
      IF (NIPI.EQ.(NSCAN+1))NIPI=1  !RESET X LOCATION

C ***** MODIFICATION FOR ZIGZAG SCAN ******************************C
      IF (ZIGANS.EQ.'Y')THEN
      IF (NIPJ.EQ.2.OR.NIPJ.EQ.4.OR.NIPJ.EQ.6.OR.NIPJ.EQ.8.OR.NIPJ.EQ.10
   1 .OR.NIPJ.EQ.12.OR.NIPJ.EQ.14.OR.NIPJ.EQ.16.OR.NIPJ.EQ.18.OR.NIPJ.
   1 EQ.20.OR.NIPJ.EQ.22.OR.NIPJ.EQ.24.OR.NIPJ.EQ.26.OR.NIPJ.EQ.28.OR.
   1 NIPJ.EQ.30.OR.NIPJ.EQ.32.OR.NIPJ.EQ.34.OR.NIPJ.EQ.36.OR.NIPJ.EQ.38.
   1 OR.NIPJ.EQ.40.OR.NIPJ.EQ.42.OR.NIPJ.EQ.44.OR.NIPJ.EQ.46.OR.NIPJ.EQ.
   1 48.OR.NIPJ.EQ.50.OR.NIPJ.EQ.52.OR.NIPJ.EQ.54.OR.NIPJ.EQ.56.OR.
   1 NIPJ.EQ.58.OR.NIPJ.EQ.60.OR.NIPJ.EQ.62.OR.NIPJ.EQ.64.OR.NIPJ.EQ.66
   1 .OR.NIPJ.EQ.68.OR.NIPJ.EQ.70.OR.NIPJ.EQ.72.OR.NIPJ.EQ.74.OR.NIPJ.
   1 EQ.76.OR.NIPJ.EQ.78.OR.NIPJ.EQ.80.OR.NIPJ.EQ.82.OR.NIPJ.EQ.84.OR
   1 .NIPJ.EQ.86.OR.NIPJ.EQ.88.OR.NIPJ.EQ.90.OR.NIPJ.EQ.92.OR.NIPJ.
   1 EQ.94.OR.NIPJ.EQ.96.OR.NIPJ.EQ.98.OR.NIPJ.EQ.100)THEN
    NIPG=NSCAN-NIPI+1  !FOR ZIGZAG SCAN, REVERSE BACK FOR DISPLAY
      ELSE
      NIPG=NIPI
      ENDIF
      elseif(zigans.eq.'N')then !george wood addition
      nipg=nipi  !George Wood addition
      ENDIF

      TYPE *,' '
      TYPE *,' '

      IF (SHAPEANS.EQ.'N')GOTO 89715
      READ(12)JJ,II,FLAG,SCANKNT  !READ WHETHER 'H' OR 'S'

      TYPE *,'X=',NIPG,' Y=',NIPJ,' FLAG= ',FLAG


      IF (FLAG.EQ.'S')THEN

89715 READ(16,REC=I16,FMT=53)DELAYB1
      I16=I16+1
      READ(16,REC=I16,FMT=53)VOLTSETB1
      I16=I16+1
      READ(26,REC=I26,FMT=53)DELAYB2
      I26=I26+1
      READ(26,REC=I26,FMT=53)VOLTSETB2
      I26=I26+1
```

```
        READ(36,REC=I36,FMT=53)DELAYRS
        I36=I36+1
        READ(36,REC=I36,FMT=53)VOLTSETRS
        I36=I36+1
        READ(46,REC=I46,FMT=53)DELAYRNS
        I46=I46+1
        READ(46,REC=I46,FMT=53)VOLTSETRNS
        I46=I46+1
        DO 54322 IJI=1,512
54322   READ(17,REC=((I17-1)*512)+IJI,FMT=54)RAWWAVEB1(IJI)
        I17=I17+1
        DO 54323 IJI=1,512
54323   READ(27,REC=((I27-1)*512)+IJI,FMT=54)RAWWAVEB2(IJI)
        I27=I27+1
        DO 54324 IJI=1,512
54324   READ(37,REC=((I37-1)*512)+IJI,FMT=54)RAWWAVERS(IJI)
        I37=I37+1

        DO 54325 IJI=1,512
54325   READ(47,REC=((I47-1)*512)+IJI,FMT=54)RAWWAVERNS(IJI)
        I47=I47+1

        ELSEIF (FLAG.EQ.'H')THEN
        GOTO 1890
        ENDIF


        II=II+1
        A = 0.
         DO 1400 I=1,512
         RAWWAVEB1(I)=RAWWAVEB1(I)/AVES
1400    A=A + RAWWAVEB1(I)
        ZERO = A/512.
         DO 1560 I=1,512
1560     BB1(I) = ( REAL(RAWWAVEB1(I)) - ZERO )*( VOLTSETB1 )*10./512.

        II=II+1
        A = 0.
         DO 1401 I=1,512
         RAWWAVEB2(I)=RAWWAVEB2(I)/AVES
1401    A=A + RAWWAVEB2(I)
        ZERO = A/512.
         DO 1570 I=1,512
1570     BB2(I) = ( REAL(RAWWAVEB2(I)) - ZERO )*( VOLTSETB2 )*10./512.

        II=II+1
        A = 0.
        DO 1402 I=1,512
        RAWWAVERS(I)=RAWWAVERS(I)/AVES
1402    A=A + RAWWAVERS(I)
        ZERO = A/512.
         DO 1580 I=1,512
1580     RRS(I) = ( REAL(RAWWAVERS(I)) - ZERO )*( VOLTSETRS )*10./512.

        II=II+1
```

```
       A = 0.
        DO 1403 I=1,512
        RAWWAVERNS(I)=RAWWAVERNS(I)/AVES
1403   A=A + RAWWAVERNS(I)
       ZERO = A/512.
        DO 1590 I=1,512
1590    RRNS(I) = ( REAL(RAWWAVERNS(I)) - ZERO )*( VOLTSETRNS )*10./512.

       IF (PHASE.EQ.'N')THEN
       CALL CORR(BB1,BB2,TWOTAU_DELAY)  !for time delay in sample
       ELSEIF (PHASE.EQ.'Y')THEN  !PHASE INVERSION FOR BETWEEN B1 & B2
       CALL MCORR(BB1,BB2,TWOTAU_DELAY)  !for time delay in sample
       ENDIF

       IF (PHASE1.EQ.'N')THEN
       CALL CORR(RRS,RRNS,DELTAT_DELAY) !for delay between reflector peaks
C                                        (sample vs. no sample)
       ELSEIF (PHASE1.EQ.'Y')THEN  !PHASE INVERSION FOR BETWEEN RN & RNS
       CALL MCORR(RRS,RRNS,DELTAT_DELAY) !for delay between reflector peaks
       ENDIF


       CALL OBTAIN_MAGNITUDE_SPECTRA(BB1,ASPECB1)
       CALL OBTAIN_MAGNITUDE_SPECTRA(BB2,ASPECB2)
       CALL OBTAIN_MAGNITUDE_SPECTRA(RRS,ASPECRS)
       CALL OBTAIN_MAGNITUDE_SPECTRA(RRNS,ASPECRNS)

       ADELAYS = DELAYB2 - DELAYB1
       ADELAYR = DELAYRNS - DELAYRS


       TWOTAU=ADELAYS+(TIMESET/51.2)*TWOTAU_DELAY !for time delay in sample
       DELTAT=ADELAYR+(TIMESET/51.2)*DELTAT_DELAY !for delay between
C                   reflector peaKS (sample vs. no sample)


       CALL NOTHICK_VEL_CALC(DELTAT,TWOTAU,VEL_NOTHICK)
       type *,'vel_nothick= ',vel_nothick


       CALL FILTER(VEL_NOTHICK,VELPREV,CFILTER,SHAPEANS,L_VEL,U_VEL,
  1                        AV_VEL,NIPG,NIPJ,SCANKNT,I18)

     VEL(SCANKNT)=VEL_NOTHICK


       VELPREV=VEL_NOTHICK

       CALL STORE_SPECTRA(ASPECB1,ACTPOINT,I7,I7SUB)   !STORE SPECTRAS AT EACH SCAN
POINT
       CALL STORE_SPECTRA(ASPECB2,ACTPOINT,I7,I7SUB)
       CALL STORE_SPECTRA(ASPECRS,ACTPOINT,I7,I7SUB)
       CALL STORE_SPECTRA(ASPECRNS,ACTPOINT,I7,I7SUB)
```

```
1890    CONTINUE

        IF (SHAPEANS.EQ.'N')SCANKNT=NPOINT
        CALL STORE_VEL(I7SUB,I85,SCANKNT,ACTPOINT,VEL)  !STORE VELOCITIES AT END OF
.SPC FILE

        END


        SUBROUTINE STORE_VEL(I7SUB,I85,NPOINT,ACTPOINT,VEL)

C       !! STORE VELOCITIES AND FIND MAX,MIN & STORE IN CAL FILE

        INTEGER*2 NPOINT,I85,ACTPOINT
        INTEGER*4 I7SUB
        REAL*4 VEL(5000)

        VUP=0.0
        VLO=10.**8.
        VACCUM=0.

        I7SUB=I7SUB+1
        DO 94326 IJI=1,NPOINT

        VMAX=AMAX1(VUP,VEL(IJI))
        VUP=VMAX
        VMIN=AMIN1(VLO,VEL(IJI))
        VLO=VMIN
        VACCUM=VACCUM+VEL(IJI)

        WRITE(7,REC=I7SUB,FMT=53)VEL(IJI)
94326   I7SUB=I7SUB+1
53      FORMAT(A4)

        VAVE=VACCUM/NPOINT

        WRITE(8,REC=I85,FMT=53)VUP
        I85=I85+1
        WRITE(8,REC=I85,FMT=53)VLO
        I85=I85+1
        WRITE(8,REC=I85,FMT=53)VAVE


        RETURN
        END


        SUBROUTINE POINT_FROM_FREQ(FREQ,TIMEPERDIV,ACTPOINT)
C
C       DETERMINE SPECTRA POINT FROM FROM SPECIFIC FREQUENCY IN SPECTRA
C
C       SEE SUBROUTINE CENTERFREQ FOR SIMILAR PROCESSING EXPLANATION
C
        INTEGER*4 DUMMYFREQ
```

```
      INTEGER*2 FREQ,ACTPOINT
      REAL*4          TIMEPERDIV,DELFREQ,TEMPPOINT
C
C
      DUMMYFREQ=FREQ*1E+06
      DELFREQ=(1./(2.*(10.*TIMEPERDIV)))
      TEMPPOINT=DUMMYFREQ/DELFREQ
      ACTPOINT=JNINT(TEMPPOINT)
C
      RETURN
      END

      SUBROUTINE OBTAIN_MAGNITUDE_SPECTRA(TWAVE,DUMMY_ASPEC)
      COMPLEX       C1(1024),CSPEC(1024)
      INTEGER*4     ISTAT
      real*4     DUMMY_ASPEC(1024),PHASE(1024),TWAVE(512)


       DO 500 I=1,512
500   C1(I)=CMPLX(TWAVE(I))
1580  CALL LSPSFFT_COMPLEX( C1, CSPEC, 1024,0,ISTAT )
      CALL LSP$PHASE_ANGLE( CSPEC, PHASE, DUMMY_ASPEC, 1024 )

      RETURN
      END

      SUBROUTINE STORE_SPECTRA(DUMMY_ASPEC,ACTPOINT,I7,I7SUB)

      INTEGER*2  ACTPOINT
      INTEGER*4  REC,I7,I7SUB
      REAL*4              DUMMY_ASPEC(1024)


      DO 94326 IJI=1,ACTPOINT
      I7SUB=((I7-1)*ACTPOINT)+IJI
94326 WRITE(7,REC=I7SUB,FMT=53)DUMMY_ASPEC(IJI)
      I7=I7+1
53    FORMAT(A4)

      RETURN
      END

      SUBROUTINE FILTER(VEL_NOTHICK,VELPREV,CFILTER,SHAPEANS,L_VEL,U_VEL,
  1                  AV_VEL,NIPG,NIPJ,SCANKNT,I18)

      CHARACTER CFILTER*1,CRUNCH_CODE*2,SHAPEANS*1
      INTEGER*2  NIPG,NIPJ,I18,SCANKNT
      REAL*4 L_VEL,U_VEL,AV_VEL
C ******** TEST FOR VELOCITY OUTSIDE FILTER LIMITS ***** C

      IF (SCANKNT.EQ.1)VELPREV=AV_VEL

      IF (CFILTER.EQ.'Y'.AND.(VEL_nothick.LT.L_VEL.OR.VEL_nothick.GT.U_VEL))THEN
      VEL_NOTHICK=VELPREV
      CRUNCH_CODE='BC'
```

```
        ICRUNCH_CODE_COUNT=1
        TYPE *,'BAD POINT AT ',NIPG,NIPJ
        ENDIF

        IF (ICRUNCH_CODE_COUNT.EQ.0)CRUNCH_CODE='G'
        WRITE(76,REC=I18,FMT=53)CRUNCH_CODE
        I18=I18+1
        WRITE(76,REC=I18,FMT=53)NIPG
        I18=I18+1
        WRITE(76,REC=I18,FMT=53)NIPJ
        I18=I18+1

53      FORMAT(A4)

        RETURN
        END

        SUBROUTINE NOTHICK_VEL_CALC(DELTAT,TWOTAU,VEL_NOTHICK)

        VELWATER=0.149  !CM/USEC

        VEL_NOTHICK=VELWATER*((DELTAT/TWOTAU)+1)
        RETURN
        END


        SUBROUTINE CORR(B1,B2,CXX)
C        CORRRELATE TWO WAVEFORMS
        COMPLEX*8 NC11(512),NC12(512),NC13(512)
        COMPLEX*8 NC14(512),NC15(512),NC22(512)
        REAL*4 NC16(512),B1(512),B2(512),CXX
        INTEGER*4 STATUS

        DO 333 I=1,512
        NC11(I)=CMPLX(B1(I))
        NC22(I)=CMPLX(B2(I))
333     CONTINUE

        CALL LSP$FFT_COMPLEX(NC11,NC12,512,0,STATUS)
        CALL LSP$FFT_COMPLEX(NC22,NC13,512,0,STATUS)

        DO 777 IO=1,512
        NC14(IO)=NC12(IO)*CONJG(NC13(IO))
777     CONTINUE
        CALL LSP$FFT_COMPLEX(NC14,NC15,512,0,STATUS)
        IF (.NOT. STATUS) CALL LIB$SIGNAL(%VAL(STATUS))

        AMAX=0.0
        CXX=0.0

        DO 765 I=1,256
        NC16(I+256)=REAL(NC15(I))
        NC16(I)=REAL(NC15(I+256))
765     CONTINUE
```

```
      DO 881 I=1,512
      IF(NC16(I).GT.AMAX)THEN
      AMAX=NC16(I)
      CXX=I
      ENDIF
881   CONTINUE
      CXX=CXX-257.
      RETURN
      END

      SUBROUTINE MCORR(B1,B2,CXX)
C     CORRRELATE TWO WAVEFORMS  !!! modified by using absolute value
C                                of minimum of correlation function
C                                   to take into account phase inversion
C                                   of B2 w/ respect to B1 such as what
C                                   happens w/ PMCs
      COMPLEX*8 NC11(512),NC12(512),NC13(512)
      COMPLEX*8 NC14(512),NC15(512),NC22(512)
      REAL*4 NC16(512),B1(512),B2(512),CXX
      INTEGER*4 STATUS

      DO 333 I=1,512
      NC11(I)=CMPLX(B1(I))
      NC22(I)=CMPLX(B2(I))
333   CONTINUE

      CALL LSP$FFT_COMPLEX(NC11,NC12,512,0,STATUS)
      CALL LSP$FFT_COMPLEX(NC22,NC13,512,0,STATUS)

      DO 777 IO=1,512
      NC14(IO)=NC12(IO)*CONJG(NC13(IO))
777   CONTINUE
      CALL LSP$FFT_COMPLEX(NC14,NC15,512,0,STATUS)
      IF (.NOT. STATUS) CALL LIB$SIGNAL(%VAL(STATUS))

      AMAX=0.0
      AMIN=1.0E+6
      CXX=0.0
      DXX=0.0

      DO 765 I=1,256
      NC16(I+256)=REAL(NC15(I))
      NC16(I)=REAL(NC15(I+256))
765   CONTINUE
      DO 881 I=1,512

C     IF(NC16(I).GT.AMAX)THEN
C     AMAX=NC16(I)
C     CXX=I
C     ENDIF

C     CORRRELATE TWO WAVEFORMS  !!! modified by using absolute value
C                                of minimum of correlation function
```

```
C                                  to take into account phase inversion
C                                  of B2 w/ respect to B1 such as what
C                                  happens w/ PMCs

      IF(NC16(I).LT.AMIN)THEN
      AMIN=NC16(I)
      DXX=I
      ENDIF

881   CONTINUE

      CXX=DXX

      CXX=CXX-257.
      RETURN
      END
```

```
CC      PROGRAM:  NOTHICK_IMAGEMAKER.FOR
C
C   Read Data file written by CRUNCH and place data into
C   "Grinnell-ready" files
C
C   Header:   X3, Y3   Dimension of scan ( SCAN DIRECTION, INDEX DIRECTION )
C            N1, N2   Number of points ( SCAN, INDEX )
C

        INTEGER*2       ACTPOINT
        BYTE            BFILEEXT(23)
        CHARACTER       FILENAME*44,FILEEXT*23,DRIVE*1
        CHARACTER       CALNAME*44,SELFREQANS*1,SHAPEANS*1,DISKT*5
        CHARACTER       HEAD*23,DIR*16
        EQUIVALENCE             ( FILEEXT, BFILEEXT )

        JMARK=0
        I85=1

        OPEN (UNIT=10,FILE='NOTHICK_DADQ1.DAT',STATUS='OLD',
     1  FORM='FORMATTED')
        READ (10,34572) FILEEXT
        READ (10,34572) DRIVE
34572   FORMAT (A)

4321    CONTINUE

        HEAD=FILEEXT

        IF (DRIVE.EQ.'A')DIR='DUC2:[ROTH.IMAG]'
        IF (DRIVE.EQ.'A')DISKT='DUC2:'
        IF (DRIVE.EQ.'C')DIR='DUC0:[ROTH.IMAG]'
        IF (DRIVE.EQ.'C')DISKT='DUC0:'

        ICHA=0
        DO I=1,LEN(FILEEXT)
        IF (ICHA.NE.0) GOTO 98564
        IF (BFILEEXT(I).EQ.32) THEN
        ICHA=I
        FILEEXT(ICHA:ICHA+4)='.SPC'
        ENDIF
98564   END DO

        FILENAME = '[ROTH.DATA]'//FILEEXT

        K=0
20      K=K+1
        IF (FILEEXT(K:K).NE.'.') GOTO 20
        FILEEXT(K+1:K+3) = 'CAL'

        CALNAME = '[ROTH.DATA]'//FILEEXT

        CALL DONDISP1S (ICHA,FILENAME,CALNAME,HEAD,DIR,DISKT,
     1  SHAPEANS,SELFREQANS,ACTPOINT)
```

```
      CLOSE(10)
      END


      SUBROUTINE DONDISP1S (ICHA,FILENAME,CALNAME,HEAD,DIR,DISKT,
     1 SHAPEANS,SELFREQANS,ACTPOINT)
C
C
C  Read Data file written by CRUNCH and write values to Grinnell
C      -UNCORRECTED & CORRECTED DATA IS DISPLAYED---
C
C  Header:  X3, Y3    Dimension of scan ( SCAN, INDEX )
C           N1, N2    Number of points ( SCAN, INDEX )
C
C
      INTEGER*4 REC,SCANPOS,XXX
      INTEGER*2 IXLENGTH_A,IXLENGTH,ACTPOINT
      INTEGER*2 X3,Y3,Y87,N1,N2,NNNNN2,NNNNN1
      INTEGER*2 DENS,NFREQ,AVES,X4,Y4,I87
      INTEGER*2 COUNT,NCOUNT,NSCAN,NINDX
      INTEGER*2 C(1024),D(460)
      INTEGER*2 SCANDIST,INDXDIST,TRFREQ,ENDFREQ,I16
      INTEGER*2 D_SHAPE(460),I89,I6,I15
      INTEGER*2 ISLANT1,ISLANT2,ISLANT3,ISLANT4,JXXX,IABC,JABC,SCANKNT
      INTEGER*2 PSEUDOGRNL(460,1024),SELFREQ
      REAL      FREQ, MEAN
      REAL      RNUP(7),RNLO(7),CBUFFER(81)
      BYTE      BSCALEMARK(4),CHFREQ(3)
      BYTE      BSUFFREQ
      BYTE      BFILENAME(44),BNAMELAB(20),BDATA_STATUS(40)
      CHARACTER FILENAME*44,FILEEXT*23,SELFREQANS*1,FFLAG*1
      CHARACTER CALNAME*44, CHEADER*32,SHAPEANS*1,ZIGANS*1
      CHARACTER NAMELAB*20,DATA_STATUS*40,NEWHEADER*35,ACTUAL_SELFREQANS*1
      CHARACTER CORNAME*15,CHFREQ_C*3,PHASE*1,PHASE1*1
      CHARACTER SCALEMARK*4,SUFFREQ*4,HEAD*23,DIR*16,DISKT*5

      EQUIVALENCE ( CHFREQ, CHFREQ_C )
      EQUIVALENCE ( BNAMELAB, NAMELAB )
      EQUIVALENCE ( BDATA_STATUS, DATA_STATUS )
      EQUIVALENCE ( BSCALEMARK, SCALEMARK )
      EQUIVALENCE ( BSUFFREQ, SUFFREQ )

      SCALEMARK='1 MM'
      SUFFREQ=' MHZ'
C
C     TAKE CHARACTER "FILENAME" AND DECODE TO BYTE "BFILENAME"
C

      DECODE (44,533,FILENAME) BFILENAME
533   FORMAT(44A1)


C
```

42

```
C       DETERMINE SHORTENED (-.SPC) FILENAME POSITION
C
        I6=1
        I15=1
        I16=1

        KMARK=0
        DO 4321 IPR=12,44
        IF (KMARK.EQ.1) GOTO 4321
        IF (BFILENAME(IPR).EQ.46) THEN        !PERIOD/DOT IS ASCII 46
        IEND=IPR
        KMARK=1
        ENDIF
4321    CONTINUE


34572   FORMAT (A)
34573   FORMAT (I)
51      FORMAT(A32)
52      FORMAT(A2)
53      FORMAT(A4)


        OPEN( unit=15, file=FILENAME(1:IEND-1)//'.datI2', status='OLD',
   +     ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
   +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )

        OPEN( unit=16, file=FILENAME(1:IEND-1)//'.datR4', status='OLD',
   +     ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
   +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )

C       OPEN( unit=26, file=FILENAME(1:IEND-1)//'.datRR4', status='OLD',
C  +      ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=4,
C  +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )

        OPEN( unit=66, file=FILENAME(1:IEND-1)//'.datCH', status='OLD',
   +     ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=32,
   +          form='FORMATTED',ORGANIZATION='SEQUENTIAL' )


C**************UNIT=7,.SPC FILE FOR SPECTRA, vel, FOR DIRECT ACCESS********C
C
C       OPEN( unit=7, file=FILENAME, status='OLD',ACCESS='DIRECT',
C  -      RECORDTYPE='FIXED',RECL=4,FORM='FORMATTED',
C  +          ORGANIZATION='SEQUENTIAL')

        OPEN (UNIT=14,FILE='NOTHICK_SELFREQ1.DAT',
   1    STATUS='OLD',FORM='FORMATTED')


79193   READ(66,REC=I6,FMT=51)CHEADER
        I6=I6+1
        READ(66,REC=I6,FMT=51)SHAPEANS
        I6=I6+1
```

```
        READ(66,REC=I6,FMT=51)ZIGANS
        I6=I6+1


        READ (14,98652) FILEEXT
        READ (14,98652) DRIVE
        READ (14,98652) PHASE
        READ (14,98652) PHASE1
        READ (14,98652) DIFFANS
        READ (14,10030) BUFLENGTH
        READ (14,10030) BUFVEL
        READ (14,10030) TRDIAM
        CLOSE (14)
98652   FORMAT (A)
10020   FORMAT (I)
10030   FORMAT (F)

89714   READ(15,REC=I15,FMT=52)SCANDIST
        I15=I15+1
        READ(15,REC=I15,FMT=52)INDXDIST
        I15=I15+1
        READ(15,REC=I15,FMT=52)NSCAN
        I15=I15+1
        READ(15,REC=I15,FMT=52)NINDX
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant1
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant2
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant3
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant4
        I15=I15+1
        READ(15,REC=I15,FMT=52)DENS
        I15=I15+1
        READ(15,REC=I15,FMT=52)TRFREQ
        I15=I15+1
        READ(15,REC=I15,FMT=52)AVES
        I15=I15+1
        READ(15,REC=I15,FMT=52)JXXX
        I15=I15+1
C       ARRAYSIZE=(NSCAN)*(JXXX) !IF SCAN FINISHED PROPERLY,JXXX=NINDX


        ENCODE (3,19878,CHFREQ) TRFREQ   !ANALYSIS FREQUENCY
19878   FORMAT (I3)

        READ(16,REC=I16,FMT=53)TIMESET
        I16=I16+1

        ENDFREQ=2.5*TRFREQ
        CALL POINT_FROM_FREQ(ENDFREQ,TIMESET,ACTPOINT)
```

```
      DO 9999 ICHOICE=1,1
      I87=1

      ACCUM=0.
      NBAD=0
            IF (ICHOICE.EQ.1) THEN
                  NAMELAB='VELOCITY  CM/US'
                  CORNAME='_VEL_C_'//CHFREQ_C
            NEWHEADER='CORRECTED DATA FOR VELOCITY'
                  NEWU=25
                  NEWU1=45
                  NEWU2=69
            ENDIF

      OPEN (UNIT=NEWU1,FILE=DISKT//FILENAME(1:IEND-1)//CORNAME//
    + '.CORHEADER',STATUS='NEW',FORM='UNFORMATTED')

12345 IF (JMARK.EQ.1) GOTO 90  !FILES ARE ALREADY OPEN

30    CONTINUE

90    CONTINUE

      IF (JMARK.EQ.1) GOTO 89306

10149 CONTINUE

      IF (SHAPEANS.NE.'Y')GOTO 89317
      OPEN(UNIT=52,FILE=FILENAME(1:ICHA+10)//'.DATHS',
    1 STATUS='OLD',FORM='UNFORMATTED') !INFO ON WHETHER WE ARE ON HOLDER/SAMPLE

89317 SCANDIST=ABS(SCANDIST)
      AD=NSCAN
      XREAL = REAL(ABS(SCANDIST))
      YREAL = REAL(INDXDIST)
      NPTS = NSCAN*JXXX !!!!IF SCAN COMPLETED PROPERLY, JXXX=NINDX

      IF (SHAPEANS.EQ.'Y')THEN
      DO 5697 I=1,NPTS
5697  READ(UNIT=52, END=89318)IABC,JABC,FFLAG,SCANKNT
      ENDIF

89318 PTS  = REAL(NSCAN)*REAL(JXXX)
      X3=ABS(SCANDIST)
      Y3=INDXDIST
      N1=NSCAN
      N2=JXXX
      IF (I.EQ.1) THEN
      NNNNN1=N1
      NNNNN2=N2
      ENDIF
```

```
      XREAL = REAL(ABS(X3))
      YREAL = REAL(Y3)
      FREQ  = REAL(NFREQ)
      PTS   = REAL(N1)*REAL(N2)

C
C  Proportion GRINNELL window similar to scan dimensions
C

 200  Y87 = ININT( REAL(Y3)*8./7. )
      IF( Y87.GE.X3 )THEN
              R1 = FLOAT(X3)/FLOAT(Y3)
              X4 = 400
              Y4 = ININT(400./R1)
              IF (Y4.GE.480)THEN
              X4=300
              Y4 = ININT(300./R1)
              ENDIF
              IF (Y4.GE.480)THEN
              X4=200
              Y4 = ININT(200./R1)
              ENDIF
              IF (Y4.GE.480)THEN
              X4=100
              Y4 = ININT(100./R1)
              ENDIF
           IF (Y4.GE.480)THEN
              X4=50
              Y4 = ININT(50./R1)
              ENDIF
           IF (Y4.GE.480)THEN
              X4=25
              Y4 = ININT(25./R1)
              ENDIF
        IF (Y4.GE.480)THEN
              X4=10
              Y4 = ININT(10./R1)
              ENDIF
           ELSEIF( Y87.LT.X3 ) THEN
              R1 = FLOAT(Y3) / FLOAT(X3)
              Y4 = IFIX( 400.*R1 )
          X4 = 400
              IF (Y4.GE.480)THEN
              X4=300
              Y4 = ININT(300.*R1)
              ENDIF
              IF (Y4.GE.480)THEN
              X4=200
              Y4 = ININT(200.*R1)
              ENDIF
              IF (Y4.GE.480)THEN
              X4=100
              Y4 = ININT(100.*R1)
              ENDIF
           IF (Y4.GE.480)THEN
```

```
                  X4=50
                  Y4 = ININT(50.*R1)
                  ENDIF
              IF (Y4.GE.480)THEN
                  X4=25
                  Y4 = ININT(25.*R1)
                  ENDIF
          IF (Y4.GE.480)THEN
                  X4=10
                  Y4 = ININT(10.*R1)
                  ENDIF
      ENDIF

CC

        XD2G = REAL(N1)/REAL(X4)
        YD2G = REAL(N2)/REAL(Y4)

        XD2X = REAL(X4)/REAL(N1)
        YD2Y = REAL(Y4)/REAL(N2)

        I_INT=JINT(XD2X)-1
        J_INT=JINT(YD2Y)+1


89306   CONTINUE

10300   format( //'$Enter choice :')

54322   FORMAT (A)
4319    FORMAT ('+','VALUE=',F)

        TYPE *,' '
        TYPE *,'Working...'
        TYPE *,' '

43191   FORMAT ('+','BAD PTS/TOT. PTS:',I5,'/',I4,
  +            ' CURRENT VALUE= ',F11.2)
7493    FORMAT (F11.2)
7494    FORMAT(I)


C
C       RETURN MAX/MIN OF DATA FOR GRINNELL DISPLAY & PRODUCE LINE
C       OF GRINNELL DATA (CBUFFER)

        CALL RETMAXMIN_FILTER (FILENAME,CORNAME,CALNAME,NAMELAB,DISKT,IEND,JXXX,
  1
NSCAN,SCANKNT,SHAPEANS,ZIGANS,ICHOICE,TIMESET,I89,COUNT,ACTPOINT,NEWU,GRBOT,
  1     GRTOP,MEAN)

7487    COUNT=NCOUNT
        RMIN=GRBOT
        RMAX=GRTOP
        I87=1
```

```
        RNLO(ICHOICE)=RMIN
        RNUP(ICHOICE)=RMAX

        DO 500 KI=1,JXXX
        DO 49721 JI=1,NSCAN
        NIPI=JI
        NIPJ=KI
        SCANPOS=((NIPJ-1)*NSCAN)+NIPI
        I87=SCANPOS
        READ (NEWU,REC=I87,FMT=53) CBUFFER(JI)
49721   I87=I87+1
462     FORMAT (F11.2)
        CALL SCGREAL (CBUFFER, C, N1,GRBOT,GRTOP,MEAN) !GREY SCALED
        DATA_STATUS='CORRECTED DATA FOR '//NAMELAB
C
C       INTERPOLATE DATA GRID (EX.81X81) FOR X4 x Y4 GRINNELL DISPLAY
C
        CALL INTR ( C,D,NSCAN,X4 )

C       IF (KI.EQ.20)TYPE *,'D=',D

C ********** MOD TO GET RID OF FALSE BORDER ***************** C
        IF (SHAPEANS.EQ.'Y')THEN

        IIXCOUNT=0
        DO 555 IOP=1,X4  !FORWARD X-DIRECTION
        IF (D(IOP).EQ.1)GOTO 555
        IIXCOUNT=IIXCOUNT+1
         IF (IIXCOUNT.EQ.1)THEN
         DO 655 IJQ=1,I_INT
655      D(IOP+IJQ-1)=1
         ENDIF
555     CONTINUE

        IIXCOUNT=0
        DO 755 IOP=X4,1,-1  !BACKWARD X-DIRECTION
        IF (D(IOP).EQ.1)GOTO 755
        IIXCOUNT=IIXCOUNT+1
         IF (IIXCOUNT.EQ.1)THEN
         DO 855 IJQ=1,I_INT
855      D(IOP-IJQ+1)=1
         ENDIF
755     CONTINUE

C       IF (KI.EQ.20)TYPE *,'D=',D

        ENDIF

C ********** MOD TO GET RID OF FALSE BORDER ********** C

         DO 480 J= 1, X4
 480    PSEUDOGRNL( J,NIPJ ) = D( J )
500     CONTINUE
```

```
CC

        OPEN (UNIT=NEWU2, FILE=DIR//HEAD//CORNAME//'.PDK',STATUS='NEW',
   +            FORM='UNFORMATTED')

        WRITE(NEWU2) X4,Y4,N1,N2,ICHOICE
        WRITE(NEWU2) SCANDIST,TRFREQ
        WRITE(NEWU2) RMIN,RMAX,MEAN

        TYPE *,X4,Y4,N1,N2,ICHOICE
        TYPE *,SCANDIST,TRFREQ
        TYPE *,RMIN,RMAX,MEAN


        IXLENGTH=0
605     DO 800  IJ= 1, X4
        IX = IJ-1

         DO 540  J= 1, N2
 540    C( J ) = PSEUDOGRNL( IJ,J )

        CALL INTR ( C,D,JXXX,Y4 )

C       IF (IJ.EQ.200)TYPE *,'D=',D


C ********** MOD TO GET RID OF FALSE BORDER ***************** C
        IF (SHAPEANS.EQ.'Y')THEN

        IIXCOUNT=0
        DO 1555 IOP=1,Y4  !FORWARD Y-DIRECTION
        IF (D(IOP).EQ.1)GOTO 1555
        IIXCOUNT=IIXCOUNT+1
         IF (IIXCOUNT.EQ.1)THEN
         DO 1655 IJQ=1,J_INT
1655     D(IOP+IJQ-1)=1
         ENDIF
1555    CONTINUE

        IIXCOUNT=0
        DO 1755 IOP=Y4,1,-1  !BACKWARD Y-DIRECTION
        IF (D(IOP).EQ.1)GOTO 1755
        IIXCOUNT=IIXCOUNT+1
         IF (IIXCOUNT.EQ.1)THEN
         DO 1855 IJQ=1,J_INT
1855     D(IOP-IJQ+1)=1
         ENDIF
1755    CONTINUE

C       IF (IJ.EQ.200)TYPE *,'D=',D

        ENDIF

C ********** MOD TO GET RID OF FALSE BORDER ********** C
```

```
C**************MODIFICATION FOR COMPLEX SHAPE ***********C

        IF (SHAPEANS.NE.'Y')GOTO 675  !NOT A COMPLEX SHAPE
        IF (SHAPEANS.EQ.'Y')THEN

        XXX=1
        IXSTART=IJ
        IYLENGTH=0
        NKEEP=0
        DO 8970 J=1,Y4
        IF (D(J).LT.2)GOTO 8970  !1 IS CODED FOR LUCITE (IN SCGREAL)
        IF (D(J).GE.2)THEN !SAMPLE DATA
        IF (NKEEP.EQ.0)IYSTART=J
        NKEEP=1
C**** FURTHER MOD FOR GEORGE'S DISCONTINUITY ON YBCO HEX SAMPLE ******
        IF (IYLENGTH.GT.1.AND.D(J).GE.2.AND.D(J-1).LT.2)THEN
8875    XXX=XXX+1
        IYLENGTH=IYLENGTH+1
        D_SHAPE(IYLENGTH)=1
        IF (D(J-XXX).LT.2)GOTO 8875
        ENDIF
C**** FURTHER MOD FOR GEORGE'S DISCONTINUITY ON YBCO HEX SAMPLE ******
        IYLENGTH=IYLENGTH+1
        D_SHAPE(IYLENGTH)=D(J)
        ENDIF
8970    CONTINUE
C       TYPE *,'IXSTART=',IXSTART,'IYSTART=',IYSTART,'IYLENGTH=',
C   1   IYLENGTH
        IF (IYLENGTH.EQ.0)GOTO 800   !ALL LUCITE IN THIS COLUMN
        IXLENGTH=IXLENGTH+1
        WRITE(NEWU2)IXSTART,IYSTART,IYLENGTH
        DO 8979 IJK=1,IYLENGTH
8979    WRITE(NEWU2)D_SHAPE(IJK)
        GOTO 800
        ENDIF
C ********************************************************** C

675     WRITE(NEWU2) D

 800  CONTINUE



        TYPE *,' '
        TYPE *,'  HIGHEST ',NAMELAB,' IS ',RMAX
        TYPE *,'  LOWEST ',NAMELAB,' IS ',RMIN
        TYPE *,' '

        WRITE (NEWU1)NEWHEADER
        WRITE (NEWU1)RMIN,RMAX
        WRITE (NEWU1)MEAN
        WRITE (NEWU1) ISCALEF
```

```
97364 FORMAT (A)
      CLOSE (NEWU)
      CLOSE (NEWU1)
      CLOSE (NEWU2)
      TYPE *,'DONE CLOSING ', HEAD//CORNAME//'.PDK'

      JMARK=1

      IF (SHAPEANS.NE.'Y')GOTO 9999
5001  REWIND(52)
9999  CONTINUE
      IXLENGTH_A=IXLENGTH
      WRITE(15,REC=I15,FMT=52)IXLENGTH_A
      CLOSE(15)

      CLOSE(52)
87124 CONTINUE


      CLOSE (6)

      RETURN
      end


C
C GRNLBASE.FOR
C     - A set of subroutines useful for applications
C     with the GRINNELL image processor.
C     GRINIT must be called in main program before calling these
C     subroutines.
C
C     David B. Stang     latest update 19-APR-88


      SUBROUTINE SCGREAL( CC,DD, N, BOT,TOP,MEAN )
C
C  Convert values in CC to 1 thru 255 ( same as SCGR, with CC REAL )
C
C       CC( N )   Input Data
C       DD( N )       Output Data
C     BOT     Desired Min for Gray Scale ( units of CC )
C     TOP     Desired Max for Gray Scale          "

      INTEGER*2    N
      INTEGER*2    DD(N)
      REAL         CC(N),MEAN

      RAN = TOP - BOT
      IF (RAN.EQ.0.)RAN=1.
      DO 2000 J = 1,N
      C0 = CC(J)
      Q = ( C0 - BOT ) / RAN
       IF ( Q.LE.0.) Q = 0.
       IF ( Q.GT.1.) Q = 1.
```

```
        Q = Q*251.
C       DD(J) =NINT( Q )+1
C***** FOR MY MODIFICATION ***************C
        IF (C0.EQ.0.)THEN
        DD(J)=1
        GOTO 2000
        ELSEIF (C0.NE.0.)THEN
        DD(J)=NINT(Q)+2
        ENDIF
C****************************************C
 2000   CONTINUE

        RETURN
        END


CC  SUBROUTINE INTR
CC
CC   Interpolate values in C(N2) to "fit" into D(NN)
C
C     SUBROUTINE INTR ( CC,DD,N2,NN )
C
C       INTEGER*2      N2,NN
C       INTEGER*2      CC(N2), DD(NN)
C
C       RN = FLOAT(N2) / FLOAT(NN)
C
C       DO 3000  K = 1,NN
C       R = FLOAT( K )* RN
C       IR = IFIX( R )
C       IR = IINT( R )
C       IRP1 = IR+1
C       RR = R - FLOAT( IR )
C         IF( IR.LT.1 ) IR=1
C     IF( NN.GT.N2 .AND. IRP1.GT.NN ) THEN
C                          IR=NN-1
C                          IRP1=NN
C         ENDIF
C       C0 = FLOAT( CC(IR) )
C       C1 = FLOAT( CC(IRP1) )
C       D0 = ( 1.-RR )*C0  +  RR * C1
C 3000  DD(K) = IFIX(D0)
C 3000  DD(K) = IINT(D0)
C
C       RETURN
C       END

        SUBROUTINE RETMAXMIN_FILTER(FILENAME,CORNAME,CALNAME,NAMELAB,DISKT,
     1  IEND,JXXX,NSCAN,SCANKNT,SHAPEANS,ZIGANS,ICHOICE,TIMESET,I89,
     1  COUNT,ACTPOINT,NEWU,GRBOT,GRTOP,MEAN)

        INTEGER*4  REC,SCANPOS,I7
        INTEGER*2  NSCAN,ACTPOINT
```

```
      INTEGER*2  I85,I87,SCANKNT
      INTEGER*2  IABC,JABC,JXXX,I89
      INTEGER*2  NCOUNT
      INTEGER*2  ZIGCOUNT
      INTEGER*2  NBAD,COUNT,LCOUNTER
      REAL    DATATHING(1024,9)
      REAL    MEAN,VEL(5000)
      REAL    CBUFFER(81)
      CHARACTER  FILENAME*44,CORNAME*15,NAMELAB*20,FFLAG*1
      CHARACTER  SHAPEANS*1,ZIGANS*1,DISKT*5,CALNAME*44
      INTEGER*4  SCANPOS1


      TYPE *,NAMELAB
      LCOUNTER=1
      ZIGCOUNT=1
      ACCUM=0.
      SCANPOS=0
      SCANPOS1=0
      NBAD=COUNT
      I87=1
11    XMAX=0.
      XMIN=10000000.
      PTS  = REAL(NSCAN)*REAL(JXXX)
      NPTS=NSCAN*JXXX

C     CAL FILE WITH MAX/MIN/MEAN
C
      OPEN( unit=8, file=CALNAME, status='OLD', ACCESS='DIRECT',
   +  RECORDTYPE='FIXED',RECL=4,FORM='FORMATTED',
   +    ORGANIZATION='SEQUENTIAL' )
      I85=1


      read(8,REC=I85,FMT=53)VUP
      I85=I85+1
      read(8,REC=I85,FMT=53)VLO
      I85=I85+1
      read(8,REC=I85,FMT=53)VAVE


      IF (SHAPEANS.EQ.'Y')THEN
      NPTS=SCANKNT
      REWIND(52)
      ENDIF

      I7=NPTS*4*ACTPOINT+1  !START OF VELOCITY READS IN .SPC FILE
C
C     SPC FILE (UNIT=7) CONTAINS ALL VELOCITY & SPECTRA DATA

      OPEN (UNIT=7,FILE=DISKT//FILENAME,STATUS='OLD',ACCESS='DIRECT',
   +         RECORDTYPE='FIXED',RECL=4,FORM='FORMATTED',
   +         ORGANIZATION='SEQUENTIAL')

      OPEN (UNIT=NEWU,FILE=DISKT//FILENAME(1:IEND-1)//CORNAME//'.COR',
```

```
+       STATUS='NEW',ACCESS='DIRECT',
+               RECORDTYPE='FIXED',RECL=4,FORM='FORMATTED',
+               ORGANIZATION='SEQUENTIAL')


        DO 500 NIPJ=1,JXXX
410     DO 450 NIPI=1,NSCAN

C*****  GET INFO FROM HOLDER.DAT (FFLAG='S' -> SAMPLE) (FFLAG='H' -> HOLDER)
        KCON=KCON+1
        J=NIPI
        SCANPOS1=((NIPJ-1)*NSCAN)+NIPI  !TRUE SCAN POSITION
        IF (SHAPEANS.NE.'Y')GOTO 87123
        READ(52)IABC,JABC,FFLAG,SCANKNT
C       TYPE *,'XH=',IABC,' YH=',JABC,' FFLAG=',FFLAG
        IF (FFLAG.NE.'S')GOTO 8702 !TRANSDUCER IS ON HOLDER/GOTO NEXT PT.
87123   SCANPOS=SCANPOS+1
CC   !! 'SCANPOS' FOR FILE RETRIEVAL FOR CIRCLE DISK SCANS
        READ(7,REC=I7,FMT=53)VEL(SCANPOS)
        I7=I7+1

        DATATHING(J,5)=VEL(SCANPOS)

        NPTS=(NIPJ-1)*NSCAN+NIPI
                IF (NPTS.EQ.NSCAN*JXXX)NPTS=NSCAN*JXXX



C       IF (ICHOICE.EQ.1)THEN
                IF (SCANPOS.EQ.1)DATATHINGPREVIOUS=VAVE
C               IF (DATATHING(J,5).LT.(VLO+VLO*0.001).OR.
C    1  DATATHING(J,5).GT.(VUP-VUP*0.001))DATATHING(J,5)=DATATHINGPREVIOUS
C       ENDIF

        IF (SHAPEANS.NE.'Y')GOTO 87651
8702    IF (FFLAG.NE.'S')THEN !SET TO 0 // TRANSDUCER IS ON HOLDER/GOTO NEXT PT.

        CBUFFER(J)=0.0

        GOTO 450
        ENDIF

87651   CBUFFER(J)=DATATHING(J,5)

390     CONTINUE

C******KEEP TRACK OF MAX & MIN LIMITS OF CORRECTED DATA********C
C **** FOR FFLAG.NE.'S' --- WE SKIP THIS STEP SO THAT '0' IS NOT CONSIDERED
        RMAX=AMAX1(CBUFFER(J),XMAX)
        RMIN=AMIN1(CBUFFER(J),XMIN)
        XMAX=RMAX
        XMIN=RMIN
```

```
      DATATHINGPREVIOUS=CBUFFER(J)

450   CONTINUE

      IF (ZIGANS.EQ.'N')THEN   !NOT A ZIGZAG SCAN - A NORMAL SCAN
      DO 49720 JI=1,NSCAN
      WRITE (NEWU,REC=I87,FMT=53) CBUFFER(JI)
       ACCUM=ACCUM + CBUFFER(JI)
49720 I87=I87+1

      ELSEIF (ZIGANS.EQ.'Y'.AND.ZIGCOUNT.EQ.1)THEN !ZIGZAG/LEFT->RIGHT
      DO 49721 JI=1,NSCAN
      WRITE (NEWU,REC=I87,FMT=53) CBUFFER(JI)
       ACCUM=ACCUM + CBUFFER(JI)
C     TYPE *,'CBUFFER(JI)=',CBUFFER(JI)
49721 I87=I87+1

      ELSEIF (ZIGANS.EQ.'Y'.AND.ZIGCOUNT.EQ.0)THEN !ZIGZAG/RIGHT->LEFT
      DO 49722 JI=NSCAN,1,-1
      WRITE (NEWU,REC=I87,FMT=53) CBUFFER(JI)
       ACCUM=ACCUM + CBUFFER(JI)
C     TYPE *,'CBUFFER(JI)=',CBUFFER(JI)
49722 I87=I87+1
      ENDIF

C***** FOR ZIGZAG SCANS - TO ALTER ROW STORAGE ***********C
      IF (ZIGANS.EQ.'Y'.AND.ZIGCOUNT.EQ.1)THEN
      ZIGCOUNT=0
      GOTO 500
      ELSEIF (ZIGANS.EQ.'Y'.AND.ZIGCOUNT.EQ.0)THEN
      ZIGCOUNT=1
      ENDIF

C500  TYPE *,'Y=',JABC,'CBUFFER=',CBUFFER
500  CONTINUE
5001  GRBOT = RMIN
      GRTOP = RMAX

      TYPE *,' '
      TYPE *,'RMIN=',GRBOT
      TYPE *,'RMAX=',GRTOP
      MEAN = ACCUM/SCANPOS
      TYPE *,'MEAN=',MEAN
      IF (SHAPEANS.NE.'Y')GOTO 88888
      REWIND(52)

88888 CONTINUE
53    FORMAT (A4)
43191 FORMAT ('+','BAD PTS =',I5,' AT LOCATION (SCANPOS) =',I5)
      RETURN
      END

      SUBROUTINE POINT_FROM_FREQ(SELFREQ,TIMEPERDIV,ACTPOINT)
C
```

```
C       DETERMINE SPECTRA POINT FROM FROM SPECIFIC FREQUENCY IN SPECTRA
C
C       SEE SUBROUTINE CENTERFREQ FOR SIMILAR PROCESSING EXPLANATION
C
        INTEGER*4 DUMMYFREQ
        INTEGER*2 SELFREQ,ACTPOINT
        REAL*4          TIMEPERDIV,DELFREQ,TEMPPOINT
C
C
        DUMMYFREQ=SELFREQ*1E+06
        DELFREQ=(1./(2.*(10.*TIMEPERDIV)))
        TEMPPOINT=DUMMYFREQ/DELFREQ
        ACTPOINT=JNINT(TEMPPOINT)
C
        RETURN
        END

        SUBROUTINE CENTERFREQ(DUMMYP,TIMEPERDIV,ACTFREQ)
C
C       DETERMINE FREQUENCY FROM POINT IN B1(F) SPECTRA
C
        INTEGER*2 DUMMYP,ACTFREQ
        REAL*4          TIMEPERDIV,DELFREQ,TEMPFREQ
C
C       WE KNOW THAT DELFREQ=(1/(2N*DELTIME))
C                       =(1/(2N*(10*TIMEPERDIV/N)))
C                       =(1/(2*(10*TIMPERDIV)))
C
C       WHERE N = 512 POINTS/ACQUISITION (SCREEN)
C          TIMEPERDIV = TIME SETTING PER DIVISION (EX. 50 NSEC)
C          2 = WE EXTENDED 512 ARRAY TO 1024 ARRAY FOR PROCESSING
C          10 = THE NUMBER OF DIVISIONS/SCREEN
C
C       FOR EXAMPLE:
C        WE CAN DETERMINE THE FREQUENCY FOR WHICH THE POINT "MAXB1P"
C       CORRESPONDS TO BY JUST MULTIPLYING (DELFREQ) * (MAXB1P)
C
        DELFREQ=(1./(2.*(10.*TIMEPERDIV)))
        TEMPFREQ=DELFREQ*DUMMYP
        TEMPFREQ=TEMPFREQ/1E+06
        ACTFREQ=JNINT(TEMPFREQ)
C       TYPE *,' '
C       TYPE *,'POINT=',DUMMYP,' FREQ=',ACTFREQ,' MHZ'
C       TYPE *,' '
C
        RETURN
        END
C
C
C
C
C
        SUBROUTINE INTR (F1, F2, N, M)
C
C
```

```
      IMPLICIT NONE
C
      INTEGER*2 I, M, N
      INTEGER*2 F1(N), F2(M)
      REAL*4 X, XA(512), Y, YA(512)
C
C
      DO I = 1, N
        XA(I) = FLOATI(I)
      END DO
C
      DO I = 1, N
        YA(I) = FLOATI(F1(I))
      END DO
C
      DO I = 1, M
        X = FLOATI(I-1) * FLOATI(N-1) / FLOATI(M-1) + 1.0
        CALL LINEAR_INTERPOLATION (XA, YA, N, X, Y)
        F2(I) = ININT(Y)
      END DO
C
C
      RETURN
      END
C
C     LINEAR_INTERPOLATION computes the value of the piecewise linear spline
C               interpolant of the points in the arrays XA and YA at the point
C               X. This routine is a modified version of the FORTRAN routine
C               SPLINT found in the book "Numerical Recipes: The Art of
C               Scientific Computing" by Press, Flannery, Teukolsky, and
C               Vetterling published by the Cambridge University Press, 1986.
C
C   Variables:
C
C               NMAX : A constant which determines the array sizes
C                       for U, X, and Y.
C               K : The midpoint between KHI and KLO... used to find the two
C                       indices into the XA table such that
C                       XA(KLO) < X < XA(KHI).
C               KHI : The greater of the two indices into the XA array such
C                       that XA(KLO) < X < XA(KHI).
C               KLO : The lesser of the two indices into the XA array such
C                       that XA(KLO) < X < XA(KHI).
C               N : The index of the arrays and Y that contain interpolation
C                       points.
C               A : Weight given to YA(KLO).
C           B : Weight given to YA(KHI).
C               H : The difference of XA(KHI) and XA(KLO).
C               X : The value of X at which to compute the value of the
C                       interpolation function.
C               XA : The table of X coordinates of the interpolation points.
C               Y : The value of the interpolation function evaluated at X.
C               YA : The table of Y coordinates of the interpolation points.
C
      SUBROUTINE LINEAR_INTERPOLATION (XA, YA, N, X, Y)
```

```
C
C
      IMPLICIT NONE
C
      INTEGER NMAX
      PARAMETER (NMAX=512)
C
      INTEGER*2 K, KHI, KLO, N
      REAL*4 A, B, H
      REAL*4 X, XA(NMAX), Y, YA(NMAX)
C
C
      KLO = 1
      KHI = N
      DO WHILE (KHI-KLO.GT.1)
    K = (KHI + KLO) / 2
    IF (XA(K).GT.X) THEN
      KHI = K
    ELSE
      KLO = K
    END IF
      END DO
C
      H = XA(KHI) - XA(KLO)
  IF (H.NE.0.0) THEN
        A = (XA(KHI) - X) / H
        B = (X - XA(KLO)) / H
        Y = A * YA(KLO) + B * YA(KHI)
      END IF
C
C
      RETURN
      END
```

```
C ****** NOTHICK_DRAW.FOR *******************C

        INTEGER*2  TRFREQ,JXXX,IXLENGTH
        INTEGER*2  SCANDIST,INDXDIST,NSCAN,NINDX,DENS
        INTEGER*2  SELFREQ,AVES,I6,I15,ISLANT1,ISLANT2,ISLANT3,ISLANT4
        CHARACTER  RESP1*1,SELFREQANS*1,RESP2*2
        CHARACTER  NEWOLD*3,SHAPEANS*1,ZIGANS*1,CHFREQ_C*3,CHDRI*1
        BYTE       B, CHFREQ(3), BSUFFREQ(4)
        BYTE       BSCALEMARK(4)
        BYTE       BDATA_STATUS(40), BLABEL(30), BFILEEXT(23)
        CHARACTER  LABEL*30, FILEEXT*23,CHEADER*32,TEBAR*1
        CHARACTER  L*48, DIR*16,DRIVE*1,NOISANS*1,DIFFANS*1
        CHARACTER  SUFFREQ*4,FILENAME*34,SCALEMARK*4,DATA_STATUS*40
        CHARACTER  ACTUAL_SELFREQANS*1,SASANS*1,PHASE*1,PHASE1*1

        EQUIVALENCE ( BFILEEXT,FILEEXT )
        EQUIVALENCE ( CHFREQ,CHFREQ_C )
        EQUIVALENCE ( L,B )
        EQUIVALENCE ( BSCALEMARK, SCALEMARK )
        EQUIVALENCE ( BSUFFREQ, SUFFREQ )
        EQUIVALENCE ( BDATA_STATUS, DATA_STATUS )
        EQUIVALENCE ( BLABEL, LABEL )

        NEWOLD='OLD'

        OPEN (UNIT=10,FILE='NOTHICK_DADQ1.DAT',STATUS=NEWOLD,
        1FORM='FORMATTED')

        READ (10,511) FILEEXT
        READ (10,511) DRIVE
511     FORMAT (A)
51      FORMAT (A32)
52      FORMAT (A2)
53      FORMAT (A4)
677     FORMAT (I)


        OPEN( unit=66, file='[ROTH.DATA]'//FILEEXT//'.datCH', status='OLD',
   +     ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=32,
   +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )

        OPEN (UNIT=14,FILE='NOTHICK_SELFREQ1.DAT',
   1    STATUS='OLD',FORM='FORMATTED')

        OPEN( unit=15, file='[ROTH.DATA]'//FILEEXT//'.datI2', status='OLD',
   !     ACCESS='DIRECT',RECORDTYPE='FIXED',RECL=2,
   +            form='FORMATTED',ORGANIZATION='SEQUENTIAL' )


        I6=1
79193   READ(66,REC=I6,FMT=51)CHEADER
        I6=I6+1
        READ(66,REC=I6,FMT=51)SHAPEANS
        I6=I6+1
        READ(66,REC=I6,FMT=51)ZIGANS
```

```
        I6=I6+1

        READ (14,98652) FILEEXT
        READ (14,98652) DRIVE
        READ (14,98652) PHASE
        READ (14,98652) PHASE1
        READ (14,98652) DIFFANS
        READ (14,10030) BUFLENGTH
        READ (14,10030) BUFVEL
        READ (14,10030) TRDIAM
        CLOSE (14)
98652   FORMAT (A)
10020   FORMAT (I)
10030   FORMAT (F)

        I15=1
89714   READ(15,REC=I15,FMT=52)SCANDIST
        I15=I15+1
        READ(15,REC=I15,FMT=52)INDXDIST
        I15=I15+1
        READ(15,REC=I15,FMT=52)NSCAN
        I15=I15+1
        READ(15,REC=I15,FMT=52)NINDX
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant1
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant2
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant3
        I15=I15+1
        READ(15,REC=I15,FMT=52)islant4
        I15=I15+1
        READ(15,REC=I15,FMT=52)DENS
        I15=I15+1
        READ(15,REC=I15,FMT=52)TRFREQ
        I15=I15+1
        READ(15,REC=I15,FMT=52)AVES
        I15=I15+1
        READ(15,REC=I15,FMT=52)JXXX
        I15=I15+1
        READ(15,REC=I15,FMT=52)IXLENGTH
C       ARRAYSIZE=(NSCAN)*(JXXX) !IF SCAN FINISHED PROPERLY,JXXX=NINDX

        ENCODE (3,19878,CHFREQ) TRFREQ  !ANALYSIS FREQUENCY
19878   FORMAT (I3)

C       DETERMINE SHORTENED (-.DAT) FILEEXT POSITION
C
C       KMARK=0
C       DO 4321 IPR=1,34
C       IF (KMARK.EQ.1) GOTO 4321
```

```
C       IF (BFILEEXT(IPR).EQ.46) THEN          !PERIOD/DOT IS ASCII 46
C       IEND=IPR
C       KMARK=1
C       ENDIF
C4321   CONTINUE
C       FILEEXT=FILEEXT(1:IEND-1)

        TYPE *,' CURRENT IMAGE FILE IS ',FILEEXT
        TYPE *,' '
        TYPE *,' IF YOU WANT A DIFFERENT IMAGE FILE, YOU MUST'
        TYPE *,' RECALL AN OLDER "NOTHICK_DADQ1.DAT" FILE'
        TYPE *,' '

        IF (DRIVE.EQ.'A')DIR='DUC2:[ROTH.IMAG]'
        IF (DRIVE.EQ.'C')DIR='DUC0:[ROTH.IMAG]'

5321    TYPE *,'CURRENT DRIVE TO READ IMAGES IS ',DIR(1:5)

        IF (DIR(1:5).EQ.'DUC0:')THEN
        TYPE *,'DO YOU WANT TO CHANGE TO DUC2: (Y/N
  1     )?'
        READ (5,51)CHDRI
        IF (CHDRI.NE.'Y'.AND.CHDRI.NE.'N')GOTO 5321
        IF (CHDRI.EQ.'Y')DIR='DUC2:[ROTH.IMAG]'
        ELSEIF (DIR(1:5).EQ.'DUC2:')THEN
        TYPE *,'DO YOU WANT TO CHANGE TO DUC0: (Y/N
  1     )?'
        READ (5,51)CHDRI
        IF (CHDRI.NE.'Y'.AND.CHDRI.NE.'N')GOTO 5321
        IF (CHDRI.EQ.'Y')DIR='DUC0:[ROTH.IMAG]'
        ENDIF

211     TYPE *,' '
        TYPE *,' DO YOU WANT TO SEE TEXT AND COLORBAR (Y/N)?'
        READ (5,51)TEBAR
        IF (TEBAR.NE.'Y'.AND.TEBAR.NE.'N')GOTO 211
        CONTINUE

        FILENAME='[ROTH.DATA]'//FILEEXT

        CALL GRINIT
        CALL GRSRST


        TYPE *,' '
        TYPE *,'IMAGE FREQUENCY (MHz) = ',TRFREQ
        ENCODE (3,9878,CHFREQ) TRFREQ
9878    FORMAT (I3)

234     TYPE *,'   ****** NOTHICKNESS VELOCITY IMAGE ****** '
        TYPE *,' '
        WRITE (5,394)
394     FORMAT ('$','    COLOR (C) OR B&W (B) IMAGE? ')
        READ (5,2222) RESP1
```

61

```
2222  FORMAT(A)
      IF (RESP1.NE.'C'.AND.RESP1.NE.'B')GOTO 234

      IF (RESP1.EQ.'C')THEN
      TYPE *,' '
      WRITE (5,499)
499   FORMAT ('$','    "COLORRED" (R) OR NORMAL COLOR (C) SCHEME? ')
      READ (5,2222) RESP2
      ENDIF

500   CALL IMAGE(NEWOLD,FILEEXT,CHFREQ_C,RESP1,RESP2,SHAPEANS,IXLENGTH,
     1 FILENAME,DIR,TEBAR)


444   CONTINUE
      STOP
      END


      SUBROUTINE IMAGE(NEWOLD,FILEEXT,CHFREQ_C,RESP1,RESP2,SHAPEANS,IXLENGTH,
     1 FILENAME,DIR,TEBAR)

      INTEGER*2  D(460),CHANNEL,INPUT,IXLENGTH
      INTEGER*2  X4,Y4,N1,N2,TRFREQ,SCANDIST
      CHARACTER*1 RESP1*1,SHAPEANS*1,RESP2*1,TEBAR
      CHARACTER  CHFREQ_C*3
      REAL       RMIN, RMAX, MEAN
      BYTE       B, CHFREQ(3), BSUFFREQ(4),BZERO(2)
      BYTE       BFILENAME(34), BSCALEMARK(4)
      BYTE       BDATA_STATUS(40), BLABEL(30)
      BYTE       CHMEAN(5),CHRMAX(5),CHRMIN(5)
      CHARACTER  FILNAM*48, LABEL*30, FILEEXT*23
      CHARACTER  L*48, DIR*16,CZERO*2
      CHARACTER  SUFFREQ*4, FILENAME*34, SCALEMARK*4, DATA_STATUS*40

      EQUIVALENCE ( L,B )
      EQUIVALENCE ( BSCALEMARK, SCALEMARK )
      EQUIVALENCE ( BSUFFREQ, SUFFREQ )
      EQUIVALENCE ( BDATA_STATUS, DATA_STATUS )
      EQUIVALENCE ( BLABEL, LABEL )
      EQUIVALENCE ( CZERO, BZERO )

      CZERO='0 '
      LLLL=0
      IIIMAGE=1

212   CONTINUE

      IF (IIIMAGE.EQ.1)FILNAM='_VEL_C_'//CHFREQ_C//'.PDK'

501   CONTINUE
      CHANNEL=0
      IF (CHANNEL.NE.0.AND.CHANNEL.NE.2.AND.CHANNEL.NE.3) GOTO 501
      IF (CHANNEL.EQ.0) THEN
        INPUT=0
```

```
      MASK=1
      ELSEIF (CHANNEL.EQ.2) THEN
      INPUT=1
      MASK=4
      ELSEIF(CHANNEL.EQ.3) THEN
      INPUT=2
      MASK=8
      ENDIF

     CALL ERASE

19   OPEN (UNIT=6,FILE=DIR//FILEEXT//FILNAM,STATUS='OLD',
     1FORM='UNFORMATTED')

     READ(6) X4,Y4,N1,N2,IVALUE
     READ(6) SCANDIST,TRFREQ
     READ(6) RMIN,RMAX,MEAN

     IF ( IVALUE.EQ.1 ) LABEL='VELOCITY CM/US'

     ICOLORBAR=0
     SUFFREQ=' MHZ'
     SCALEMARK='1 MM'
     DATA_STATUS=LABEL

     CALL GRNIN(1,INPUT,INPUT,INPUT)
     CALL GRNBY(1,1,1,1)
     CALL GRSBFD

C *********************MODIFICATION FOR COMPLEX SHAPES ******C
     IF (SHAPEANS.NE.'Y')IX49=X4

     IF (SHAPEANS.EQ.'Y')THEN
     IX49=IXLENGTH
     ENDIF

     DO 100 I=1,IX49
     IF (SHAPEANS.NE.'Y')THEN
     IXSTART=I-1
     IYSTART=1
     IYLENGTH=Y4
   READ(6)D
     GOTO 789
     ELSEIF (SHAPEANS.EQ.'Y')THEN
       IF (I.NE.1.AND.IYLENGTH.EQ.1)GOTO 100
     READ(6,END=100)IXSTART,IYSTART,IYLENGTH
     DO 7897 IJK=1,IYLENGTH
7897 READ(6)D(IJK)
789  CONTINUE
     ENDIF
       CALL GRWAW(D,IXSTART,IYSTART,1,IYLENGTH,0,0,0,1,1)
C ************************************************************ C
       CALL GRSBFD
100    CONTINUE
```

```
        IF (RESP1.EQ.'B')THEN
        IF (TEBAR.EQ.'N')GOTO 213
        CALL PLACEBAR(0)
        GOTO 8999
        ELSEIF (RESP1.NE.'B')THEN

        IF (RESP2.EQ.'C')THEN
        CALL COLORS (IVALUE,ICOLORBAR)
        ELSEIF (RESP2.EQ.'R')THEN
        CALL COLORRED (IVALUE,ICOLORBAR)
        ENDIF

        ENDIF


        IF (TEBAR.EQ.'N')GOTO 213


8999    DECODE (34,8989,FILENAME) BFILENAME
8989    FORMAT (34A1)

        ENCODE (3,909,CHFREQ) TRFREQ
909     FORMAT (I3)


        CALL GRFCD (1,255,0,0,BFILENAME,1,441,6,0,34,0,0,0)
        CALL GRFCD (1,255,0,0,CHFREQ,200,441,6,0,3,0,0,0)
        CALL GRFCD (1,255,0,0,BSUFFREQ,215,441,6,0,4,0,0,0)

CC
CC PRINT LABEL TO GRINNELL
CC

        NCHAR=LEN(DATA_STATUS)
        DO 765 IKY=1,NCHAR
          IKX=400-(IKY-1)*13
          CALL GRFCD (1,255,0,0,BDATA_STATUS(IKY),505,IKX,0,0,1,0,0,0)
          CALL GRSBFD
765       CONTINUE

CC
CC CALCULATE MAX, MIN, AND MEAN
CC

        IF (IVALUE.EQ.1.OR.IVALUE.EQ.2.OR.IVALUE.EQ.6.OR.IVALUE.EQ.7) THEN
      IF (IVALUE.EQ.1) THEN
            IF (RMAX.EQ.1.0) RMAX=.9999
            ENDIF
          RRMAX=RMAX*10.**4.
          RRMIN=RMIN*10.**4.
          RMEAN=MEAN*10.**4.


        ELSEIF (IVALUE.EQ.3.OR.IVALUE.EQ.4) THEN
         RRMAX=RMAX/100.
```

```
        RRMIN=RMIN/100.
        RMEAN=MEAN/100.

        ELSEIF (IVALUE.EQ.5) THEN
            IF (RMAX.GE.100.)RMAX=99.9
            IF (RMIN.GE.100.)RMIN=99.9
            IF (MEAN.GE.100.)MEAN=99.9
            IF (RMAX.LT.10.)THEN
              RRMAX=RMAX*10.**4.
              RRMIN=RMIN*10.**4.
              RMEAN=MEAN*10.**4.
              ELSE
              RRMAX=RMAX*10.**3.
              RRMIN=RMIN*10.**3.
              RMEAN=MEAN*10.**3.
              ENDIF
            ENDIF
        IF (IVALUE.EQ.2.OR.IVALUE.EQ.6.OR.IVALUE.EQ.7) THEN
          JKMN=465
        ELSEIF (IVALUE.EQ.1.OR.IVALUE.EQ.3.OR.IVALUE.EQ.4)THEN
          JKMN=463
        ELSEIF (IVALUE.EQ.5)THEN
          JKMN=470
          ENDIF

CC DRAW DECIMAL POINT FOR MIN AND MAX TO GRINNELL

        DO 9879 IUY=0,350,350
          CALL GRFAR (1,255,0,0,JKMN,IUY,1,1)
          CALL GRSBFD
9879      CONTINUE



        IMEAN=JNINT(RMEAN)
        IRMAX=JNINT(RRMAX)
        IRMIN=JNINT(RRMIN)

        TYPE *,' '
        TYPE *,'CORRECTED:'
        TYPE *,'IRMAX=',IRMAX
        TYPE *,'IRMIN=',IRMIN
        TYPE *,'IMEAN=',IMEAN
        TYPE *,' '

        IF (IMEAN.GE.1.0*10.**5.) GOTO 73920
        ENCODE (5,9878,CHMEAN) IMEAN
73920   IF (IRMAX.GE.1.0*10.**5.) GOTO 73921
        ENCODE (5,9878,CHRMAX) IRMAX
73921   IF (IRMIN.GE.1.0*10.**5.) GOTO 73922
        ENCODE (5,9878,CHRMIN) IRMIN
73922   CONTINUE
9878    FORMAT (I5)
```

65

```
      IF (IMEAN.GE.1.0*10.**6.)GOTO 93920
      ZZZZZZ=RRMAX-RRMIN
      IF (ZZZZZZ.EQ.0.)ZZZZZZ=1.
      SCALEF=((RMEAN-RRMIN)/(ZZZZZZ))*350.  !SC. MEAN TO CLR BAR
      ISCALEF=ININT(SCALEF)
93920 CONTINUE

      IF (IMEAN.GE.1.0*10.**6.)GOTO 83920
      CALL GRFCDS (1,255,CHMEAN,458,ISCALEF,6,0,4)
83920 IF (IRMAX.GE.1.0*10.**6.)GOTO 83921
      CALL GRFCDS (1,255,CHRMAX,458,350,6,0,4)
83921 IF (IRMIN.GE.1.0*10.**6.)GOTO 83922
      CALL GRFCDS (1,255,CHRMIN,458,0,6,0,4)
      CALL GRSBFD
83922 CONTINUE
9877  CONTINUE


      IF (IVALUE.EQ.2) THEN
     JKMN=465
        ELSEIF (IVALUE.EQ.1.OR.IVALUE.EQ.3.OR.IVALUE.EQ.4.OR.IVALUE.EQ.6
  1           .OR.IVALUE.EQ.7)THEN
       JKMN=463
      ELSEIF (IVALUE.EQ.5)THEN
       JKMN=470
       ENDIF
      CALL GRFAR (1,255,0,0,JKMN,ISCALEF,1,1)
      CALL GRSBFD
95631 CONTINUE

CC
CC DRAW SCALE ONTO IMAGE
CC

      RSCANDIST=FLOATI(SCANDIST)
      PIXELS=(X4*1.)/(RSCANDIST)
      IPIXELS=ININT(PIXELS)
      CALL GRFVCS (1,255,340,420,340+IPIXELS,420)
      CALL GRFCDS (1,255,BSCALEMARK,345,410,6,0,4)
      CALL GRSBFD

C!  FOR DRAWING INITIAL ZEROES FOR ATTENUATION COEFF. < 0.1
      IF (IVALUE.EQ.2.AND.RRMIN.LT.1000.)THEN
      CALL GRFCDS (1,255,BZERO,JKMN,0,6,0,2)
      CALL GRSBFD
      ENDIF

213   CONTINUE

201   CLOSE(6)


 1    FORMAT('$',' WHICH IMAGE TO VIEW [*.PDK IN ROTH.IMAG]?')
 2    FORMAT(A)
 3    FORMAT('$','Channel  (0,2,3) ?')
```

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```
4      FORMAT( '$Description ?? ' )
5      FORMAT('0')
6      FORMAT( ' ',A )
7      FORMAT( '  Range = ',A,' , ',A )
8      FORMAT( '  Mean =   ',A15,'   ',A )
9    FORMAT(I)

       TYPE *,' '

999    CALL GRSEND

444    CONTINUE
       RETURN
       END


       SUBROUTINE COLORSUB (IVALUE,ICOLORBAR)

       INTEGER*2 NR(256),NB(256),NG(256),IARRAY(18)
       DATA IARRAY/0,2,1,0,1,2,1,0,2,1,2,0,2,0,1,2,1,0/

       IF (IVALUE.GT.10) GOTO 9876
       CALL GRINIT_OLD
       CALL GRSRST
       CALL GRZFC(0,0)
       CALL GRZCL(0,255,255)
       CALL GRZON(0,1)
       CALL GRSBFD

       B=4
       A=2

       L=256
       IL=L/B
       JL=A*IL

       DO 100 I=1,IL
       NB(I)=255
       NR(I)=0
       NG(I)=B*I
       IF(NG(I).GT.255)THEN
       NG(I)=255
       ENDIF
100    CONTINUE

       DO 200 I=IL+1,JL
       BB=((B/(1-A))*I)+((A/(A-1))*L)
       NG(I)=255
       NR(I)=0
       NB(I)=BB
       IF (NB(I).GT.255)THEN
       NB(I)=255
       ENDIF
200    CONTINUE
```

```
      DO 300 I=JL+1,JL+IL
      RR=(B*I)-(A*L)
      NG(I)=255
      NB(I)=0
      NR(I)=RR
      IF (NR(I).GT.255)THEN
      NR(I)=255
      ENDIF
300   CONTINUE

      DO 400 I=JL+IL+1,L
      GG=((-B)*I)+(B*L)
      NR(I)=255
      NB(I)=0
      NG(I)=GG
      IF(NG(I).GT.255)THEN
      NG(I)=255
      ENDIF
400   CONTINUE


800   KC=0


      NR(1)=0
      NG(1)=0
      NB(1)=0
      NR(256)=255
      NG(256)=255
      NB(256)=255

889   CALL GRNWR(1,NB,IARRAY(1+KC),0,256,0)
      CALL GRNWR(1,NG,IARRAY(2+KC),0,256,0)
      CALL GRNWR(1,NR,IARRAY(3+KC),0,256,0)
      CALL GRSBFD
      CALL GRNIN(0,0,0,0)
      IF (ICOLORBAR.EQ.1) THEN
      CALL GRNBY (0,0,0,0)
      ENDIF
      CALL GRSBFD
C     IF (IVALUE.EQ.1.OR.IVALUE.EQ.3.OR.IVALUE.EQ.5.OR.IVALUE.EQ.7) THEN
      DO 1111 I=1,300
      DO 1111 J=1,900
1111  CONTINUE
      GOTO 950
950   KC=0
9876  RETURN
      END


      SUBROUTINE PLACEBAR (ICOLORBAR)

CC ------Draw colorbar at right side of screen-------

      INTEGER*2 NA(45)
```

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```
      IF (ICOLORBAR.EQ.1) GOTO 1010
      CONTINUE
      DO 1000 I=0,350
      DO 2000 J=1,19
      G=I*(254.0/350.0)
      NA(J)=G
2000  CONTINUE
      CALL GRWLW(NA,410,I,19,0,0,1,1)
      CALL GRSBFD
1000  CONTINUE
1010  CONTINUE
      RETURN
      END


      SUBROUTINE SAVEBAR

      INTEGER*2 BAR(6)

      TYPE *,' '
      TYPE *,'Creating and saving the color bar...'
      TYPE *,' '

      OPEN(UNIT=34,NAME='BARFILE',STATUS='NEW',
      IFORM='UNFORMATTED',BLOCKSIZE=1024)

      CALL GRNIN(1,0,0,0)
      CALL GRNBY(1,1,1,1)
      CALL GRSBFD

   DO 2060 IBBEL=0,459,3
    CALL GRRLW (410,IBBEL,6,1,BAR)
      WRITE(34) BAR
2060 CONTINUE

      CALL GRSBFD
      CLOSE(34)
      RETURN
      END


      SUBROUTINE ERASE

      M=4095
      N=4095
   CALL GRFER (M,N,0)
      CALL GRSBFD
   END


      SUBROUTINE COLORS (IVALUE,ICOLORBAR)
```

```
      INTEGER*2 NR(256),NB(256),NG(256),IARRAY(18)
      DATA IARRAY/0,2,1,0,1,2,1,0,2,1,2,0,2,0,1,2,1,0/
      INTEGER*2 NA(45)

      IF (IVALUE.GT.10) GOTO 9876
      CALL GRINIT_OLD
      CALL GRSRST
      CALL GRZFC(0,0)
      CALL GRZCL(0,255,255)
      CALL GRZON(0,1)
      CALL GRSBFD

      B=4
      A=2

      L=256
      IL=L/B
      JL=A*IL

      DO 100 I=1,IL
      NB(I)=255
      NR(I)=0
      NG(I)=B*I
      IF(NG(I).GT.255)THEN
      NG(I)=255
      ENDIF
100   CONTINUE

      DO 200 I=IL+1,JL
      BB=((B/(1-A))*I)+((A/(A-1))*L)
      NG(I)=255
      NR(I)=0
      NB(I)=BB
      IF (NB(I).GT.255)THEN
      NB(I)=255
      ENDIF

200   CONTINUE

      DO 300 I=JL+1,JL+IL
      RR=(B*I)-(A*L)
      NG(I)=255
      NB(I)=0
      NR(I)=RR
      IF (NR(I).GT.255)THEN
      NR(I)=255
      ENDIF
300   CONTINUE

      DO 400 I=JL+IL+1,L
      GG=((-B)*I)+(B*L)
      NR(I)=255
```

```
      NB(I)=0
      NG(I)=GG
      IF(NG(I).GT.255)THEN
      NG(I)=255
      ENDIF
400   CONTINUE


800   KC=0

      NR(1)=0
      NG(1)=0
      NB(1)=0
      NR(256)=255
      NG(256)=255
      NB(256)=255

889   CALL GRNWR(1,NB,IARRAY(1+KC),0,256,0)
      CALL GRNWR(1,NG,IARRAY(2+KC),0,256,0)
      CALL GRNWR(1,NR,IARRAY(3+KC),0,256,0)
      CALL GRSBFD
      CALL GRNIN(0,0,0,0)
      IF (ICOLORBAR.EQ.1) THEN
      CALL GRNBY (0,0,0,0)
      ENDIF
      CALL GRSBFD
      DO 1111 I=1,300
      DO 1111 J=1,900
1111  CONTINUE
      GOTO 950
950   KC=0

CC -------Draw colorbar at right side of screen-------

9876  IF (ICOLORBAR.EQ.1) GOTO 1010
      CONTINUE
      DO 1000 I=0,350
      DO 2000 J=1,19
      G=I*(254.0/350.0)
      NA(J)=G
2000  CONTINUE
      CALL GRWLW(NA,410,I,19,0,0,1,1)
      CALL GRSBFD
1000  CONTINUE
1010  CONTINUE
      RETURN
      END


      Subroutine colorred(IVALUE,ICOLORBAR)

      INTEGER*2 NR(256),NB(256),NG(256),IARRAY(18)
      DATA IARRAY/0,1,2,0,2,1,1,0,2,1,2,0,2,0,1,2,1,0/
      INTEGER*2 NA(45)
```

```
10010  format(A)
10020  format(I)
        NM256 = 0

        IF (IVALUE.GT.10) GOTO 9876

        CALL GRINIT_OLD
C       CALL GRSRST
        CALL GRSBFD
        L=256
        IL=L/3
        JL=2*IL
        NM256=255

        DO 100 I=1,IL
        NB(I)=0
        NR(I)=I*3
        NG(I)=0
        IF( NR(I).GT.253 )NR(I)=253
 100   CONTINUE

        DO 200 I=IL+1,JL
        NG(I)=3*(I-IL)
        NR(I)=253
        NB(I)=0
        IF( NG(I).GT.253 )NG(I)=253
 200   CONTINUE

        DO 300 I=JL+1,255
        NG(I)=253
        NR(I)=253
        NB(I)=3*(I-JL)
        IF( NR(I).GT.253 )NR(I)=253
300    CONTINUE

 800   KC=6
        NR(1)=0
        NG(1)=0
        NB(1)=0
        NR(256)=NM256
        NG(256)=NM256
        NB(256)=NM256

 840    CALL GRNWR(1,NB,IARRAY(1+KC),0,256,0)
        CALL GRNWR(1,NG,IARRAY(2+KC),0,256,0)
        CALL GRNWR(1,NR,IARRAY(3+KC),0,256,0)
        CALL GRSBFD
        CALL GRNIN(0,0,0,0)
        CALL GRSBFD
        CALL GRNBY(0,0,0,0)
        CALL GRSBFD
C       WRITE( 5,10860 )
C10860  format( '$ <CR> for next color scheme, Q to quit :' )
C       READ( 5,10010 )ANS
```

```
C       IF( ANS.EQ.'Q' .OR. ANS.EQ.'q' )GOTO 9876
        GOTO 9876
        KC = KC+3
        IF (KC.GE.18) KC=0
        GOTO 840


CC -------Draw colorbar at right side of screen-------

9876    IF (ICOLORBAR.EQ.1) GOTO 1010
        CONTINUE
        DO 1000 I=0,350
        DO 2000 J=1,19
        G=I*(254.0/350.0)
        NA(J)=G
2000    CONTINUE
        CALL GRWLW(NA,410,I,19,0,0,1,1)
        CALL GRSBFD
1000    CONTINUE
1010    CONTINUE


C 900   CALL GRSEND
        return
        END
```

What is claimed is:

1. A pulse-echo, immersion method for ultrasonic evaluation of a material, employing automatic scanning and digital imaging to obtain an image of a property of said material, wherein said material is held in a holding apparatus which is positioned in an immersion liquid over an acoustic reflector, said reflector having an acoustic impedance which is greater than that of said liquid, and wherein nonlevelness in said holding apparatus and material thickness are accounted for and eliminated, said method comprising:

(i) ultrasonically scanning said material at a plurality of scan points and receiving the first and second echoes, each of which is a complete waveform, reflected off the back surface of said material and the first echo reflected off the front surface of said reflector both with and without the presence of said material;

(ii) adjusting the time delay for each said received echo from each said scan point during said scanning in (i) above, gating each said received echo so that it is centered within its respective time window;

(iii) automatically scanning said material at said scan points to receive said first and second back surface echoes and said two front surface echoes using the information obtained in (ii) above, so that each echo received from each scan point during said automatic scanning is centered within its time window;

(iv) digitizing each echo received during said automatic scanning and determining the time delay between said first two successive sample back surface echoes, 2τ, and the time delay, Δt, between the two different reflector front surface echoes received at each scan point during said automatic scanning and calculating the wave velocity, using a cross correlation function, at each said scan point from

$$v = c\left(\frac{\Delta t}{2\tau} + 1\right)$$

where c is the speed of the ultrasonic wave transmitted in said liquid, and

(v) scaling the velocity values obtained in (iv) to corresponding proportional color or grey scale values and displaying the resulting image.

2. A method according to claim **1** wherein a single transducer is used.

3. A method according to claim **2** wherein said transducer is a high frequency transducer which emits a frequency between 1–100 MHz.

4. A pulse-echo, immersion method for ultrasonic evaluation of a material employing a single transducer, automatic scanning and digital imaging to obtain an image of a property of said material, wherein said material has a uniform thickness variation and is positioned in an immersion liquid between said transducer and an accoustic reflector, said method comprising:

(I) accounting for and eliminating nonlevelness in the set-up and said material thickness variation by;

(a) performing a preliminary scan along both the x-and y-directions of the material to provide slant correction factors which are input into a computer to account for said nonlevelness and thickness variation during the subsequent automatic scanning for said material evaluation in (ii) below;

(b) adjusting the time delay during said preliminary scan for any received echoes which are not centered in the scan time window, so that each received echo is centered in its time window;

(ii) automatically scanning said material at a plurality of scan points in both the x- and y-directions to receive the first and second back surface echoes and front surface echoes with and without the presence of said material between said transducer and reflector using the information obtained in (i) above, so that each echo received from each scan point during said automatic scanning is centered within its time window;

(iii) digitizing each echo received during said automatic scanning and determining the time delay between said first two successive sample back surface echoes, 2τ, and the time delay, Δt, between the two different reflector front surface echoes received at each scan point during said automatic scanning and calculating the wave velocity at each said scan point from

$$v = c\left(\frac{\Delta t}{2\tau} + 1\right)$$

where c is the speed of the ultrasonic wave transmitted in said liquid, and

(iv) scaling the velocity values obtained in (iii) to corresponding proportional color or grey scale values and displaying the resulting image.

5. A method according to claim **4** wherein said back and front surface echoes received from the first and last scan points in both the x- and y-directions during said preliminary scan determine said time base adjustments needed for each echo to be centered within the time frame for it.

6. A method according to claim **5** wherein the location of the time window during said automatic scanning for said material evaluation is automatically adjusted via computer control by using the formula:

$$W_{DT} = T_I + [(X_{SC})(X_{SN})(X_{SI}) + (Y_{SC})(Y_{SN})(YSI)]$$

wherein W_{DT} is the correct delay time window at a particular scan location, T_I is the time delay at the the initial scan location, X_{SC} and Y_{SC} are the x- and y-direction slant correction factors, X_{SN} and Y_{SN} are the scan point numbers in the x- and y-directions, and X_{SI} and Y_{SI} are the x- and y-direction scan increments.

7. A method according to claim **6** wherein two scans are automatically made to obtain said first two back surface echoes and said two different reflector front surface echoes.

8. A method according to claim **7** wherein said first two back surface echoes and said reflector echo with said material present are made in said first scan.

9. A method according to claim **6** wherein three scans are automatically made to obtain said first two back surface echoes and said two different reflector front surface echoes.

10. A method according to claim **9** wherein said first two back surface echoes are received in one scan, wherein said reflector echo with said material present is made in another scan, and wherein and said reflector echo without said material present is received in yet another scan.

11. A method according to claim **9** wherein said first back surface echo is received in said first scan, wherein said second back surface echo is received in said second scan, wherein said reflector echo with said material present is made in said third scan, and wherein said reflector echo without said material present is received in said fourth scan.

12. A method according to claim **6** wherein four scans are automatically made to obtain said first two back surface echoes and said two different reflector front surface echoes.

13. An ultrasonic, pulse-echo, immersion method employing automatic scanning and digital imaging to obtain an image of a microstructural property of a material positioned in an immersion liquid between a transducer and an acoustic reflector, said method comprising:

(i) automatically scanning said material at least three times at a plurality of scan points in both the x- and y-directions to receive the first and second back surface echoes and front surface echoes with and without the presence of said material between said transducer and reflector, each of said echoes received being a complete waveform and gated within a time window;

(ii) digitizing each echo received during said automatic scanning and determining the time delay between said first two successive sample back surface echoes, 2τ and the time delay, Δt, between the two different reflector front surface echoes received at each scan point during said automatic scanning and calculating the wave velocity at each said scan point from

$$v = c\left(\frac{\Delta t}{2\tau} + 1\right)$$

where c is the speed of the ultrasonic wave transmitted in said liquid, and

(iii) scaling the velocity values obtained in (ii) to corresponding proportional color or grey scale values and displaying the resulting image.

14. A method according to claim **13** wherein four scans are automatically made to obtain said first two back surface echoes and said two different reflector front surface echoes.

15. A method according to claim **14** wherein said first back surface echo is received in said first scan, wherein said second back surface echo is received in said second scan, wherein said reflector echo with said material present is made in said third scan, and wherein and said reflector echo without said material present is received in said fourth scan.

* * * * *